Journal of the Korean Society of Mathematical Education Series D:
Research in Mathematical Education
Vol. 15, No. 2, June 2011, 127–140

The Textbook Analysis on Probability: The Case of Korea, Malaysia and U.S. Textbooks[1]

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(Received April 23, 2011; Revised May 15, 2011; Accepted June 2, 2011)

"Statistical literacy" is important to be an effective citizen ([Gal, I. (2005). Towards "probability literacy" for all citizens: Building blocks and instructional dilemmas. In: G. A. Jones (Ed.), *Exploring probability in school: Challenges for teaching and learning* (pp. 39–63). New York: Springer]). Probability and statistics has been connected with real context and can be used to stimulate students' creative abilities. This study aims at identifying the extent that textbooks in three countries include experimental probability concepts and non-routine, open-ended, application and contextual problems. How well textbooks reflect real application situations is important in the sense that students can employ probability concepts when solving real world problems. Results showed that three textbook series did not mention experimental probability. Furthermore, all of textbooks had more routine, close-ended, knowing, and non-contextual problems.

Keywords: Probability, statistics, textbook analysis, cross-country study

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[1] This article will be presented at the 16th Korean International Seminar of Mathematics Education on Creativity Development and Gifted Students at Chungnam National University, Yuseong-gu, Daejeon 305-764, Korea; August 11–13, 2011.

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MESC Classification: K50, U20
MSC2010 Classification: 97K50

1. INTRODUCTION

Mathematics is a critical tool in an industrialized society. It has also been vital for people to develop logical thought, problem solving ability, and information processing capacity. “Statistical literacy” is emphasized in terms of statistical interpretation, is often used in human life, and is required of effective citizens (Gal, 2005). In addition, people need to make decisions based on interpretations of data in newspapers, books, and other diverse media on a daily basis. Thus probability and statistics is one of the most applicable mathematical subjects for human activities (Hodges & Lehmann, 1964).

After the American Statistical Association [ASA] and the National Council of Teachers of Mathematics [NCTM] published The Statistics Teacher Network in 1985 and the Conference Board of Mathematics and Sciences emphasized the topics of statistics and probability, content has been included in middle school curriculum materials and textbooks. The Guidelines for Assessment and Instruction in Statistics Education (GAISE) (Franklin *et al*., 2007) and the NCTM standards for Data Analysis and Probability recommended that statistics and probability be taught starting at the elementary level and should be learned with connections to the real world with the goal of developing statistical literacy. In the case of Texas, the Texas Essential Knowledge and Skills [TEKS] at the elementary level requires that students collect data, construct graphs with concrete pictorial objects, and interpret information from them. In addition, the Ministry of education, science and technology of the Korean government strongly suggests including probability and statistics in middle school curriculum.

Significance of Probability Concept

As mentioned above, probability concepts are closely connected to the real world. People invest money in the stock market or real estate, bet on horse racing based on probability concepts regardless of whether they realize it or not. People unavoidably must “interpret, react to, or cope with situations that involve probabilistic elements or different levels of predictability or unpredictability” (Gal, 2005, p. 40). Furthermore, most academic fields require probability and statistics. For example, in meteorology meteorologists forecast the weather using historical data and this is associated with the concept of experimental probability.

The concept of probability is required for students to learn because the advanced contents such as sampling, effect size, and statistical significance require that foundation.

Mathematics, including probability and statistics, should be learned subsequently because each content is interdependent with the others. For example, the probability density function (PDF) is foundational. If students do not understand it well or have misconceptions about part of its content, there will be additional difficulties while learning subsequent content. Probability is what students learn first in probability and statistics. Students should understand the concepts of probability and be able to apply them across various contexts.

Teachers of school mathematics have the responsibility for making sure social and academic needs are met. Because computation has been a focus in the mathematics classroom, students also have been asked to calculate probability and statistics through algorithms, and generally not within a reform-oriented perspective. According to Stohl (2005), teachers can figure out students' difficulties with probability; however, they still teach probability through a computational approach while encouraging students to find single convergent answers.

Difficulties in learning probability

Many studies have reported that secondary students had difficulties learning statistics and probability concepts (Carpenter *et al*., 1981; Garfield, 1989; Shaughnessy, 1981). In addition, probability and statistics was one of the fields in which students showed diverse misconceptions (Capraro, Kulm & Capraro, 2005; Carter & Capraro, 2005; Conners, McCown & Roskos-Ewoldsen, 1998; Fast, 1997; Hirsch & O'Donnell, 2001; Shaughnessy, 1981). For example, students' lack of understanding of basic statistical concepts has made it difficult for them to solve statistical problems (Garfield, 1989). Additionally, the idea of representativeness has been reported as one of misconceptions many students possessed (Carter & Capraro, 2005; Hirsch & O'Donnell, 2001; Mokros & Russell, 1995). Because representativeness is a fundamental concept in developing advanced statistical conceptions, these students' difficulties in learning probability and statistics were even more severe.

Students showed further difficulties especially with open-ended problems (Bragg & Nicol, 2008). After students answered the multiple-choice or short-answer questions, they were also asked to explain their reasoning process. Even though students could find correct answers, they experienced difficulties explaining them in statistical language. Furthermore, this meant that students just guessed the answers without appropriate understanding of problems and the solution processes. This was because there were fewer chances for students to learn with open-ended problems. On the other hand, an open-ended learning environment could encourage students to have interests in learning probability and statistics (Stohl, 2001) and to reflect their intuitive beliefs (Land &

Hannafin, 1996). The open-ended learning environment can be provided with diverse materials such as textbooks as well as computer software.

Textbooks

Textbooks are the primary material that teachers use for planning their lessons (Baroody, Ginsburg & Waxman, 1983; Chen, 2006). Although teachers who use other resources such as the internet and video media are increasing, textbooks remain the primary resource for teaching and learning. However, textbooks have limited content and have not covered some topics related to probability such as fairness, conditional events and chance language (Watson, 2005) and did not apply guidelines by the ASA and NCTM. In addition, many teachers in elementary and secondary school level did not have opportunities to learn how to teach statistics and probability in their post-secondary schooling (Metz, 2010). Because of this reason, teachers rely more on textbooks for teaching statistics and probability.

For many decades, textbooks have been a main resource and teaching tool for facilitating curriculum in classrooms (American Association for the Advancement of Science [AAAS], 2000) especially for novice teachers. Textbooks are a prominent form of curriculum materials in most educational systems (Altbach & Kelly, 1988), which are designed to help teachers organize their lessons (*e.g.*, Johansson, 2005; Reys, Reys & Chavez, 2004). Carlson (1998) pointed out, "The pace at which content is presented, the context in which it is presented, as well as the types of activities in which we engage students appear to have an enormous impact on what students know and what they can do when they exit a course" (p. 143). In addition, Kulm and Capraro (2008) claimed, "Highly-rated materials provide a powerful set of carefully selected and sequenced tasks to evoke student conceptualization and development of important mathematical ideas and skills" (p. 257). Hence, the content and organization of a particular concept in textbooks should present a meaningful learning experience for students' understanding.

Many studies found that mathematics textbooks make a significant contribution to the way teachers teach, influencing students' learning of a particular concept (*e.g.*, Reys, Reys & Chavez, 2004; Stein, Remillard & Smith, 2007). In conjunction, a cross-national comparison of mathematics textbooks is important to glimpse into what and how mathematical concepts are presented and taught in different educational systems. The analysis of content and organization of textbooks provides implicit understanding about the kind of learning opportunities offered in different countries (Cai & Watanabe, 2002). Such analyses offer information to identify possible ways of improve variations of mathematical curricula treatment in each education system.

How well textbooks reflect real application situations is closely related to how students are able to connect learning to their lives. Thus, this study can contribute to understanding about the role of textbooks for classroom instruction that can possibly influence students' mathematical learning. Moreover, from the cross-system variations (Korea, Malaysia and U.S.) educators can learn the differences among probability and statistics textbooks to better organize and develop textbooks in the future.

2. METHODS

Textbook selection

Eight mathematics textbooks across three countries, Korea, Malaysia, and U.S., were analyzed to identify how the concept of probability was defined and what type of examples and exercise items were included. Two Korean textbook series (*Doosan Donga, Chunjae*), two Malaysian textbook series (*Cerdik, Darul Fikir*) and four U.S. textbook series (*Glencoe, Saxon, McDougal Littell, Prentice Hall*) were selected. Although the education system of Korea is standardized by the government, there are 10 or more textbook series of mathematics used. Two textbook series, *Doosan Donga, Chunjae,* are most widely used in Korea. Similar to Korea, Malaysia has a highly centralized education system in which the Ministry of Education (MOE) coordinates and oversees the materials written in the textbook. The Malaysian MOE publishes three series of mathematics textbooks that have similar content and organization of the concepts. For this study we selected *Cerdik* and *Darul Fikir* which were conveniently available. Malaysian textbooks are written in English because it is the language of instruction in mathematics and sciences. On the other hand, textbooks in Korea are written in Korean. The selected U.S. textbook series were also primarily used across the country including the state of Texas. The Malaysian textbook is 10th grade, Korean textbook is 8th grade and U.S. textbooks are 6th grade. These three selected grade levels for each country is the point in time when students are first presented formal concepts related to probability. The specific questions guiding the textbook analysis were:

a) How do the textbook series definitions differ across education systems?
b) How do examples and exercise problems differ in textbooks by education system?

Coding Procedure

In this study, we examined the definition, examples, and exercise problems in the probability chapters of the textbooks. The definition of probability of each series was differentiated from each other textbook authors introduced several statistical terms such as event, case, or outcome before defining probability. These terms were used to defer the definition of probability. Examples and exercise problems were analyzed by framework including four categories: routine vs. non-routine, close-ended vs. open-ended, knowing vs. applying vs. reasoning, and contextual vs. non-contextual (Trend in Mathematics and Science Study [TIMSS], 2007/2008; Yan & Lianghuo, 2006). Examples and exercise problems were coded as routine when they were solved with standardized formulas or equations. Close-ended examples and exercise problems had only one solution whereas open-ended items had more than one answer. The category consisted of knowing, applying and reasoning adopted from TIMSS (2007/2008).

> The first domain, knowing, covers the facts, procedures, and concepts students need to know, while the second, applying, focuses on the ability of students to make use of this knowledge to select or create models and solve problems. The third domain, reasoning, goes beyond the solution of routine problems to encompass the ability to use analytical skill, generalize, and mathematics to unfamiliar or complex contexts (TIMSS, 2008, p. 17).

The term, *contextual*, means literally “relating to”, “dependent on” or “using context”. The authors defined contextual examples and exercise problems related to real world contexts and required using higher domain than applying the TIMSS’ framework. All examples and exercise problems in the probability chapters were coded based on these four categories. Some exercise problems that were not associated with probability were excluded, because U.S. textbook series included exercise problems reviewing previous chapters’ content topics.

Initially, the researchers coded two series adopted from the U.S. published by Glencoe (US1) and Saxon (US2) to establish high inter-rater reliability. The analysis of definitions was focused on terms used for describing probability based on theoretical and experimental approach. The examples and exercise problems in each textbook were examined independently based on categories that were established a priori (*e.g.*, routine vs. non routine). Any disagreements were discussed and resolved before analyzing the remaining textbooks.

Data Analysis

In this study, we employed the classical content analysis technique that focuses on “the number of times each code is utilized” (Leech & Onwuegbuzie, 2007, p. 569). Specifically, we read through examples and exercise problems, and then coded them into the a priori categories. After coding the data, the researchers counted the frequency of occurrence in each category and calculated percentages based on the total number of examples and exercise problems provided in the textbooks. By using this technique, the researchers could identify which categories were mainly used that might be the most important focus of the textbooks.

3. RESULTS

The results showed some variations of probability terms, examples, and exercise problems were presented in the selected textbooks across educational system. Each textbook used a different definition of probability employing specific terms, and only one textbook among the eight analyzed textbooks included experimental probability. In general, Korean and Malaysian textbooks presented a large amount of examples and exercise problems followed by fewer in U.S. textbooks. Specifically, Doosan Donga (Korean) contained the greatest quantity with 63 examples and 143 exercise problems, followed by Malaysian textbooks (60, 83), U.S, (Glencoe (35, 93), McDougal Littell (29, 89)), and Korean (Chunjae) (42, 98). Two U.S. textbooks, Saxon and Prentice Hall presented the least number which ranging between 5 to 16 examples and 17 to 42 exercise problems.

Further analysis demonstrated that all textbooks focused more on routine, close-ended, knowing, and non-contextual examples and exercise problems. Almost all routine examples and exercise problems were coded as close-ended items. All of the U.S. textbooks except Saxon provided a large number of open-ended and reasoning exercise problems whereas Korean and Malaysian texts emphasized close-ended and knowing categories. A majority of exercise problems in the Malaysian textbook were contextual relating to daily application.

Probability Terms

Eight textbooks commonly contained several terms such as probability, sample space, and complement of event. However, probability terms that were used to define probability concepts were different by textbook. Both of the Korean and Malaysian textbooks but only Prentice Hall used the terms, “expected number”, “event” and “trial” and defined probability as “expected number of times event A occurs / number of trials”. The Saxon textbook used the term “outcomes” and defined the probability as “number of outcomes in the event / number of possible outcomes”. Glencoe and McDougal Littell textbooks included the term “favorable outcomes” and defined probability as the “number of favorable outcomes / number of possible outcomes”

Only McDougal Littell explained the two kinds of probability; theoretical and experimental. The McDougal Littell defined the experimental probability as “number of successes / number of trials”. The other five textbooks did not mention experimental probability.

Examples and Exercise Problems

Routine and non-routine

The results showed that, Saxon and McDougal Littell and a Malaysian textbook, Cerdik provided 100% routine examples whereas the other textbooks had between 3% and 10% non routine problems. Doosan Donga (Korean) provided the greatest quantity of non-routine among the textbooks. The U.S. textbooks (McDougal Littell, Glencoe, Saxon) that contained the most routine examples showed the greatest proportion when comparing routine to non-routine exercise problems. For instance, McDougal Littell provided the highest proportion of non-routine exercise problems with 24.7% (22 of 89), followed by Glencoe and Saxon with 15.1% (14 of 93) and 12% (2 of 15) respectively. Malaysian and Korean textbooks consistently presented a large proportion of routine examples and exercise problems accounting for between 89% and 100%.

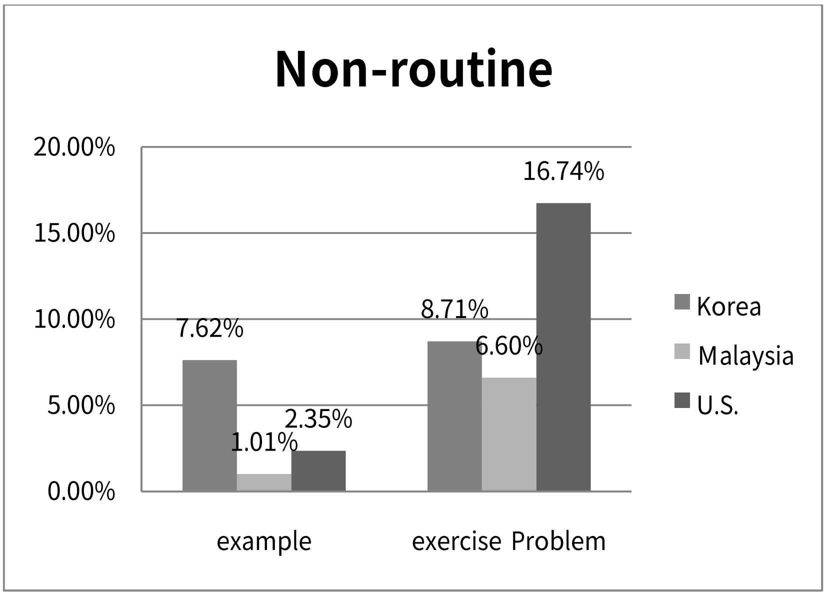

Figure 1. Non-routine example and exercise problem

Close-ended and open-ended

The textbooks of three countries had more close-ended than open-ended examples and exercise problems. The percentage of open-ended exercise problems was higher than the percentage of open- ended examples in three countries' textbooks. Korean, Malaysian and U.S. textbooks included 5.71% (6 of 105), 0% (0 of 98) and 2.35% (2 of 85) open-ended examples respectively. For the exercise problems, Korean, Malaysian and U.S. textbooks had 4.15% (10 of 241), 6.63% (13 of 197) and 16.32% (39 of 239) respectively. The Korean textbook series showed the highest percentage of open-ended example items whereas U.S. textbook series consisted of most open-ended exercise problems. One of the U.S. textbooks, McDougal Littell, had 18 open-ended items out of 89 exercise problems.

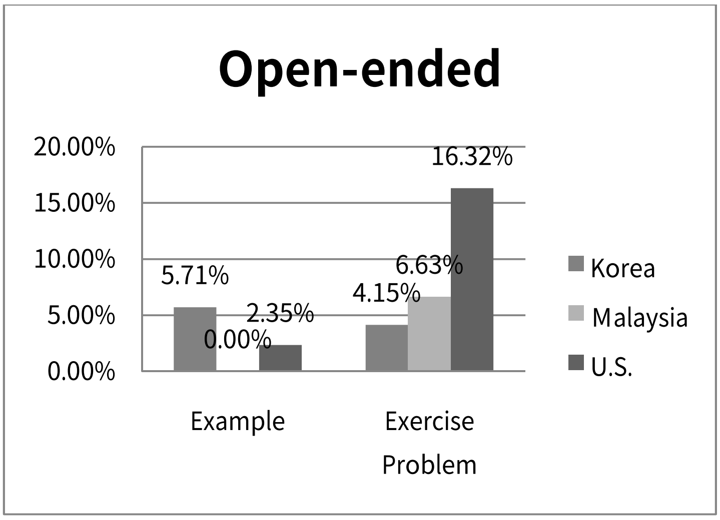

Figure 2. Open-ended example and exercise problems

Knowing, Applying, and Reasoning

As noted earlier, all the textbooks mainly focused on TIMSS' category of knowing for examples and exercise problems. Specifically, this category accounted between 86% and 100% of examples presented in each textbook. In addition, Korean textbooks provided 8% to12% of applying examples and 2% to 6% of reasoning examples as well. For exercise problems, Malaysian textbooks and one U.S. textbook (Prentice Hall) had the greatest quantity for category of knowing which accounted between 92% and 95% of the total problems. Even though the U.S. textbooks focused on category of knowing for examples, Glencoe and McDougal Littell had a different approach when presenting their exercise problems. These textbooks provided more reasoning exercise problems wherein 15% and 18% of the total were accounted for this category. Also, Doosan Donga (Korea) and Darul Fikir (Malaysia) had approximately 6% of the exercise problems for category of reasoning. On the other hand, both Korean textbooks presented most exercise problems among other textbooks for category of applying which accounted for 22% and 29% of the total.

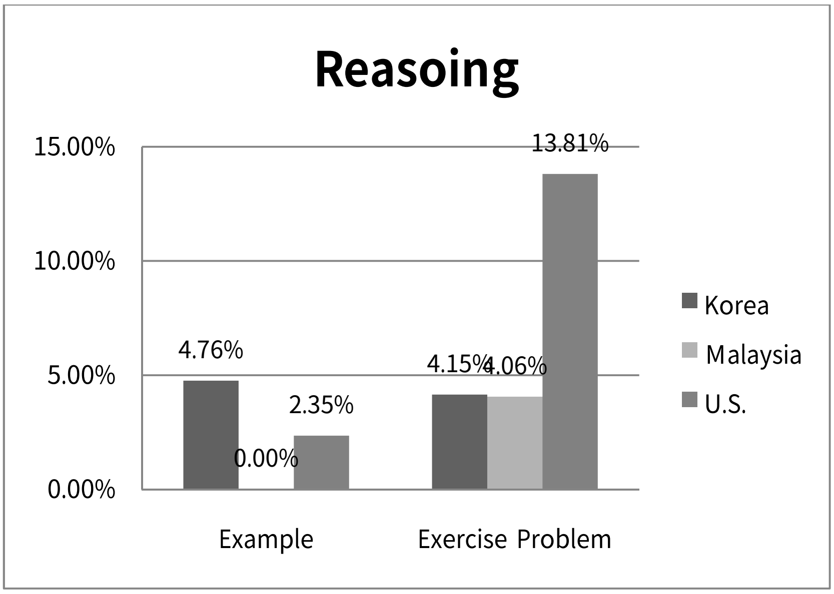

Figure 3. Reasoning example and exercise problems

Contextual and non-contextual

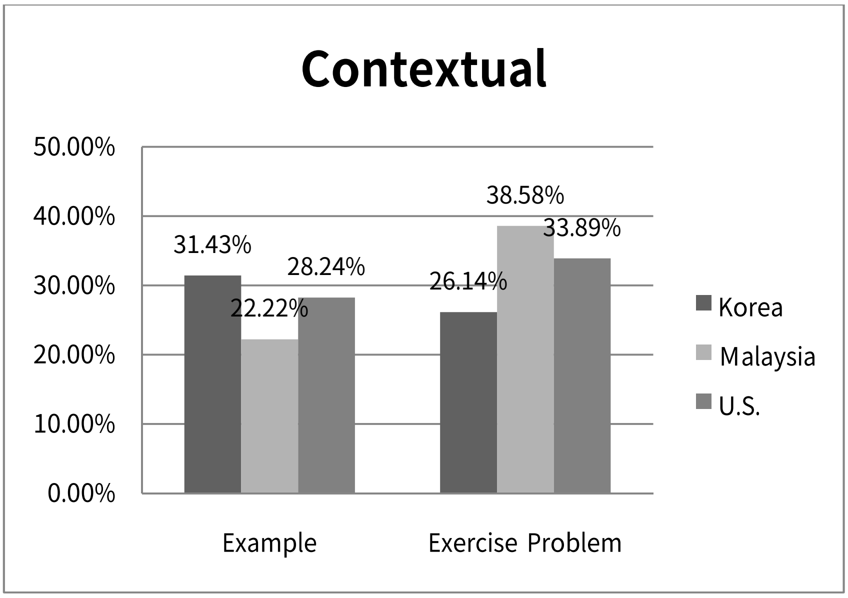

Figure 4. Contextual example and exercise problems.

In general, seven textbooks except Prentice Hall had more non-contextual than contextual exercise problems. Prentice Hall included 55% (22 of 40) of contextual problems. Across countries, the Korean textbooks showed highest proportion of contextual examples, whereas the Malaysian textbooks had most contextual exercise problems (Figure 4). The Korean textbooks provided 27% to 38% contextual examples and 26% to 27% exercise problems. U.S. textbooks showed a large variation in the proportion of contextual exercise problems. Whereas McDougal Littell presented 20% contextual exercise problems, Prentice Hall had 55% contextual exercise problems. Malaysian textbooks had a generally higher proportion of contextual exercise problems (32% to 48%).

4. DISCUSSION

These findings provide insights into probability and statistics' content in textbooks' using real world applications. There have been few studies of textbook analyses dealing with probability. Because probability is regarded as critical knowledge, school curriculum should include appropriate content. Therefore, probability content contained in textbooks can seriously affect the citizenry's statistics abilities.

The probability concepts contained in the textbooks were analyzed for only specific terms and did not differentiate the experimental probability concept. Each textbook defined probability only one way and this can cause misconceptions with probability. For example, when probability is defined using the term "number of favorable outcomes", students may develop different meanings of "favorable" and confuse whether a outcome is favorable or not. In addition, all of the textbooks except McDougal Littell included only theoretical probability. Students who learned from these textbooks might think the concept of probability is limited to a theoretical perspective and have difficulties developing and applying experimental probability it to their daily lives. In terms of problems in the real world is more related to experimental probability, both theoretical and experimental probability concepts should be introduced and taught.

U.S. textbooks showed higher proportions of non-routine, open-ended and reasoning examples and exercise problems than Korean and Malaysian textbooks. This might be because that U.S. curriculum is not nationalized. In addition, U.S. textbooks were comprised of more pages than the other textbooks. Thus the U.S. textbooks included broader contents and problems compared to the other countries. Even though this situation was described as a problem causing teachers and students' distraction (Kulm, Roseman & Treistman, 1999), this study shows that students can have more opportunities to see diverse problem presentations.

As Stohl (2005) pointed out, most teachers focused on procedures and skill-based activities, most textbooks in each country included more examples and exercise problems based on theories and algorithms. There were few non-routine, open-ended, reasoning, and contextual examples and exercise problems. This instructional trend has influenced students' learning of probability and statistics without real-world contexts and has caused students to miss opportunities to learn how to apply knowledge learned from their classroom to their real lives. In this study, it is difficult to determine how textbook content affects teachers' instructional method and students' learning achievement. Further study is necessary to examine the relationship between the type of example and exercise problems and student achievement.

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