Textbook Research as Scientific Research: Towards a Common Ground for Research on Mathematics Textbooks

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Abstract

This article explores research issues and methods of textbook research. Drawing on literatures and the author's own work in the area of mathematics textbook research, it conceptualizes textbooks as an intermediate variable in the context of education and hence defines textbook research as disciplined inquiry into issues about textbooks and the relationships between textbooks and other factors in education. Furthermore, it argues that to further advance the field of textbook research, researchers need to expand research issues from descriptive issues focusing on what textbooks are to correlational and especially causal issues including why the textbooks are and how textbooks function in the context of education, and for this purpose, researchers must go beyond textbook analysis, comparison and use to employ more empirically-based and particularly experimental method and view more rigorously textbook research as scientific research.

Key words: Mathematics textbooks; Textbook research; Research issues; Research methods; Scientific research

Introduction

School textbooks, because of their importance as instruments of education in children's schooling, have been the subject of research internationally for quite a long history. According to Nicholls (2003), as early as in the 1920s, the international organization, League of Nations, the predecessor to the United Nations, had paid much attention to the importance of comparative textbook research, though it focused primarily on the textbooks of history, geography, and civic studies due to the special nature of these school subjects. The book published by the United Nations Educational, Scientific, and Cultural Organization (UNESCO) in connection with the Georg Eckert Institute for International Textbook Research, *UNESCO Guidebook on Textbook Research and Textbook Revision* (Pingel, 1999/2010), reflects such a long-standing recognition and development of textbook and textbook research.

In the mathematics subject, school textbooks have also received increasing attention in the international research community over the last few decades. For example, the 10th International Congress on Mathematics Education (ICME10) held in Denmark devoted one Discussion Group (DG14) to textbooks with the theme "Focus on the development and research of mathematics textbooks", which attracted many researchers' interest (Fan & Zhu, 2007). In 2008, ICME11, which was held in Mexico, again assigned a Discussion Group (DG17) to textbooks with the focus being "The changing nature and roles of mathematics textbooks: form, use, access". In 2010, an APEC conference entitled "Replicating Exemplary Practices in Mathematics Education among APEC Economies" was held in Thailand, in which three curriculum plenary sessions were specifically devoted to the processes and principles of the publication of mathematics textbooks (see Fan, 2010; Shimizu & Watanabe, 2010). In early 2011, the 5th APEC-Tsukuba International Conference, which was in relation to lesson study originated from Japanese classroom, had the theme: "Focusing on Mathematics Textbooks, e-Textbooks and Educational Tools". This Shanghai conference, as its title "2011

International Conference on School Mathematics Textbooks" suggests, is also an important indication of the latest international interest among mathematics educators in school mathematics textbooks.

However, it appears clear that, overall, mathematics textbook research as a field of research in mathematics education is still at an early stage of development, as compared to many other fields of research in mathematics education. Similarly to other school subjects' textbook research, the philosophical foundation, theoretical framework, and research methods for disciplined inquiry on different issues in mathematics textbook research are still lacking or fundamentally underdeveloped [also see criticism made by Nicholls (2003, 2005), and Razat (2006)]. It is my view that the time has mature for mathematics textbook researchers to start thinking more rigorously about textbook research as a scientific research and, accordingly, establish a common ground or "research paradigm" (Kuhn, 1962) as the underlying assumptions and intellectual framework for the field of textbook research. Towards this purpose, I will below primarily focus on two fundamental and related matters, that is, issues and methods, for conducting mathematics textbook research.

Issues for Textbook Research

There is no doubt that the ultimate goal of any educational research is to produce new knowledge for the betterment of education and hence the society in general. However, operationally, like any other educational research, a specific textbook research is to address a specific research issue(s). Identifying, and hence establishing a common understanding of, what constitute fundamental and significant issues and, in what sense, is essential for the advancement of the whole field of textbook research, as research issues provide directions for research effort.

As commonly agreed [though there have been different views (e.g., see Johnson, 2000)], a useful general framework to classify different kinds of educational research is based on the purposes and issues of the research, as briefly described below.

1. Descriptive research. The fundamental issue for this type of research is what things are.
2. Correlational research. The fundamental issue for this type of research is how two or more things are related.
3. Causal research. The fundamental issue for this type of research is, is there a causal relationship between two things?

Using the above framework, Tables 1-3 list all the questions of focus in their "call for papers" in ICME-10 DG14, ICME11 DG17, and APEC-Tsukuba International Conference V, respectively. In the tables, the classification of issues added here in the brackets indicates a likely direction of conducting the type of research to address the issues: D-descriptive research, CO-correlational research, CA-causal research, and NA- Not applicable, or difficult to classify using the above framework. Needless to say, the classification only reflects the view of the author.

It must also be pointed out that conference organizers might not be intended to list these issues solely from the perspective of research due to the objectives of different conferences (or Discussion Groups).

Table 1
Issues concerning textbooks identified/proposed in ICME10 DG14 (Theme: Mathematics textbooks)

Aspect	Issues and classification of types
1. Development of mathematics textbooks	How are textbooks developed in different countries (D) and how should they be developed (NA)? Who are the authors of mathematics textbooks (D) and who should be the authors (NA)? Should textbook development be experience-driven, research-driven, or market-driven (NA), and what are the realities and restrictions in different countries (D)? What role does technology play in the development of mathematics textbooks (D), and how does it affect the development of textbooks (NA)? What are the peculiarities of an electronic textbook (D)? What role do the government, mathematicians, mathematics education researchers, curriculum specialists, and classroom teachers play in textbook development (D)? What are the interests and forces that drive the development of textbooks in different countries and how should different interests and forces be viewed and dealt with for improvement (D)? How does different socio-cultural value influence the development of mathematics textbooks in different education systems (D)? What lessons can we learn from the history of math textbook development in different countries (NA)?
2. Relationship between mathematics curriculum standards/syllabi and textbooks	How should mathematics textbooks follow and reflect the intended curriculum standards/syllabi, if there are such standards or syllabi (NA)? To what extent are mathematics textbooks in different countries aligned with curriculum standards/syllabi (D)? How can the gaps between mathematics textbooks and curriculum standards/syllabi be filled (NA)? How do textbooks serve as a means to transmit socio-cultural norms and values embedded in different education systems or national curriculum standards/syllabi (D)?
3. Role of textbooks in the teaching and learning of mathematics	Are textbooks essential in the teaching and learning of mathematics, and under what situation (CA)? Should mathematics textbooks be written for teachers or students or both (CA)? Should textbooks be treated only as an information source or should they be regarded as an instrument of organizing student's educational cognitive activity (CA)? How do textbooks shape the teaching and learning of mathematics within and outside schools and classrooms, for worse or for better，and to what extent (D)? How do teachers and students use mathematics textbooks (e.g., do they follow textbooks closely or just use them as one kind of information source) (D)? And why do they use textbooks this way or that way (CA)? How can teachers and students benefit from having/using a textbook, and to what extent (CA)? What are the influences of textbooks on students' achievement in mathematics, and how can this be measured (CA)?
4. Evaluation of mathematics textbooks	How can judgments about the quality of mathematics textbooks for research and for other practical purposes be made (NA)? What criteria and constructs should we use in making such evaluations (NA)? What textbooks may be called "good" for students, or teachers, or even

	parents (NA)? How can the evaluation of textbooks be related to the adoption of textbooks (CO)? What are the current processes of decision-making for textbook adoption in different countries, and how can such processes be improved (D)? Who (e.g., educational administers, school principals, heads of mathematics departments, classroom teachers, students and parents) should be involved in the decision-making process, and how (NA)?
5. Research in the area of mathematics textbooks	What is the status of mathematics textbooks as a subject for disciplined inquiry in the international mathematics education community (NA)? How can awareness of the importance of textbooks in mathematics education research be increased (NA)? What are the important issues in this area (NA)? What methods should be used to conduct research centring on mathematics textbooks, in addition to the commonly used ones such as comparative study and document analysis (NA)? What can we do to raise the level of research in mathematics textbooks (NA)?

Source: Fan, Turnau, Dole, Gelfman, & Li (2008).
Note. The fifth aspect in the table is not directly about mathematics textbooks. Instead, it is about research (in the area of mathematics textbooks).

Table 2
Issues concerning textbooks identified/proposed in ICME11 DG17 (Theme: The changing nature and roles of mathematics textbooks: form, use, access)

	Issues and classification of types
Main questions	To what extents do mathematics textbooks shape the actual teaching and learning of mathematics, for better or worse (D)? What is the balance between textbook impact and that of other forces, e.g. curricula and assessment, which influence mathematics teaching (D)? What are the interests and forces that drive the publication and adoption of textbooks in different countries (D)? Who are the authors of mathematics textbooks in different countries, and what are their backgrounds (D)?
Additional questions	What do textbooks look like (D)? Do textbooks reflect educational standards of specific national or international contexts (D)? How do the authors represent mathematical knowledge (D)? How does the interplay between educational values, conceptual understanding, and procedural fluency unfold in mathematics textbooks (D)? What are the pedagogical intentions (implicit, or explicit) of textbooks (D)? Does the incipient movement for wiki-based textbooks hold promise for better mathematics programs (NA)? What are the challenges in using new technologies to design and develop coherent educational materials (D)? What impact do commercial publishers (good, bad, and neutral) have on the nature of mathematics learning in schools (D)? To what extent does research inform the contents of textbooks (D)? How are students, or teachers, expected to use the textbook (D)? Is it a student or teacher book (D)? Who has access to (which) textbooks in classrooms/schools (D)? What does that mean in terms of learning opportunities for pupils (NA)?

Source: ICME-11 official website at http://dg.icme11.org/tsg/show/18, retrieved August 28, 2011.

Table 3
Issues concerning textbooks identified/proposed in the Fifth APEC-Tsukuba International Conference (Theme: Innovation of Classroom Teaching and Learning through Lesson Study: Focusing on Mathematics Textbooks, e-Textbooks and Educational Tools)

Aim (Target) of Conference	Issues and classification of types
Sharing the methods of teaching with textbooks and knowing theories on curriculum and textbooks	How do you use your textbooks in your country (D)?
Elaborating the model approaches using textbooks to develop mathematical thinking and communication	How can we use our textbooks meaningfully (NA)?
Sharing the various ways of utilizing traditional equipment in classroom such as blackboards as well as projectors and computers	How do you use blackboards and projectors in your country (D)?
Knowing the innovative tools to develop e-textbooks and sharing the methods of teaching	How can we innovate our teaching approaches for teachers (NA)?

Source: Conference official website http://www.criced.tsukuba.ac.jp/math/apec/apec2011, retrieved August 28, 2011.

Given the importance as well as the themes of the three conferences (Discussion Groups), it seems clear that issues receiving most attention are descriptive in nature, which was also reflected in the contributions submitted.

According to the organizers, ICME10 DG14 and ICME17 DG17 each only accepted nine papers. All the papers accepted for ICME10 DG14 focused on issues listed under the second, third, and fourth aspects, while all the papers accepted for ICME11 DG17 were on issues related to the role of textbooks, the representation of mathematical knowledge, teachers' use of textbooks, evaluation of textbooks and mathematical tasks in textbooks, and the development of quality textbooks[1]. This is to some degree an indicator of both quantity and quality of the research work that have done and the need for further development in this area. In relation to this, the organizing team of ICME10 DG14, as it claimed, were "a bit disappointed by the lower-than-expected contributions that were received, which suggests that mathematics textbooks are still under-researched and that more attention is needed to this important area" (Fan, et al., 2008, p. 487).

In a large sense, what showed in Table 1 can be considered a framework to understand and classify issues in relation to textbook research. Under this framework, major issues for researchers are found in the five aspects as listed in the table. Nevertheless, I think this seminal framework falls short in explicitly taking into consideration the relationship between different aspects as listed in the table in terms of research issues and the important nature of textbooks that they exist in the whole context of education and society.

To establish a more systematic and coherent framework to identify and understand issues for textbook research, I believe a starting point of conceptualization is to consider textbook as a variable and, more precisely, an intermediate variable in the context of education[2]. So the

[1] Readers who are interested to know more about these papers accepted for both ICME10 DG14 and ICME11 DG17 can read/download them from the official websites of ICME10 (http://www.icme10.dk/) and ICME11 (http://www.icme11.org/), as of 28 August 2011.

[2] An intermediate variable is a variable in a causal pathway that causes variation in the dependent variable and is itself caused to vary by the independent variable (e.g., see http://www.lexic.us.)

basic issue is not only about what the textbooks are, but also about how they are affected by other factors (independent variables), and how they affect other factors (dependent factors).

The following diagram (Figure 1) illustrates the existence of textbooks in the educational context.

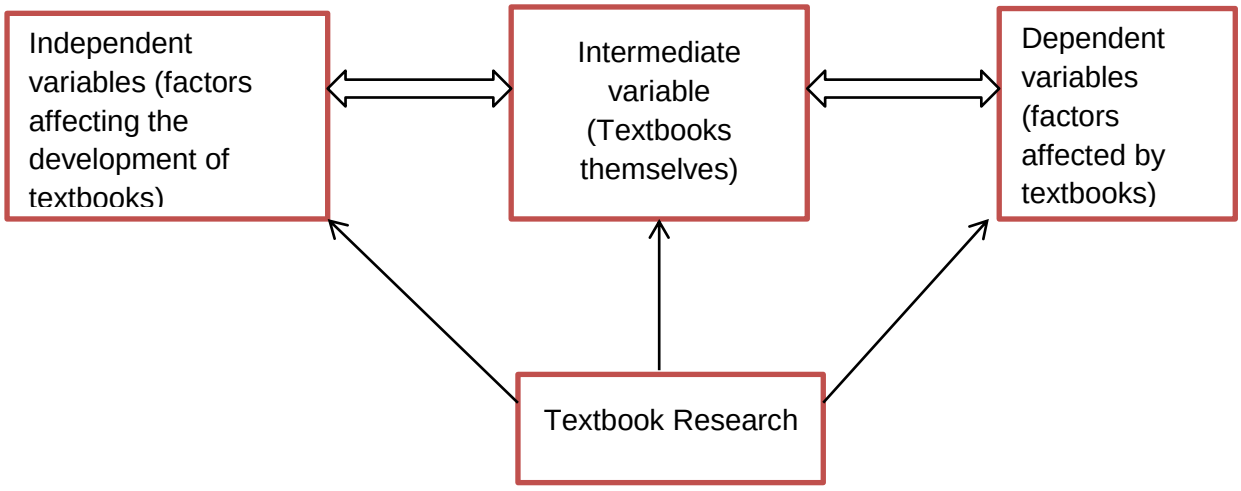

Figure 1. Textbooks in the context of education.

Using the above diagram, we can identify and investigate the issues of textbook research in the following three broad areas: 1. Issues about the textbooks themselves, i.e., textbooks as subject of research; 2. Issues about the factors that affect the development of textbooks or make textbooks textbooks, in other words, textbooks as a dependent variable (compared to other factors being independent variables), and 3. Issues about the factors that are affected by the textbooks, that is, textbooks as independent variable (compared to other factors being dependent variables). With these three broad areas, Table 4 presents a new framework including a list of some specific issues, most of which are directly, or with modification, from the three international conferences mentioned above, under each area.

Under this framework, textbook research can be defined as disciplined inquiry into issues about textbooks as well as the relationship between textbooks and other factors in education. In addition, it becomes evident that most research focusing on the issues in the first area will fall into the category of descriptive research, while issues in the other two areas call more for correlational and in particular, causal research.

As researchers generally agree, causal issues are usually the most important ones for education (e.g., see, Postlethwaite, 2005, p. 9). This is also true in mathematics textbook research, because for the ultimate goal of improving the quality of mathematics education, it is only the first step to know what the textbooks are or look like, for example, how the topic of function is treated in a textbook, or how different types of problems are presented in a textbook or in textbooks in different countries.

Table 4
A new framework to understand issues for textbook research

Area	Issues for research
1. Textbook itself as subject of research (Fundamental issue: what the textbooks are)	What are the features of mathematics textbooks? How do textbooks represent mathematical knowledge (of certain topics, types, etc)? How about problem solving? How do textbooks reflect intended curriculum standards (if there are)? How do textbooks reflect certain pedagogy (e.g., cooperative learning, constructivism learning)? How do textbooks reflect cultural and societal value and development? How is the development of modern technology reflected in mathematics textbooks? What are the similarities and differences of mathematics textbooks in different countries (in what aspect)? ……
Textbooks as dependable variable (Fundamental issue: why the textbooks are)	How are textbooks developed (in different countries)? What factors caused the differences found in different textbooks? What role do different parties (e.g., government, mathematicians, mathematics educators, curriculum specialists, and classroom teachers) play in textbook development? How does different socio-cultural value influence the development of mathematics textbooks in different education systems? What are the challenges in using new technologies for the development of mathematics textbooks? How does research inform the contents of textbooks? What are the interests and forces that drive the publication and adoption of textbooks in different countries? …….
Textbooks as independent variable (Fundamental issue: how the textbooks function)	How do textbooks impact the behaviour of teaching and learning of mathematics, and to what extent? How are mathematics textbooks used by teachers and students, and why? What are the influences of textbooks on students' achievement in mathematics? How do textbooks serve as a means to transmit socio-cultural norms and values embedded in different education systems or national curriculum standards/syllabi? ……

More fundamentally, we need to further understand why a certain way of treatment of the topic is better than others for the teaching and learning of mathematics under certain context, and how we can produce such textbooks for better. In connection to this, it appears clear that we must go beyond textbook analysis and comparison in textbook research, even though this type of research has been well advanced and established in comparison to other kinds of research in this field and is still of important value (e.g, see Bao, 2002; Chandler & Brosnan, 1995; Fan & Zhu, 2007; Howson, 1995). Ultimately, researches of this kind can only tell us the information about what the textbooks concerned look like and how they differ in the aspects concerned, but not directly evidence-based answers about whether certain treatment or arrangement is really desirable or which is better, nor how can we bring about the improvement, which essentially requires researches particularly designed to answer causal questions.

Methods of Textbook Research

Very few researchers have directly addressed issues about methods for textbook research. As Nicholls (2003) pointed out, the methods employed in textbook research were rarely discussed clearly and in depth, and "too little work has been conducted on generic methods for textbook research and it remains as a gap hole in the field". Referring to textbook analysis and comparison, he argued that sophisticated textbook research can only be guaranteed with the systematics development of generic framework and research instruments. In the mathematics subject, McNaught, Tarr, and Sears (2010), Remillard (2005), and Rezat (2005) also raised concerns about the methodological issues with all focus on one area of textbook research, i.e., textbook use. In particular, McNaught et al. (2010) employed the concept of "implementation fidelity" and developed multiple instruments which mainly included teacher's self-report data (consisting of "textbook-use diaries" and "table of content records") and researchers' "classroom visit protocols" to measure "content fidelity" and "presentation fidelity", two main concepts used to indicate implementation fidelity, in the use of mathematics textbooks. Remillard (2005) conducted a comprehensive review about the constructs of research in the use of mathematics curriculum material (mainly textbooks) and proposed a framework emphasizing teachers' interactions with curriculum materials in this special area of research. Rezat (2005) also proposed a model of textbook use based on the perspective of activity theory.

In my view, a more general issue about the field of textbook research is that too few studies displayed sophistication of "scientific" methods, which is a serious challenge for the advancement of textbook research. Although different issues and types of educational research often require different research methods, and textbook research is no exception, it is fundamentally important to use scientific methods in the field of textbook research. In this regard, it must be emphasized that an essential concept related to modern science or scientific research is that all evidences should be empirical or empirically based, in other words, produced by observation and experiment and collected in a systematic manner. In particular, experimental method is widely accepted as the most scientific, if not the only, method to test a hypothesis or investigate a causal relationship between two or more variables (e.g., see Postlethwaite, 2005; also see Fan, 1993).

As the ICME10 DG14 reading document, *A Bibliography of Textbook Studies* (Zhu & Fan, 2004), revealed, a large majority of literatures in this field are not based on empirical methods. The same observation can also be made on the 18 papers submitted to the two ICME DGs, as mentioned earlier. This is largely understandable because of the following three reasons: first, quite a number of literatures in this area are not meant to be research-based; more often than not, they are for introducing textbooks, sharing experiences, and discussing relevant questions; second, these research-based literatures often focused on textbook analysis and comparison, with the data mainly gathered through document analysis and coding. Although there have been studies addressing the issues about the use of textbooks with data collected empirically-based through classroom observation, interviews, etc. (e.g., see Fan, Chen, Zhu, Qiu, and Wu, 2004), as Love and Pimm (1996) noted, the number has been limited given the difficulty of collecting data from classroom. In fact, it is arguable that this challenge might have well affected or prevented some researchers (particularly research students) from attempting to attack issues in the second and third areas listed in Table 4.

Let me here briefly share two textbook studies I was involved as a researcher. In the mid 1990s, I conducted a comparative study on applications of arithmetic in the United States and Chinese textbooks. After I established a framework for analyzing the application problems of addition and subtraction, which is not as simple as one might think, I coded all the application problems in the national primary mathematics school textbook from Grade 1 to Grade 6 in China and a series of textbook in USA. The results showed that within the same series the

distribution of different types of application problems is irregular, and across the two series it is much different or inconsistent, which is of course a concern for a further examination, and probably, action from the textbook developers. Overall, my view based on the coding results was that the distribution of application problems appeared not well planned (for details, see Fan, 1998). But without experimental research to address causal question how and why different treatments of the topic cause the differences in teaching and learning, the study cannot really tell which one is better and how it should be improved.

The other study was about textbook use completed with my colleague Kaeley. The study investigated the influence of textbooks on teaching strategies by comparing teaching strategies of 14 teachers using University of Chicago School Mathematics Project (UCSMP) secondary mathematics textbooks to those of another 14 teachers using non-UCSMP textbooks in 13 schools. Data were collected from classroom observations, teacher interviews and a questionnaire survey (therefore it is certainly an empirically based study). The results suggested that textbooks appear to affect teaching strategies by conveying pedagogical messages to teachers and providing an encouraging or discouraging curricular environment for them to employ different teaching strategies. Note that we used the word "appear" in the above sentence because the two groups of teachers were not randomly selected, and control of other variables was not possible (for details, see Fan & Kaeley, 2000).

There is no question that using empirically-based methods and in particular quasi- or true experimental methods is significantly more challenging, and in some cases, impossible, not only just in textbook research, but also in many other educational studies. However, for the further advancement of the field of textbook research and its application, including the research-based development, evaluation, and use of textbooks, it is necessary to raise the awareness and take on the challenge[3]. Moreover, this is also more feasible and important than ever before due to the fact that curriculum and textbook reform has become a regular national or local effort in many counties (e.g., China, Japan, Singapore, USA and UK), because of the modern social, technological and economic development. In fact, in the latest curriculum reform, all the new textbooks for the compulsory education stage in China (6 series for primary schools, and 9 series for junior secondary schools in mathematics), which were developed following the new national curriculum standards, were officially and, rightly, known as "experimental textbooks", which implies the importance and necessity of experimental work in textbook research and development.

When Johnson and Onwuegbuzie (2004) discussed mixed methods research, they pointed out that mixed methods research will be successful as more researchers study and help advance its concepts and as they regularly practice it, I think the same idea applies to the scientific methods in the textbook research, and in this connection, the time has come for more action in both theory and practice.

Concluding Remarks

The purpose of this article is to explore research issues and methods of textbook research with focus on the school mathematics textbooks. Essentially, it presented a re-look at what constitute fundamental and significant questions, what constitute acceptable evidence, and what methods will lead to acceptable evidence and hence research results and conclusion. From the discussion and analysis, one can see that textbooks as the subject of research can be viewed as an intermediate variable in the context of education and hence defines textbook research as disciplined inquiry into issues about textbooks and the relationships between textbooks and other factors in education. Moreover, to further advance the field of textbook

[3] In a recent MEI mathematics conference held in Keele, UK, Parker (2011) gave a plenary presentation entitled "28 reasons to ignore the textbooks". I think it signals a fundamental challenge to textbook researchers and developers for developing better textbooks based on sound research.

research, researchers need to expand research issues from descriptive issues such as what textbooks are to correlational and especially causal issues including why the textbooks are and how textbooks function in the context of education, and for this purpose, we must go beyond textbook analysis, comparison and use to employ more empirically based and particularly experimental method and conduct textbook research as scientific research.

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