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Opportunities to learn: Mathematics textbooks and students' achievements☆

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ABSTRACT

This study explores how textbooks function in education. It asked whether opportunities provided in math textbooks to engage in tasks demanding different levels of understanding correlate with students' achievements on tasks demanding equivalent levels of understanding on a standardized exam. The textbooks evaluated were two 8th grade mathematics textbooks used by students in the Arab community in Israel, showing that Textbook A makes more cognitive demands than Textbook B. The study correlated textbooks' cognitive demand with the scores of all 8th grade students in the Arab community who completed the national math test in 2015 and studied in schools using either Textbook A or B (N = 4040), while attending to mediating variables. The findings show that if a textbook provides the opportunity to engage in tasks demanding higher levels of understanding, students using this book will have higher scores. The study shows that gender and SES play an important role in how opportunities provided in textbooks interact with students' scores. Many factors influence variations in mathematics achievements within and between nations. The findings illuminate textbooks' ability to provide opportunities to learn mathematics. As a result, they raise new questions about how teachers use textbooks and about the role of textbooks in promoting access and equity in mathematics education. Although the work explored specific textbooks, its findings shed light on how learning opportunities relate to achievements more generally.

1. Introduction

Mathematics plays an essential role in daily life. Thus, the mathematical achievements of students are of considerable interest at a national level, leading many countries to develop standards that apply to all students. A standards-based agenda shifts the orientation in math education towards students' opportunities to learn (Cogan, Schmidt, & Wiley, 2001; Törnroos, 2005; Tran, Reys, Teuscher, Dingman, & Kasmer, 2016). Definitions of students' opportunities to learn relate, for example, to the content domains or cognitive skills provided in curriculum documents or textbooks (Floden, 2002); allocation of time or student engagement with different aspects (Floden, 2002); and access to qualified teachers (Akiba, LeTendre, & Scribner, 2007). Whichever meaning is preferred, the insistence on standards as a mechanism for improving mathematics teaching and learning is based on the idea that the opportunity to learn is a main determinant of students' content and cognitive achievements (Cogan et al., 2001). Precisely how opportunity is tied to student achievement is, however, less well understood (Grouws et al., 2013; Xin, 2007).

This study described herein examined the relations between the learning opportunities provided by math textbooks in the cognitive domain and students' cognitive achievements in national standardized tests in the context of the Israeli national curriculum. Cognitive achievement is defined as the score on a test related to the specific thinking processes assessed (Grønmo, Lindquist, Arora, & Mullis, 2015). Textbook is defined as a printed and published resource designed to be used by teachers and students in the learning process; Van Steenbrugge, Valcke, & Desoete, 2013). Textbooks provide explanations and exercises for students to complete and offer instructional guides for teachers (Van Steenbrugge et al., 2013). Despite the recognition that textbooks provide important opportunities to learn mathematics, linking textbooks with achievement is difficult because of the many other factors that might impact how and what students learn (Tarr et al., 2008). Bearing this complexity in mind, textbook research can provide valuable information about student learning and help bridge the gap between curriculum development and educational research (Clements, 2007).

2. Theoretical background

2.1. Role of textbooks in teaching and learning

Textbooks are major conveyors of curricula, playing a major role in education across school subjects (Fan, Zhu, & Miao, 2013; Sherman, Walkington, & Howell, 2016). The power of textbooks lies in their

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ability to provide a structured scheme of ideas (Palló, 2006), organize teaching and learning, and enable the development of thinking and understanding of the subject (Fan et al., 2013; Mahmood, 2009). Textbooks are designed for use by both teachers and students and are a central resource for teaching and learning (Remillard, 2005). The centrality of textbooks is evident in Houang's and Schmidt's (2008) three curriculum levels model: the *intended* – what a system intends students to learn; the *implemented* – what is taught in classrooms; and the *attained* – what students are able to demonstrate. Within this model, textbooks are viewed as *potential implemented curricula,* in that they take the intended curriculum a step towards implementation (Houang & Schmidt, 2008; Valverde, Bianchi, & Wolfe, 2002).

Textbooks tie the intended curriculum and the implemented curriculum together (Schmidt et al., 2001). They reflect the intended curriculum by translating it into a sequence of contents (Kalmus, 2004). In this translation, textbooks influence the implemented curriculum, shaping the instruction in the classroom by, for example, defining the contents to be discussed during mathematics lessons (Törnroos, 2005). Thus, the choice of what to put into textbooks shapes schooling by providing certain opportunities to learn at the expense of others (Houang & Schmidt, 2008). What is in a textbook can determine both the components and the methods of learning (Awasthi, 2006; Stern & Roseman, 2004). The implication is that students' learning experiences can be limited by what textbooks offer.

In mathematics, textbooks are thought to characterize the teaching-learning process more than in other subjects (Fan et al., 2013). Studies examining how mathematics textbooks influence instruction generally agree that they have a significant influence on students' opportunities to learn mathematics (Stylianides, 2009). The particular textbook a teacher uses can influence what students learn, how they learn, and the cognitive level at which they learn (Grouws et al., 2013; Stein, Remillard, & Smith, 2007). Textbooks are also a source for teacher learning (Newton & Newton, 2007; Remillard, 2009) and are considered to play an active role in teachers' pedagogy.

Many studies have probed the interplay of textbooks and teachers. Chval, Chávez, Reys, and Tarr (2009) showed that, during instruction, many math teachers directly follow textbooks. Fan and Kaeley (2000) found teachers using different types of math textbooks implement different teaching strategies. In their view, textbooks convey pedagogical messages and provide encouragement or discouragement to teachers to employ certain teaching strategies. In their study of mathematics classrooms, Weiss, Pasley, Smith, Banilower and Heck (2003) found that the textbook designated for a class is a major factor in the teacher's selection of lesson content. When Tarr, Chávez, Reys and Reys (2006) studied the extent of textbook use by middle school mathematics teachers utilizing different textbook series, they found the "textbook strongly influences both *what* and *how* mathematics is taught… Coupled with the high frequency of textbook use by teachers, these data suggest that textbooks likely impact students' mathematics experience in important ways" (p.200; italics in original).

Studies into teachers' autonomy take a different approach, suggesting textbooks have less influence on instruction and, thus, on what students learn (Charalambous, Delaney, Hsu, & Mesa, 2010; Kilpatrick, 2003; Seeley, 2003). In this understanding, teachers are active developers of the curriculum, implementing it in accordance with various circumstances of their classrooms and in relation to the materials available to them (Ben-Peretz, 1990; Clandinin & Connelly, 1992; Remillard, 2005; Tarr et al., 2008). There is evidence that teachers make use of curriculum materials in different ways in their classrooms (Stein & Kaufman, 2010). As pointed out by Grouws et al. (2013), "Teachers may cover most of the chapters in the textbook or not; they may move through the textbook sequentially or not; they may teach differently than what the textbook recommends or not; they may supplement the textbook problems or not; they may use technology in developing content or not" (p.419).

The general acknowledgement of the importance of how teachers use curricula suggests textbooks provide possible rather than conclusive opportunities to learn mathematics (Charalambous et al., 2010). As noted by Mesa (2004), textbooks may be considered opportunities, as they answer the question: "What would students learn if they had to solve all the exercises in the textbook?" (p. 256). Although this perspective acknowledges that textbook analysis examines only the *potential* implemented curriculum, not the *actual* implemented curriculum (Charalambous et al., 2010), a comparison of textbooks can reveal similarities and differences in structuring pedagogical situations and offer insights into the opportunities for students to learn (Fan et al., 2013).

2.2. The opportunity to learn in math textbooks and achievement

The association of textbooks with opportunities to learn has triggered a rapid growth in related research (Fan et al., 2013). Fan (2011) and Fan et al. (2013) classify textbook research into four areas. The first is the role of textbooks in mathematics teaching and learning. The second research area looks for similarities and differences in math textbooks. The third asks how textbooks shape ways of teaching and learning mathematics, and the fourth comprises textbook research in other areas.

While research recognizes the prominent position of mathematics textbooks in teaching and learning, there is little consistency in the understanding of the impact of textbooks on students' achievements (Van Steenbrugge et al., 2013). Many things besides textbooks can mediate the relationship between the intended and the implemented curriculum. Researchers (Chávez, Tarr, Grouws, & Soria, 2015; Remillard, 2005; Stigler & Hiebert, 2004; Van Steenbrugge et al., 2013) have highlighted many mediating factors, including organizational and policy contexts, classroom structures, norms, teacher beliefs, orientations, engagement, and usage of textbooks in teaching.

Several attempts have been made to link teaching and learning materials (including textbooks) to students' achievements. In their analysis of the focus and coherence of curriculum documents, Houang and Schmidt (2008) show positive relations between these documents and achievements across countries; they suggest a link can be established by analyzing aspects lying beyond the documents' content. When Chávez et al. (2015) studied the effect of two types content organization (an integrated approach and a subject-specific approach), they found students in the integrated curriculum scored significantly higher than those in the subject-specific curriculum on a common objectives test but not on a standardized test. Earlier studies by the same researchers (Grouws et al., 2013; Tarr, Grouws, Chávez, & Soria, 2013) showed that an integrated curriculum correlated with higher student scores on the standardized achievement test. These studies also found that teacher related variables significantly moderated student outcomes. Cai, Wang, Moyer, Wang and Nie (2011) examined the impact of standards-based and traditional mathematics curricula on students' learning; they found the former contributed to significant growth in problem solving.

While attempts have been made to connect the "intended curriculum" or the "textbook curriculum" (Tarr et al., 2008) to students' achievements, the use of curriculum analysis to generate indicators of learning is in its early stages (Polikoff, 2015). Much of the research into textbooks is not connected to achievements (Charalambous et al., 2010; Polikoff, 2015; Stylianides, 2009). Fan (2011) suggests that to advance the field of textbook research, researchers need to move from descriptive to correlational studies showing how textbooks function in education.

The study described here answered the call. It correlated the opportunities provided in math textbooks to solve tasks demanding different levels of understanding with students' achievements in tasks on national standardized tests requiring an equivalent level of understanding. Put otherwise, it evaluated written curricula by attending to its effects. Following Houang's and Schmidt's (2008) curriculum model, it focused on the sequence from potential implemented curricula (i.e.