Why Documenting the Implementation of Curricula Matters

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As noted by Begle (1973) and Valverde et al. (2002), curriculum materials have a powerful influence on what students learn. When educators and the general public raise questions about the use of specific curricula, at least two main aspects should be considered: (1) what students learn about specific content; and (2) what factors account for differences in student performance among students using the same curriculum as well as among students using different curricula. Indeed, as Kilpatrick (2003) notes,

> Two classrooms in which the same curriculum is supposedly being "implemented" may look very different; the activities of teacher and students in each room may be quite dissimilar, with different learning opportunities available, ..., and different outcomes achieved. (p. 473)

Research suggests that discussions about achievement with particular curricula are incomplete if they do not provide some evidence of the nature of implementation. When achievement differences are noted among students in comparable classes, they may be due to differences in the curricula themselves or they may be due to factors beyond the control of the curriculum developers, such as the extent to which teachers use the materials as intended. (See Tarr et al., 2006; Tarr et al., 2008 for reports on middle school teachers' implementation of curricula.) Thus, providing some evidence of implementation when reporting achievement is essential to researchers and consumers in order to evaluate the quality of the research and any conclusions drawn from it (see also recommendations from the National Research Council 2004). As Hiebert and Grouws (2007) note,

> The curriculum the teacher is required to use … surely influences students' opportunity to learn. … The emphasis teachers place on different learning goals and different topics, the expectations for learning that they set, the time they allocate for particular topics, the kinds of tasks they pose … all are part of teaching and all influence the opportunities students have to learn (p. 379).

In the United States, there is a long tradition of individual teacher control of the classroom

curriculum. Although schools, school districts, and states may establish benchmarks or standards to be addressed, teachers typically enjoy considerable autonomy in determining how they will address these benchmarks. This variability influences students' opportunity to learn mathematics, and likely their achievement.

This paper adds to the growing research evidence about teachers' use of curriculum and highlights four reasons why documenting curriculum implementation matters. Throughout, we control for type of curriculum by focusing only on teachers using the same curriculum materials, specifically one of two field-trial versions of materials developed by the University of Chicago School Mathematics Project (UCSMP).

UCSMP is a K-12 curriculum research and development project that began in 1983 with three main goals: (1) to upgrade student achievement; (2) to update the curriculum to include content important for the 21st century and appropriate technology; and (3) to increase enrollment in high school mathematics beyond algebra and geometry. Since then, the UCSMP has developed a coherent mathematics curriculum for grades K-12. (For additional information about UCSMP, visit http://socialsciences.uchicago.edu/ucsmp/index.html or see Hirschhorn, Thompson, Usiskin, & Senk, 1995; Usiskin, 2007.)

From its inception, UCSMP has engaged in research related to the effectiveness of its secondary materials as part of its research and development process (see, for example, Senk, 2003; Senk & Thompson, 2006; Thompson & Senk, 2001, 2006). As the curriculum team began revising its secondary materials in 2005 for a third edition, an evaluation team collected information about classroom implementation from the following sources cited in this paper.

- Chapter evaluation forms on which teachers report lessons taught for each chapter, length of time spent per lesson, questions assigned, and insights into the use of technology or

other features of the materials;

- Opportunity-to-learn (OTL) forms on which, for each item on a posttest, teachers identify whether they taught the content needed for their students to answer the item.

These measures of implementation are relatively low cost and low inference. Together with data not discussed in this paper (minimal classroom observations, a teacher interview, and beginning and end-of-year teacher questionnaires), they enable the evaluation team to develop a profile of classrooms and teachers so that the curriculum developers can understand the conditions under which their materials were field-tested, how differences in achievement among classes might be understood related to differences in opportunity to learn, and what revisions are needed prior to commercial publication.

As previously indicated, we outline four reasons why we believe documentation of curricular implementation must be part of the development of curricula and research about student achievement when it is used. We support each reason with data from the third edition formative evaluation studies of two UCSMP courses.

- *Pre-Transition Mathematics* (primarily for Grade 6) helps students solidify arithmetic proficiency while studying geometry, measurement, and basics of data analysis.
- *Geometry* (primarily for Grades 9 and 10) connects coordinates and transformations and includes work with measurement and three-dimensions. Proof is sequenced from single-step proofs to more complex proofs. Dynamic geometry software is used for exploration.

Our focus here is on the implemented curriculum as evidenced by data collected from teachers; it is not about the curriculum achieved by students. Although we use data from UCSMP to support our arguments, the paper is not intended to report research about UCSMP. Rather, we use data from UCSMP studies to raise issues about documenting curriculum implementation that

we believe are applicable to a variety of textbook-based mathematics curricula across countries; in fact these same issues apply to curricula across many other disciplines.

Reason 1: Teachers who use the same curriculum do not necessarily teach the same content.

Content in curriculum materials may or may not be taught, even in early chapters of a text containing core content. Teachers often make decisions to skip lessons based on local or state curriculum frameworks. Table 1 reports the percent of lessons taught in *Pre-Transition Mathematics* from 11 teachers in 10 schools in six states, overall and by thirds of the book.

Table 1. Percent of Lessons Taught in *Pre-Transition Mathematics* by Teacher (2006-2007)

Teacher	Chapters 1-4 (n = 36)	Chapters 5-8 (n = 33)	Chapters 9-12 (n = 29)	Chapters 1-12 (n = 98)
A	100	42	0	51
B	100	100	0	70
C	100	100	31	80
D	100	100	62	89
E	100	100	66	90
F	100	100	28	79
G	100	100	31	80
H	86	55	10	53
I	100	97	0	69
J	100	100	0	70
K	100	100	24	78

Note: Based on Thompson and Senk (in preparation, b). n = number of lessons

As the results indicate, the percent of lessons taught varied from 51% to 90%. Although almost all teachers taught all the lessons in the first four chapters, two of the teachers taught less than 60% of the lessons in the middle third of the book. Four teachers never reached the final third of the book; only two of the eleven teachers taught more than 50% of the final third. Figure 1 illustrates the coverage on a lesson-by-lesson basis, using a visual display similar to that used by Tarr et al. (2006). The figure illustrates that, with the exception of Teacher H, most teachers taught the lessons in order; the percent of the book taught is a function of pace rather than of choices about omitting particular lessons.

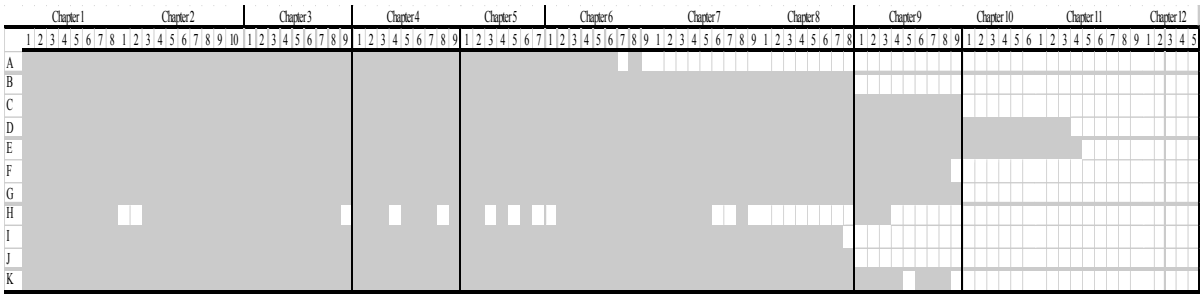

Figure 1. Coverage of Lessons Taught by Teachers A-K in *Pre-Transition Mathematics*

However, data from 12 teachers in 12 schools in nine states teaching UCSMP *Geometry* highlight a quite different picture, as shown in Table 2 and Figure 2. There is much more variability among the classroom implementation of *Geometry* teachers than *Pre-Transition Mathematics* teachers, with many *Geometry* teachers regularly omitting lessons in each chapter. For example, although Teachers C and D each taught about the same percentage of lessons, their pattern of coverage was different, and so, their students' opportunity to learn was different. Teacher F chose to teach Chapter 7 from an earlier edition of the UCSMP text, perhaps influencing the extent to which subsequent content in the third edition could build on new approaches to content. Coverage of content from Chapters 11 to 14 varied considerably, with teachers often teaching only a few lessons from these chapters, if at all.

Additional analyses of the content of lessons covered provide insight into how success or lack thereof with an early lesson can influence implementation of subsequent lessons. For instance, Lesson 1-7 of *Geometry*, which all teachers taught, introduces students to a dynamic geometry drawing tool. Several teachers reported that they or their students had difficulty with the technology in this lesson. Lesson 2-8, which also utilized a dynamic geometry drawing tool, was taught by fewer than half of the teachers. Such data can provide important feedback to curriculum developers and those who conduct professional development, so they may modify

lessons or reflect upon the extent to which the experience with one lesson influences teachers' willingness to attempt another lesson using the same technology or approach.

Table 2. Percent of Lessons Taught in UCSMP *Geometry* by Teacher (2006-2007)

Teacher	Chapters 1-5 (n = 39)	Chapters 6-10 (n = 45)	Chapters 11-14 (n = 30)	Chapters 1-14 (n = 114)
A	56	64	27	52
B	87	51	17	54
C	95	84	10	68
D	90	84	7	66
E	100	100	43	85
F	92	64	0	57
G	100	100	70	92
H	90	71	57	74
I	97	73	0	62
J	100	87	20	74
K	95	58	0	55
L	100	89	33	78

Note: Based on Thompson and Senk (in preparation, a). n = number of lessons

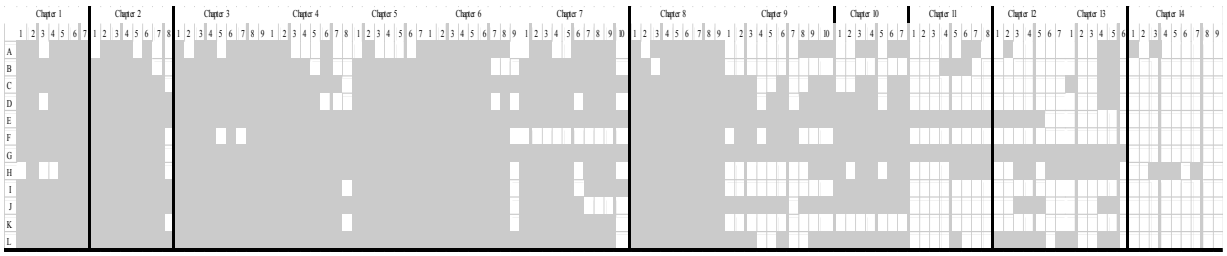

Figure 2. Coverage of Lessons Taught by Teachers A-L in *Geometry*

Reason 2: Teachers who use the same curriculum materials do not necessarily assign comparable problems for students to complete.

The lessons that teachers teach provide one measure of students' opportunity to engage with content. Homework assignments in which students are expected to work on problems related to the content provide opportunities for students to assess their understanding and generate questions to clarify that understanding. Thus, most mathematics teachers assign homework to

give students opportunities to work on tasks related to the classroom lesson. How different are the assignments made by teachers using the same curriculum materials?

Many U. S. mathematics textbooks for secondary school contain a large number of problems where students might be assigned just even or odd numbered problems. In contrast, UCSMP textbooks have fewer problems, with the problems grouped in four types:

- Questions *Covering the Ideas* deal with the core ideas of the lesson.
- Questions *Applying the Mathematics* use the core ideas in new settings or in new ways that have not necessarily been discussed in the lesson.
- *Review* questions provide an opportunity for students to continue working on concepts over several lessons or chapters. UCSMP uses distributed practice, so the review problems are essential for students to build proficiency.
- *Exploration* problems extend the mathematics of the lesson in an exploratory manner.

The developers recommend that teachers assign virtually all questions within a lesson on a daily basis, with the possible exception of the Exploration problems.

Table 3 reports the percent of problems in the entire book assigned by the teachers using *Pre-Transition Mathematics*. The results suggest that even when teachers taught most of the content, as was the case for the lessons in Chapters 1-4 (see Table 1), the opportunity given to students to engage with the content during independent practice varied quite a bit. Teachers A, C, H, and I assigned no more than half of the questions in their textbook, whereas all other teachers assigned at least 65% of the problems.

Table 4 reports on the problems assigned but only in the lessons teachers taught. Thus, this table reports on opportunity-to-learn in terms of alignment with the curriculum developers' philosophy about the nature of the problems.

Table 3. Percent of Textbook Problems Assigned by *Pre-Transition Mathematics* Teachers

Teacher	Chapters 1-4 (n = 946)	Chapters 5-8 (n = 806)	Chapters 9-12 (n = 576)	Chapters 1-12 (n = 2328)
A	73	24	0	38
B	87	84	0	65
C	68	52	19	50
D	86	76	47	73
E	96	100	39	83
F	100	99	19	80
G	99	100	32	82
H	68	28	3	38
I	40	81	0	44
J	100	93	0	73
K	86	81	18	68

Note: Based on Thompson and Senk (in preparation, b). n = number of problems

Table 4. Percent of Covering the Ideas, Applying the Mathematics, and Review Problems Assigned by *Pre-Transition Mathematics* Teachers A-K Based Only on the Lessons Taught

Teacher	Covering the Ideas			Applying the Mathematics			Review		
	No. Assigned	No. Possible	%	No. Assigned	No. Possible	%	No. Assigned	No. Possible	%
A	494	586	84	182	277	66	85	255	33
B	800	800	100	251	359	70	140	317	44
C	675	880	77	482	492	98	221	460	48
D	940	948	99	282	539	52	215	516	42
E	887	956	93	557	583	96	199	561	35
F	844	873	97	538	588	91	516	567	91
G	880	880	100	517	532	97	496	511	97
H	516	602	86	539	539	100	500	516	97
I	452	797	57	242	385	63	84	344	24
J	774	800	97	333	487	68	249	451	55
K	854	868	98	476	492	97	443	460	96

Except for Teacher I, teachers generally assigned at least three-fourths of the Covering the Ideas questions, ensuring that students engaged with the core concepts of the lesson. Five of the eleven teachers assigned less than three-fourths of the Applying the Mathematics problems, which provide more challenge than the Covering the Ideas tasks. Particularly startling is that only five of the 11 teachers assigned at least half of the review problems in the lessons they taught; two of the teachers assigned no more than a third of the review problems. Previous

research has shown that distributed practice is an effective feature for attaining mastery of content. Failure to assign most of the review problems raises questions about the extent to which students have sufficient opportunities to develop proficiency with the content and the extent to which the teacher is implementing the curriculum as intended. For people interested in determining the effectiveness of a curriculum, failure to document the nature of the assignments used with students makes it difficult to understand any differences in achievement.

Variation in the assignment of questions in UCSMP *Geometry* is even more dramatic. Table 5 reports the percent of problems in the book assigned by each teacher.

Table 5. Percent of Textbook Problems Assigned by UCSMP *Geometry* Teachers (2006-2007)

Teacher	Chapters 1-5 (n = 929)	Chapters 6-10 (n = 989)	Chapters 11-14 (n = 650)	Chapters 1-14 (n = 2568)
A	27	22	8	20
B	42	18	3	23
C	90	49	0	51
D	46	67	7	44
E	99	100	44	86
F	29	11	0	15
G	83	78	70	78
H	58	48	24	46
I	87	69	0	58
J	95	66	16	64
K	78	38	0	43
L	68	59	21	53

Note: Based on Thompson and Senk (in preparation, a). n = number of problems

Overall, Teachers A, B, and F assigned less than 25% of the questions in their textbook; they, along with teacher D, assigned less than half of the questions in the first third of the book. Overall, Teacher A taught the least number of lessons (52%; see Table 2) and also assigned the second fewest percent of problems of any teacher (20%). It may be that this teacher assigned problems from another source, but the implementation data raise the question of whether the intended curriculum was actually implemented as expected by the curriculum developers.

Table 6 disaggregates the data related to problems according to the type of problem and focusing only on the lessons taught. In these lessons, only six of these twelve teachers assigned more than 60% of the review problems. In fact, five of the teachers assigned less than a fourth of the reviews. Given that review problems are an essential feature of the curriculum, it is natural to wonder whether any lack of proficiency in geometric concepts or skills that might arise is due to the curriculum or to less than complete implementation.

Table 6. Percent of Covering the Ideas, Applying the Mathematics, and Review Problems Assigned by *Geometry* Teachers A-L Based Only on the Lessons Taught

Teacher	Covering the Ideas			Applying the Mathematics			Review		
	No. Assigned	No. Possible	%	No. Assigned	No. Possible	%	No. Assigned	No. Possible	%
A	306	577	53	139	437	32	71	368	19
B	349	590	59	176	457	39	67	386	17
C	574	725	79	481	592	81	261	478	55
D	259	698	37	510	572	89	361	463	78
E	903	903	100	714	714	100	581	587	99
F	202	611	33	131	496	26	54	398	14
G	819	972	84	636	770	83	540	634	85
H	675	779	87	388	621	62	107	507	21
I	628	656	96	484	529	91	372	440	85
J	738	788	94	491	622	79	400	514	78
K	481	598	80	371	469	79	245	391	63
L	748	841	89	509	663	77	104	542	19

Reason 3. When teachers teach the same lessons, they may provide different opportunities for their students to learn.

The previous two sections have focused on the book as a whole or the lessons that individual teachers taught. What variability in the implemented curriculum exists when teachers teach exactly the same lessons? Some variability exists in instruction. For *Pre-Transition Mathematics*, the number of class periods spent on Chapter 1 varied from 10.5 to 22, with a median of 16 class periods. The variability may be a function of students' prerequisite knowledge, but may also

reflect teacher expectations; some teachers may expect mastery before proceeding from one lesson to the next, even though UCSMP does not expect mastery until the end of the chapter. The text contains numerous activities embedded within lessons to provide opportunities for students to engage in hands-on activities, games, or small-group discussions. Some teachers did several of the activities, either as a whole class, in pairs, or as a teacher demonstration. Other teachers decided that activities were too time consuming and so omitted them.

In addition to the differences in terms of instructional approach, there were differences in terms of the problems assigned. Similar to the analysis of problem assignments for the entire book, the assigned problems in this chapter varied from 40% to 100% (median 86%). This is Chapter 1, and so the teacher is likely establishing expectations for the entire year. The small percent of problems assigned by Teacher I in the first chapter (40%) continued throughout the text.

Similar trends were evident in *Geometry*, with some teachers choosing to complete activities, others only talking through the activities, and still others omitting them altogether. The results from both courses indicate that teachers provide very different opportunities for students to learn, both in terms of instruction and assignments, as they provide different experiences with homework problems, even when they all teach the same lesson.

Reason 4. Teachers who teach the same course from the same curriculum materials may have different perceptions about the extent to which students have an opportunity to learn the content assessed on end-of-course assessments.

The differences in curriculum implementation outlined in the previous three reasons also impact outcomes, particularly on end-of-year assessments. For every posttest, teachers responded to an opportunity-to-learn (OTL) form on which they indicated whether they taught or reviewed

the content needed for their students to answer each item correctly. Figure 3 provides a visual display of the consistency of the OTL responses for *Pre-Transition Mathematics* teachers on a standardized test. For only 18 of the 32 items (56%) did all the teachers report having taught the content needed for their students to answer the items.

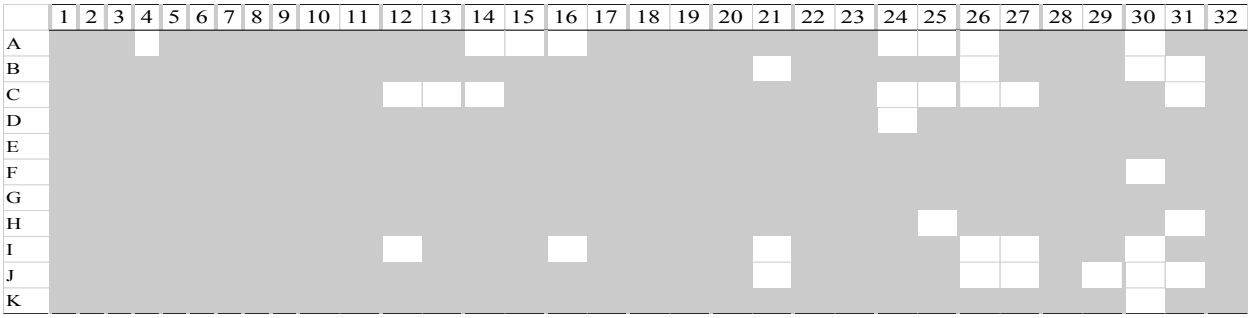

Figure 3. *Pre-Transition Mathematics* Teachers Reported Opportunity-to-Learn for the Terra Nova CAT Survey: Mathematics Level 17

Similar results are found in Figure 4 based on a UCSMP-constructed test for *Geometry*. For only 23 of the 60 items (38%) did all teachers report *Yes* on the OTL form. These teachers were all teaching from the UCSMP curriculum. If there is this much variability on an end-of-year assessment among teachers using the same curriculum materials, there is likely even more variability when teachers are using different curricula. So, just reporting achievement without some indication of teachers' perception of the extent to which the assessment items reflect the implemented curriculum may lead to biased reporting or inappropriate interpretation of any achievement differences.

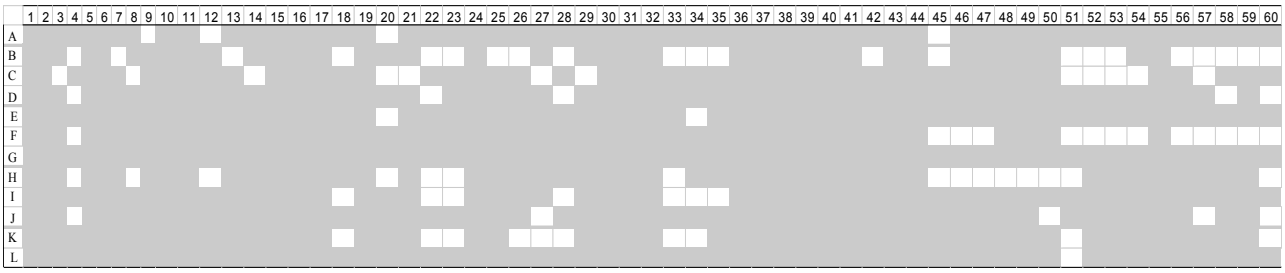

Figure 4. *Geometry* Teachers Reported Opportunity-to-Learn for a UCSMP-constructed Posttest

Discussion and Conclusion

In this paper, we have provided data to indicate that documenting curriculum implementation matters because implementation is highly teacher dependent. Even when teachers are using the same curriculum, they provide quite different opportunities for students to learn, in terms of the content they teach, the number and nature of the problems they assign, and the nature of items on end-of-year assessments that they consider as having taught, and thus, perhaps consider as being *fair*. Given this variability in implementation of curriculum, it is essential that curriculum developers and researchers document the variability and find some way to report implementation as part of research reports about curriculum and achievement. Without such documentation, it is difficult to interpret results or to make comparisons between classes.

Several comments about the results and their potential contribution need to be made. First, these data were collected during a formative field-test of curriculum materials; although many teachers had used earlier versions of UCSMP *Geometry*, the third edition was, nevertheless, a new book. Many researchers (e.g., Tarr et al., 2008) consciously choose not to study curricula in the first year of implementation because teachers often cover less in the first year of using a new text. Second, this study documented the actual problems assigned, which is a category of implementation not reported by others. The insights about the problems assigned might be due to the nature of the assignments; perhaps the problem sets were too long in this field-trial version

and teachers needed to limit assignments to stay within the norms of outside school work in their community. Third, the data reported here are for both lower secondary school (*Pre-Transition Mathematics*) and upper secondary school (*Geometry*); many previous studies have focused only on elementary or lower secondary (middle school). Fourth, all of the implementation data reported here come from chapter evaluation forms or the opportunity-to-learn forms, low-cost, low-inference data collection sources.

The variability in implementation documented in this paper by teachers using the same curriculum suggests that even greater variability would likely be reported by teachers teaching from different curricula. Supervisors, evaluators, and curriculum developers clearly need to pay much more attention than has been paid in the past to how curricula are implemented. Given the reasons outlined in this paper with supporting documentation, failure to include implementation information makes any achievement data hard to interpret.

References

Begle, E. G. (1973). Lessons learned from SMSG. *Mathematics Teacher, 66*, 207-214.

Hiebert, J. & Grouws, D. A. (2007). The effects of classroom mathematics teaching on students' learning. In F. K. Lester, Jr. (Ed.), *Second handbook of research on mathematics teaching and learning* (pp. 371-404). Reston, VA: National Council of Teachers of Mathematics.

Hirschhorn, D. B., Thompson, D. R., Usiskin, Z., & Senk, S. L. (1995). Rethinking the first two years of high school mathematics: The University of Chicago School Mathematics Project. *Mathematics Teacher*, *88*, 640 - 647.

Kilpatrick, J. (2003). What works? In S. L. Senk & D. R. Thompson (Eds.), *Standards-based school mathematics curricula: What are they? What do students learn?* (pp. 471-488). Mahwah, NJ: Lawrence Erlbaum.

National Research Council. (2004). *On evaluating curricular effectiveness: Judging the quality of K-12 mathematics evaluations*. Committee for a review of the evaluation data on the effectiveness of NSF-supported and commercially generated mathematics curriculum materials. J. Confrey & V. Stohl (Eds.), Mathematical Sciences Education Board, Center for Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

Senk, S. L. (2003). Effects of the UCSMP secondary school curriculum on students' achievement. In S. L. Senk & D. R. Thompson (Eds.), *Standards-based school mathematics curricula: What are they? What do students learn?* (pp. 425-456). Mahwah, NJ: Erlbaum.

Senk, S. L., & Thompson, D. R. (2006). Strategies used by second-year algebra students to solve problems. *Journal for Research in Mathematics Education, Vol. 37(2)*. 116-128.

Tarr, J. E., Chávez, Ó., Reys, R. E., & Reys, B. J. (2006). From the written to the enacted curricula: The intermediary role of middle school mathematics teachers in shaping students' opportunity to learn. *School Science and Mathematics*, 106(4), 191-201.

Tarr, J. E., Reys, R. E., Reys, B. J., Chávez, Ó., Shih, J., & Osterlind, S. J. (2008). The impact of middle-grades mathematics curricula and the classroom learning environment on student achievement. *Journal for Research in Mathematics Education*, 39(3), 247-280.

Thompson, D. R., & Senk, S. L. (in preparation, a). *An evaluation of the Third Edition of UCSMP Geometry*. Chicago, IL: University of Chicago School Mathematics Project.

Thompson, D. R., & Senk, S. L. (in preparation, b). *An evaluation of the Third Edition of UCSMP Pre-Transition Mathematics*. Chicago, IL: University of Chicago School Mathematics Project.

Thompson, D. R., & Senk, S. L. (2001). The effects of curriculum on achievement in second-year algebra: the example of the University of Chicago School Mathematics Project. *Journal for Research in Mathematics Education, 32,* 58-84.

Thompson, D. R., & Senk, S. L. (2006). Methods for controlling for opportunity-to-learn. In S. Alatorre, J. L. Cortina, M. Sáiz, & A. Méndez (Eds.), *Proceedings of the Twenty-Eighth Annual Meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education* (pp. 179-186, Volume 2). Mérida, Mexico: Universidad Pedagógica Nacional.

Usiskin, Z. (2007). The case of the University of Chicago School Mathematics Project-Secondary Component. In C. R. Hirsch (Ed.), *Perspectives on the design and development of school mathematics curricula* (pp. 173-182). Reston, VA: National Council of Teachers of Mathematics.

Valverde, G. A., Bianchi, L. J., Wolfe, R. G., Schmidt, W. H., & Houang, R. T. (2002). *According to the book: Using TIMSS to investigate the translation of policy into practice through the world of textbooks*. Dordrecht, Netherlands: Kluwer Academic Publishers.