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Impact of Curriculum Reform: Evidence of Change in Classroom Practice in The United States

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Abstract

The purpose of the study reported in this article is to examine the impact of curriculum on instruction. Over a three-year period, we observed 579 algebra-related lessons in grades 6–8. Approximately half the lessons were taught in schools that had adopted a *Standards*-based mathematics curriculum called the Connected Mathematics Program (CMP), and the remainder of the lessons were taught in schools that used more traditional curricula (non-CMP). We found many significant differences between the CMP and non-CMP lessons. The CMP lessons, emphasized the conceptual aspects of instruction to a greater extent than the non-CMP lessons and the non-CMP lessons emphasized the procedural aspects of instruction to a greater extent than the CMP lessons. About twice as many CMP lessons as non-CMP lessons were structured to use group work as a method of instruction. During lessons, non-CMP students worked individually on homework about three times as often as CMP students. When it came to text usage, CMP teachers were more likely than non-CMP teachers to work problems from the text and to follow lessons as laid out in the text. However, non-CMP students and teachers were more likely than CMP students and teachers to review examples or find formulas in the text. Surprisingly, only small proportions of the CMP lessons utilized calculators (16%) or manipulatives (11%).

Highlights

► Over a 3-year period, we observed 579 algebra-related lessons in grades 6-8. ► Half used the CMP curriculum and half used “traditional” curricula (non-CMP). ► CMP lessons stressed conceptual issues more and procedural lessthan non-CMP lessons. ► CMP lessons used group work and adhered to the text more often than non-CMP lessons. ► Non-CMP students worked on homework, reviewed examples and found formulas more often.

1. Purpose

The ultimate goal of educational research, curriculum[1] development, and instructional improvement is to enhance student learning. Historically, curricula have been used not only to communicate what students should learn (NCTM, 1989), but also to guide instruction (Ball & Cohen, 1996). Accordingly, many advocates of mathematics education reform believe that changing the curriculum is an effective way to improve classroom practice and enhance student learning (Howson et al., 1981, NCTM, 1989, NCTM, 2000, Senk and Thompson, 2003). However, it is by no means guaranteed that the curriculum assigned to a teacher will significantly influence that teacher's classroom instruction, let alone significantly influence it in ways that the authors intended (Ball and Cohen, 1996, Fullan and Pomfret, 1977). Therefore, important questions with regard to curricula are whether, how, and to what extent they influence the instruction of the teachers who use them.

The purpose of this article is to shed light on those questions by constructing instructional profiles of teachers who use one or the other of two types of middle school mathematics curricula: *Standards*-based or traditional. The results presented in this article were gleaned from data gathered during our NSF-funded study titled Longitudinal Investigation of the Effect of Curriculum on Algebra Learning (LieCal). The LieCal Project is designed to longitudinally compare the effects of the Connected Mathematics Program (a *Standards*-based curriculum, hereafter called CMP) to the effects of more traditional middle school curricula (hereafter called non-CMP) on students’ learning of algebra.

2. Background and theoretical considerations

2.1. Standards-based mathematics curricula

In the late 1980s and early 1990s, the National Council of Teachers of Mathematics (NCTM) published its first round of *Standards* documents (e.g., NCTM, 1989, NCTM, 1991, NCTM, 1995), which provided recommendations for reforming and improving K-12 school mathematics. In the *Standards* and related documents that appeared, the discussions of goals for mathematics education emphasize the importance of thinking, understanding, reasoning, and problem solving, with an emphasis on representations, connections, applications, and communication. This view stands in contrast to a more conventional view of the goals for mathematics education, which emphasizes the memorization and recitation of de-contextualized facts, rules, and procedures, with the subsequent application of well-rehearsed procedures to solve routine problems.

In the 1990s, the National Science Foundation provided extensive funding to develop and implement a number of school mathematics curricula that align with the recommendations in the NCTM *Standards* (National Research Council, 2004, Senk and Thompson, 2003). The resulting NSF curricula use the exploration of real-life problems as a way to strengthen students' understanding of important mathematics. The implementation of these so-called *Standards*-based curricula requires that teachers change the way they have traditionally taught mathematics and that students change their views of what learning mathematics entails. Unfortunately for the reform movement, teachers face challenges when trying to implement these innovative curricula. Even in classrooms where teachers attempt to teach for understanding as specified by the NCTM *Standards*, teachers often maintain many existing mathematics practices inconsistent with the recommendations specified in the NCTM *Standards* (Gross and Merchlinsky, 2002, Hiebert and Stigler, 2000, RAND Mathematics Study Panel, 2002, Spillane and Zeuli, 1999).

Each of the publishers of the non-CMP curricula studied in the LieCal Project claim that their curriculum is *Standards*-based. However, these curricula are commonly considered by mathematics educators to be traditional in nature. In keeping with this generally accepted opinion, we refer to the non-CMP curricula as 'traditional,' and we refer to the CMP curriculum as *Standards*-based.

2.2. Standards-based curriculum research

Given the disparity between the beliefs of reform advocates and reform opponents, research on the effectiveness of *Standards*-based curricula has been ongoing since the 1990s (e.g., Carroll, 1997, McCaffrey et al., 2001, Ridgway et al., 2003, Riordan and Noyce, 2001, Schoen et al., 2003, Tarr et al., 2008). Classroom instruction is considered a central component in the development and the organization of students' thinking and learning (Detterman, 1993, Rogoff and Chavajay, 1995, Wozniak and Fischer, 1993). However, much of the research that studied the effectiveness of reform curricula on student achievement did not investigate the type of instructional experiences that teachers provide when implementing *Standards*-based curricula.

Ridgway et al. (2003) conducted three studies of the effectiveness of the Connected Mathematics Program (CMP). Of all the variables in the large-scale study database (including teacher, class, school, site, gender, and fall test achievement levels), the only one associated with gains in attainment was curriculum. However, none of the three studies included in-depth information about *how* CMP was actually used in the schools. Ridgway et al. concluded that there is a need to document the nature of instruction occurring in the classrooms where reform curricula are being implemented.

Schoen et al. (2003) examined the relatedness of student achievement to the instructional practices of 40 high school teachers who were using a high school *Standards*-based curriculum (Coxford et al., 1997). Schoen et al. conducted classroom observations of each teacher during the course of a school year; they also administered two instruction-related self-report surveys to the teachers. Results showed that the implementation of cognitively demanding tasks for students and adherence to reform principles during instruction were significantly and positively associated with student achievement. In contrast, results also showed that the percentages of lesson time spent on both teacher presentations and whole class discussions were negatively associated with student achievement. In a more recent study, Tarr et al. (2008) showed that an NSF-funded curriculum implemented in a *Standards*-Based Learning Environment (SBLE) in the middle grades was positively associated with student achievement on the Balanced Assessment in Mathematics. To determine the level of

SBLE, Tarr et al. quantified the extent to which the following five classroom events were evident during observed lessons: (1) the lesson provided opportunities for students to make conjectures, (2) the lesson fostered the development of conceptual understanding, (3) students explained their responses or strategies, (4) multiple perspectives were encouraged and valued, (5) the teacher valued students' statements about mathematics and used them to develop the lesson.

Because NSF-funded curricula like CMP claim to have different learning goals than traditional curricula, and because the layout and organization of reform texts is typically quite different than traditional mathematics texts, natural questions to ask are: does instruction using a *Standards*-based curriculum really differ from instruction using a traditional curriculum? If so, what are the important features of instruction using an NSF-funded *Standards*-based curriculum that distinguish it from instruction using so-called traditional curricula? In what ways does a *Standards*-based curriculum like CMP influence instruction that are different from the ways that more traditional middle school curricula influence instruction?

2.3. A profile of curriculum use in classrooms

To answer questions like these, researchers need to investigate the way teachers teach *Standards*-based and traditional curricula (Kilpatrick, 2003, National Research Council, 2004, Wilson and Floden, 2001). In doing so, researchers must attend to those aspects of teaching that have potential to influence students' learning opportunities in effective and positive ways.

Hiebert et al. (2003) analyzed hundreds of videotapes of 8th grade mathematics lessons taught by teachers from seven countries. Based on their analysis of the videotapes, they identified the following three aspects of teaching as contributing to students' learning opportunities: (1) the way lessons were organized; (2) the nature of the content of the lessons; and (3) the instructional practices.

Koehler and Grouws (1992) argued that all teaching research, regardless of the underlying philosophical perspective, would benefit from a deep investigation of the quality of instruction. They suggest one approach to a meaningful investigation of instructional quality is to study the time allocated to 'development' as opposed to the time allocated to other activities such as seatwork or practice. They maintain, however, that the investigation of the quality of teaching must move beyond simple time considerations—to judgments about the quality of the development activities, including the extent to which the development activities emphasize students' meaningful acquisition of ideas.

The research of Stein, Grover, and Henningsen (1996) aligns with that of Hiebert et al. and of Koehler and Grouws. In particular, Stein et al. suggest that an important way to help characterize the nature of the content of a lesson as well as to judge the quality of the development activities is to analyze the manner in which mathematical tasks are chosen, set up, and implemented in a lesson.

Guided by the research cited above, we collected LieCal Project data on the following three components of classroom instruction: (1) the structure of the lesson and use of materials, (2) the nature and quality of the instruction, and (3) the analysis of the mathematical tasks used in the lesson. As we stated above, for this article we have constructed instructional profiles of teachers who use one or the other of two types of middle school mathematics curricula: *Standards*-based or traditional. We constructed these profiles by analyzing lesson observation data to determine the relationship between curriculum type and components (1) and (2). We report elsewhere the relationship we found between curriculum type and component (3) (Cai, Wang, Nie, Moyer, & Wang, 2011).

3. Method

3.1. Research site

The research reported here was conducted as part of a large NSF-funded project titled Longitudinal Investigation of the Effect of Curriculum on Algebra Learning (LieCal Project). The LieCal Project is being conducted in 14 middle schools and 10 high schools of an urban school district serving a diverse student population. At the start of the project, 27 of the 51 middle schools in the school district had adopted the CMP curriculum while the remaining 24 middle schools were using other, more traditional curricula.

3.2. Participating schools and students

Seven CMP schools were randomly selected from the 27 schools that had adopted the CMP curriculum. After the 7 CMP schools were selected, 7 non-CMP schools were chosen based on comparable ethnicity, family incomes, accessibility of resources, and state and district test results. A total of approximately 650 CMP students from 26 classes and 600 non-CMP students from 24 classes participated in the study, and these approximately 1250 students were followed for three years, from grades 6 to 8.

3.3. Data

The data for this study was collected while the students were in grades 6–8 during 579 lesson observations of over 50 mathematics teachers participating in the LieCal Project. Approximately half of the observations were of LieCal teachers using the Connected Mathematics Program (CMP) (Lappan, Fey, Fitzgerald, Friel, & Philips, 2002). The other half were observations of LieCal teachers using more traditional curricula (non-CMP).

3.3.1. Observers

Two highly qualified retired mathematics supervisors conducted and coded all the observations. Each observer observed and coded about 100 algebra-related lessons each year, approximately half in CMP classes and half in non-CMP classes. Each LieCal class was observed four times, during two consecutive lessons in the fall and two in the spring. In almost all cases, the teachers knew well in advance when they would be observed. The coders recorded extensive information about each lesson in a 28-page LieCal Project-developed observation instrument.

Before each observation, the observer interviewed the teacher to learn the teacher's goals, the lesson's objectives, and to find out any background information related to the day's lesson. During the observation, the observer made a minute-by-minute record of the lesson on specially designed pages of the LieCal observation instrument. After the observation, the observer interviewed the teacher regarding the teacher's assessment of the lesson's effectiveness and the teacher's plans for future instruction, including assessment.

3.3.2. Coding and reliability

As soon after the observations as was practical, the observers coded their minute-by-minute record of the lessons' activities into data about the structure of the lesson, the use of materials, and the nature of the instruction. The coders received extensive training that included frequent checks for reliability and validity throughout the three years. On three separate occasions each year (fall, winter, and spring), both observers jointly observed the same lesson being taught by one of the LieCal teachers. Afterwards each time, the observers independently coded the lesson and then met with each other and the PIs to compare and then negotiate differences in the resulting codes. Over the course of the 6th-grade year, for example, we checked the reliability of the observers' coding three times. The reliability achieved during the three sessions averaged 79% perfect agreement, using the criterion that the observers' coded responses were considered equivalent only if they were identical (i.e., perfect match). The reliability averaged 95% using the following criteria: (a) If an item or sub-item was 'scored' using an ordinal scale (usually 1–5), then the observers' coded responses were considered equivalent if they differed by at most one unit; (b) If an item or sub-item (e.g., representation) was 'scored' by choosing appropriate words or phrases from a list of more than five alternatives, then the observers' coded responses were considered equivalent if they had at least one choice in common (e.g., symbolic and pictorial vs. pictorial). The observers reached similar high reliabilities for the 7th and 8th grade observations. The disagreements were resolved through discussion.

3.3.3. Structure of the lesson

To determine the structure of the lesson, the coders (observers) coded the amount of time spent on each of 14 different types of lesson activities, listed in Fig. 1. Each minute of every lesson was coded into exactly one of these activities, so that the sum of the minutes coded on each activity equaled the total number of minutes in the lesson.

Fig. 1. Activities coded to ascertain the lesson structure.

(1) Instruction on New Material

- *(i) Commonly associated with traditional instruction*
  - d. Presentation of new content by teacher
  - h. Individual work (not on homework)
- *(ii) Commonly associated with standards-based instruction*
  - f. Student presentation
  - g. Group work (including prompt and/or directions)
- *(iii) Commonly associated with both types of instruction*
  - e. Discussion between teacher and students of new content
  - j. Summary by teacher

(2) Instruction on Non-New Material

- a. Opening/warm-up problem(s)
- c. Review prior work
- i. Short assessment
- m. Discussion between teacher and students (not on new content)
- n. Management issues

(3) Homework-Related Instruction

- b. Go over homework
- k. Assign homework
- l. Students work individually on homework

3.3.4. Use of materials

We focused on the following three types of materials: textbooks, calculators/computers, and manipulative materials. Since the student textbook is an integral part of most curricula, the observers coded whether the teacher and/or student used the textbook during the lesson, as well as the purposes for which it was used. Also, since the use of calculators and computers is such a volatile topic among proponents of reform-based and traditional instruction, the observers coded whether calculators or computers were used as an integral part of instruction. Finally, since manipulative materials are often considered a hallmark of reform-based instruction, the observers coded whether manipulatives were used as an integral part of the lesson. For all types of materials, the codes distinguished between teacher usage and student usage.

3.3.5. Nature of instruction

Using the second component of the observation instrument, the coders rated the nature of the instruction that they observed during each lesson. To do so, they used well-defined rubrics to code a set of 21 items about the nature of the instruction on a scale of 1 (low)–5 (high) for each lesson they observed. Examples of these items, as well as a discussion of their makeup, are given in the next section.

4. Results

4.1. Aspect 1: structure of the lesson and use of materials

4.1.1. Structure of the lesson

For purposes of the analysis for this article, we have divided the 14 types of activities (see Fig. 1) into three categories which we present and analyze in turn. The categories are: (1) structure of instruction on new material, (2) structure of instruction on non-new material, and (3) structure of homework-related activities.

4.1.2. Structure of instruction on new material

We tracked six types of activities that can be used to structure instruction to help students learn new material. We further divided these six activity types into three subcategories: (i) those generally associated with more traditional instruction (Activity d: Presentation of New Content by Teacher; Activity h: Individual Work – not on homework), (ii) those generally associated with *Standards*-based instruction (Activity f: Student Presentation; Activity g: Group Work – including prompt and/or directions), and (iii) those that are generally associated with both types of instruction (Activity e: Discussion Between Teacher and Students of New Content; Activity j: Summary by Teacher). Table 1 shows the percent of lessons and the percent of time spent on each of these activities during the 305 CMP lessons and the 274 non-CMP lessons that we observed over the course of three years.

Table 1. The structure of instruction on new material.

% Of lessons vs. % of time	**Curriculum**	***n***	**(i) 'Traditional'**		**(ii) '*Standards*-based'**		**(iii) 'Both'**	
			d. Teacher Presentation	**h. Individual Work**	**f. Student Presentation**	**g. Group Work**	**e. Discuss New**	**j. Teacher Summary**
% Lessons: spent on activity	CMP %	305	26.9%	41.6%	5.3%	33.4%	60.7%	4.3%
	Non-CMP %	274	21.2%	48.9%	1.8%	15.0%	71.9%	3.7%
	z		1.6	−1.75	2.20*	5.15**	−2.85**	0.38
% Time (min): spent on activity	CMP %	17,104	5.2%	14.1%	1.1%	12.8%	29.1%	0.35%
	Non-CMP %	14,904	6.6%	12.4%	0.3%	4.6%	33.2%	0.38%
	z		−5.36***	4.42***	8.96***	25.67***	−7.81***	−0.37

*$p < 0.05$.

** $p < 0.01$.
*** $p < 0.001$.

Activities associated with traditional instruction: Activities d and h. The first activity in the 'traditional' category is Activity d: Presentation of New Content by Teacher. This is a whole class activity with little or no interaction between teacher and student, except for the students taking notes. It is the type of instruction that is often called 'lecture.' A common phrase that characterizes this type of instructional activity is 'sage on the stage.' Each unit in the CMP curriculum is composed of a sequence of investigations designed to be launched, explored, and summarized during each lesson. Using this CMP scenario, the teacher does not so much present new content as launch investigations in which students explore new content. It is somewhat surprising, then, that the percent of observed lessons in which non-CMP teachers presented new content (21.2%) was not significantly greater than the percent of lessons in which CMP teachers presented new material (26.9%). However, when we consider the amount of *time* spent presenting new content we see that there is a significant difference ($z = -5.36$, $p < 0.001$) between CMP and non-CMP teachers, with the non-CMP teachers spending about 25% more time (6.6% vs. 5.2%) presenting new material than the CMP teachers.

The other 'traditional' activity we considered was Activity h: Individual Work (not on homework). This type of activity is often termed 'seat work.' For this activity students often work on teacher- or curriculum-provided worksheets, or on problems from the textbook. As with Activity d: Presentation of New Content by Teacher, there is no significant difference between the percent of lessons in which CMP and non-CMP students engaged in individual work. However, the percent of time spent on individual work was 14% greater (14.1%/12.4% = 1.14) in CMP lessons than in non-CMP lessons ($z = 4.42$, $p < 0.001$).

Activities associated with Standards-based instruction: Activities f and g. Turning to the '*Standards*-based' activities, it was disconcerting to find that student presentations were rarely made in either type of classroom. Specifically, students in CMP classrooms spent only about 1% of total lesson time on Activity f: Student Presentation, and non-CMP students only spent about 0.3% of total lesson time doing so. On the other hand, there were huge disparities between CMP and non-CMP classrooms on Activity g: Group Work (including prompt and/or directions). CMP students worked in groups during about a third of the observed lessons, while non-CMP students did so in only about 15% of the lessons ($z = 5.15$, $p < 0.01$). The *time* spent working in groups was even more disparate, relatively speaking (13% vs. 5%; $z = 25.67$, $p < 0.001$). Group work was used in 102 CMP lessons for a total of 2189 min. So, when CMP teachers used group work in a lesson, they did so for an average of almost 21.5 min. By comparison, non-CMP teachers who used group work did so for an average of less than 17 min (41 lessons, 686 min). This means that when group work was used in CMP lessons, it was used about 4.5 min longer, on average, or more than a fourth again as long.

Activities associated with both types of instruction: Activities e and j. Finally, we come to the category of activities that are typically associated with both '*Standards*-based' and 'traditional' instruction. The first of the activities is Activity e: Discussion Between Teachers and Students of New Content. This activity is a whole class activity that most often took the form of 'discussions' via questions that the teacher asked and the students answered during the course of the teacher's presentation of new content. This is in contrast to Activity d: Presentation of New Content by Teacher, in which the teacher presents new content without interacting with the students.

These 'discussions' between teachers and students occurred significantly more often ($z = -2.85$, $p < 0.01$) and consumed more minutes ($z = -7.81$, $p < 0.001$), relatively speaking, in non-CMP lessons than in CMP lessons. They occurred in 185 of the 305 CMP lessons (60.7%), consuming a total of 4978 min. On average, these 'discussions' lasted 26.9 (4978/185) min in CMP classrooms. In non-CMP classrooms the 'discussions' occurred in

197 of the 274 lessons (71.9%), consuming a total of 4941 min, yielding an average of 25.1 min per 'discussion.' So, we see that the CMP teachers spent about 1.8 more minutes (~7% more time) per 'discussion.' Even though the CMP teachers had relatively fewer discussions, the average duration of each discussion consumed more minutes than the average discussion led by non-CMP teachers.

CMP teachers used Activity j: Summary by Teacher least often of all the activities for teaching new content (4.3% of lessons; 0.35% of time). This result does not appear to align well with the CMP curriculum structure. Given the 'Launch, Explore, Summarize' structure of CMP lessons, one might expect that Activity j would be used in nearly as many lessons as Activity g: Group Work. Non-CMP teachers summarized in about the same proportion of lessons (3.7% of lessons) as the CMP teachers, and both groups spent about the same proportion of time summarizing (~0.4% of time). Unlike in the CMP lessons, Activity j: Summary by Teacher was not the least used method for teaching new material in non-CMP lessons. That distinction goes to Activity f: Student Presentation, which was used even less (1.8% of lessons, 0.3% of time) by non-CMP teachers than Activity j: Summary by Teacher.

Looking across all the activities in Table 1, Activity e: Discussion Between Teacher and Students of New Content was by far the most prevalent way for teachers to present new material in both the CMP classrooms (60.7% of lessons; 29.1% of time) and the non-CMP classrooms (71.9% of lessons; 33.2% of time). The 'traditional' Activity h: Individual Work (not on homework) was second most prevalent for both CMP (41.6% of lessons; 14.1% of time) and non-CMP lessons (48.9% of lessons; 12.4% of time). In third place for CMP teachers was the 'Standards-based' Activity g: Group Work (including prompt and/or directions), which they used in 33.4% of lessons and which consumed 12.8% of the time. However, for non-CMP teachers, the third most common type of instruction on new material was the 'traditional' Activity d: Presentation of New Content by Teacher (21.2% of lessons; 6.6% of time). The total time devoted to instruction on new material was significantly greater ($z = 9.43$; $p < 0.001$) in CMP classrooms (62.7%) than in non-CMP classrooms (57.5%).

4.1.3. Structure of instruction on non-new material

This category is composed of five activities that teachers do during a lesson that are not directly associated with the new material to be learned. These five activities are: Activity a. Opening/Warm-Up Problem(s); Activity c. Review Prior Work; Activity i. Short Assessment; Activity m. Discussion Between Teacher and Students (not on new content); and, Activity n. Management Issues. Table 2 gives the implementation data for these five activities.

Table 2. The structure of instruction on non-new material.

% Of lessons vs. % of time	**Curriculum**	***n***	**a. Warm-up**	**c. Review**	**i. Short Assessment**	**m. Discuss Non-New**	**n. Management**
% Lessons: spent on activity	CMP %	305	38.0%	16.7%	2.6%	28.5%	42.0%
	Non-CMP %	274	55.5%	17.5%	3.3%	29.6%	33.2%
	z		-4.20^{***}	−0.25	−0.47	−0.27	2.17^{*}
% Time (min): spent on activity	CMP %	17,104	7.9%	3.2%	0.88%	7.5%	5.1%
	Non-CMP %	14,904	12.0%	4.6%	0.93%	7.4%	3.4%
	z		-12.37^{***}	-6.29^{***}	−0.41	0.48	7.70^{***}

$^{*}p < 0.05$.

***$p < 0.001$.

Activity a: Opening/Warm-Up Problem(s). Teachers in our study often used opening/warm-up problems to help settle students. The warm-up problems typically required students to use existing knowledge to practice procedures or solve problems. CMP teachers used warm-ups in more than a third of their lessons. Non-CMP teachers used warm-ups significantly more frequently (55.5% vs. 38.0% of lessons; $z = -4.20$, $p < 0.001$) and spent a significantly greater proportion of their total lesson minutes on them (12.0% vs. 7.9%; $z = -12.37$, $p < 0.001$). Non-CMP teachers engaged in opening warm-up problems at the beginning of 152 lessons for a total of 1786 min. That is an average of about 12 min per warm-up activity. Interestingly, when CMP teachers used a warm-up activity, on average they spent about the same amount of lesson time on it as non-CMP teachers, namely about 12 min on average, even though non-CMP teachers consumed a greater percentage of their total lesson minutes on warm-up activities.

Activity c: Review Prior Work. Not all opening activities were coded as Activity a: Opening/Warm-Up Problems. For example, if a teacher opened a lesson with a formal review of the material from the previous day's lesson, the activity was coded as Activity c: Review Prior Work, even though it was used to open the lesson. The percents of time spent on each of these activities (CMP: 3.2%; non-CMP: 4.6%) were significantly different in CMP and non-CMP classrooms ($z = -6.29$, $p < 0.001$), although the percents of lessons (CMP: 16.7%; non-CMP: 17.5%) were not.

Activity i: Short Assessment Table 2 shows that there were no × the frequency or the time that CMP and non-CMP spent on Activity i: Short Assessment. Furthermore, the percent of time spent on short assessment for CMP teachers (0.88%) and non-CMP teachers (0.93%) was, respectively, the 2nd and 3rd lowest percentage of time spent on any of the activities. This is probably due to the fact that we told the teachers that we did not want to observe lessons where written assessments comprised a significant percent of the lesson time.

Activity m: Discussion Between Teacher and Students (not on new content). There was no significant difference between the percentages of lessons in CMP (28.5%) and non-CMP (29.6%) classrooms in which there was discussion between teacher and students of non-new content. Neither was there a significant difference between the percentages of time spent discussing non-new content (CMP 7.5%; non-CMP 7.4%), which were fairly high (6th highest of all CMP activities and 5th highest of all non-CMP activities).

Activity n: Management Issues. CMP teachers attended to management issues in more than 40% of their lessons, and non-CMP teachers did so in more than 30% of their lessons. This represents a statistically significant difference ($z = 2.17$, $p < 0.05$). The percents of time spent on management issues (CMP: 5.1%; non-CMP: 3.4%) were fairly small in both types of classrooms, although they were significantly different ($z = 7.70$, $p < 0.001$),

4.1.4. Structure of homework-related activities

Finally, Table 3 presents the data from the category (3) activities: structure of the homework-related activities. This category comprises the following activities: Activity b: Go Over Homework; Activity k: Assign Homework; and Activity l: Students Work Individually on Homework. The total time devoted to all three homework-related activities was significantly greater ($z = -4.16$; $p < 0.001$) in non-CMP classrooms (14.4%) than in CMP classrooms (12.8%), as was the time spent on each individual activity.

Table 3. The structure of homework-related activities.

% Of lessons vs. amount of time	**Curriculum**	***n***	**b. Go Over HW**	**k. Assign HW**	**l. Individual HW**
% Lessons: spent on activity	CMP %	305	30.2%	29.2%	10.8%
	Non-CMP %	274	24.1%	47.1%	37.2%

	z		1.64	-4.44^{***}	-7.50^{***}
% Time (min): spent on activity	CMP %	17,104	9.7%	1.3%	1.8%
	Non-CMP %	14,904	3.7%	2.2%	8.5%
	z		21.10^{***}	-6.26^{***}	-27.77^{***}

$^{***}p < 0.001$.

Activity b: Go Over Homework. The percent of lessons in which CMP teachers went over homework (30.2%) is not significantly different than the percent of lessons in which non-CMP teachers went over homework (24.1%). However, the percent of time spent going over homework in CMP lessons (9.7%) was more than 2.5 times as great as in non-CMP lessons (3.7%), and is significantly different ($z = 21.10$, $p < 0.001$).

Activity k: Assign Homework. CMP teachers assigned homework significantly less often ($z = -4.44$, $p < 0.001$) than non-CMP teachers. Non-CMP teachers assigned homework in almost half of their lessons, as compared with homework being assigned in a little more than a fourth of the CMP lessons. The percent of in-class time spent assigning homework was small (non-CMP: 2.2%; CMP: 1.3%;) for both types of lessons, but significantly different. The percents of time that CMP and non-CMP teachers spent assigning the homework were approximately proportional to the number of assignments.

Activity l: Students Work Individually on Homework. We recorded the number of lessons during which students worked on homework, as well as the time they spent. Non-CMP students worked on homework during more than three times as many lessons (37.2%) as CMP students (10.8%), and spent more than four times as long (8.5%) as CMP students (1.8%).

4.1.5. Use of materials

We tracked the usage of textbooks, calculators/computers, and manipulative materials as part of our LieCal observations and coding.

4.1.6. Textbook use

Table 4 shows the frequencies with which teachers used their texts for various purposes during the LieCal observations in grades 6–8. Table 5 gives analogous information on student usage. The text was used for more than one purpose in most lessons. A number of things in these tables stand out. First, CMP and non-CMP teachers used the texts in large and statistically equal percentages of lessons, as did the CMP and non-CMP students (approximately 90% for teachers and slightly less for students). Second, although the percentage of lessons in which teachers worked problems from the text was almost 10 percentage points greater ($z = 2.36$, $p < 0.05$) for CMP teachers (62.3%) than for non-CMP teachers (52.6%). the percentages of lessons in which the two types of students worked problems from the text were statistically the same (∼70%). Third, CMP and non-CMP teachers referred to diagrams, charts, or pictures in the text during approximately equal percentages of lessons (∼15%). However, the difference between student usage of diagrams, charts, or pictures was significant ($z = 5.02$, $p < 0.001$), with CMP students doing so about 3 times more often than non-CMP students (22.3% vs. 7.3%). Fourth, both non-CMP students and non-CMP teachers referred to the text for examples and formulas about three times as often as CMP students and CMP teachers; however, CMP students read from the text more than twice as often (41.0%) as non-CMP students (18.3%). These differences in reading the text and in use of the text for examples and formulas are both statistically significant. Finally, Table 4, Table 5 provide evidence that CMP teachers tried significantly more often than non-CMP teachers to adhere strictly to the author's conception of instruction. Table 4 shows that CMP teachers followed the lesson as laid out in the text a third again as often as non-CMP teachers (55.1% vs. 41.2%; $z = 3.34$, $p < 0.001$), while Table 5 shows that CMP students followed the text activity almost twice as often as non-CMP students (20.7% vs. 11.7%; $z = 2.92$, $p < 0.01$).

Table 4. Teacher textbook use (percent of lessons).

Curriculum	*n*	a. Working problems from text	b. Review diagrams, charts or pictures	c. Review examples or find formulae	d. Followed lesson as laid out in text	e. Text not used
CMP	305	62.3%	15.1%	16.4%	55.1%	10.9%
Non-CMP	274	52.6%	15.7%	47.8%	41.2%	10.2%
z		2.36*	−0.20	−8.14***	3.34***	0.27

*$p < 0.05$.
***$p < 0.001$.

Table 5. Student textbook use (percent of lessons).

Curriculum	*n*	a. Working problems from text	b. Review diagrams, charts or pictures	c. Review examples or find formulae	d. Read from text	e. Follow text activity	f. Text not used
CMP	305	74.1%	22.3%	3.9%	41.0%	20.7%	11.9%
Non-CMP	274	68.6%	7.3%	13.1%	18.3%	11.7%	12.8%
z		1.46	5.02***	−4.02***	5.94***	2.92**	−0.33

**$p < 0.01$.
***$p < 0.001$.

4.1.7. Calculators, computers, and manipulatives

Fig. 2 shows the number of CMP and non-CMP lessons during which students or teachers used calculators/computers and manipulative materials as an integral part of instruction. The mean percent of lessons that the CMP students used calculators as an integral part of instruction (16.1%) is not significantly different than that for non-CMP students (20.2%). The same is true of CMP and non-CMP teachers' use of calculators, although the means are about half as large (7.2% and 11.0%). CMP and non-CMP students and teachers used manipulatives in about 10% of the lessons that we observed. Neither of the differences between CMP and non-CMP students or teachers' use of manipulatives is statistically significant.

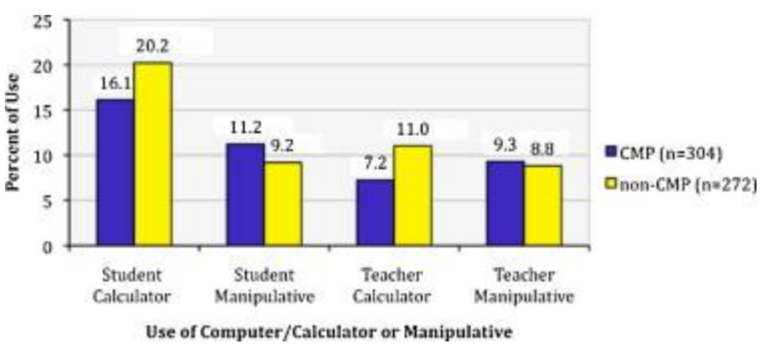

Fig. 2. Frequency of computer/calculator and manipulative use by students and teachers in grades 6–8.

4.2. Aspect 2: nature of the instruction

As described above, the coders used well-defined rubrics to code a set of 21 items about the nature of the instruction on a scale of 1 (low)–5 (high) for each lesson they observed.

4.2.1. Factor analysis

A stepwise factor analysis of the resulting data yielded three factors, which we named Conceptual Emphasis (4 items), Procedural Emphasis (4 items), and Learning Environment (9 items). These factors accounted for 65% of the total variance among the ratings of all 305 CMP lessons and 274 non-CMP lessons in grades 6–8. Fig. 3 gives an example statement of an item from each of the three factors. The items in the Conceptual Emphasis factor clearly rate the *Standards*-based Learning Environment (SBLE) aspect of instruction identified by Tarr et al. (2008); that is, 'the lesson fostered the development of conceptual understanding.' The items in the Procedural Emphasis factor, on the other hand, are related to an aspect of classroom instruction that is more typical of traditional learning environments. The items in the Learning Environment factor rate the nature of a more neutral aspect of instruction that includes elements like the teacher's planning, organization, pacing, knowledge, and respect for students.

Fig. 3. One sample question chosen from each of the 3 sets of factor questions.

Factor 1: Conceptual Emphasis

The teacher's questioning strategies were likely to enhance the development of student conceptual understanding/problem solving.

Factor 2: Procedural Emphasis

Students had opportunities to learn procedures (by teacher demonstration, class discussion, or some other means) before they practiced them

Factor 3: Learning Environment

The pace of the lesson was appropriate for the purpose of the lesson.

To determine the extent of the differences between the nature of instruction in the CMP and non-CMP lessons, we created three summated scales based on the factor structure. Specifically, we summed the ratings on all the items associated with each factor. Then we performed statistical tests of the null hypothesis that there is no difference between the means of the summated scale ratings of the CMP and non-CMP instruction for each factor. As shown in Table 6, for factors 1 and 2 (Conceptual Emphasis and Procedural Emphasis), CMP and non-CMP instruction differed significantly within each grade level, across grade levels, and overall. For factor 3 (Learning Environment), the results are mixed.

Table 6. Comparison of CMP and non-CMP instruction on three factors rating the nature of instruction.

Factor	**Curriculum**	**Grade 6**			**Grade 7**			**Grade 8**			**Overall**		
		n	**Mean**	**Std. dev.**	***n***	**Mean**	**Std. dev.**	***n***	**Mean**	**Std. dev.**	***n***	**Mean**	**Std. dev.**
1	CMP	96	14.51	3.70	101	12.52	3.70	108	13.27	3.65	305	13.41	3.76
	Non-CMP	87	9.44	2.50	95	10.11	2.31	92	10.61	2.73	274	10.06	2.55
	t	10.76***			5.43***			5.75***			12.40***		
	Two-way ANOVA	$F(3, 575) = 53.43$***											
2	CMP	96	11.67	3.03	101	11.70	3.05	108	11.48	3.44	305	11.61	3.18
	Non-CMP	87	13.77	3.58	95	14.24	3.32	92	15.41	3.27	274	14.49	3.44
	t	−4.30***			−5.59***			−8.24***			−10.43***		
	Two-way ANOVA	F(3, 575) = 37.77***											
3	CMP	96	35.89	5.60	101	35.18	4.71	108	33.19	6.88	305	34.70	5.93
	Non-CMP	87	31.98	6.83	95	34.41	5.82	92	33.92	5.14	274	33.47	6.02
	t	4.25***			1.02			−0.84			2.46*		
	Two-way ANOVA	F(3, 575) = 3.64*											

Note. Factor 1: Emphasis on Conceptual Understanding. Factor 2: Emphasis on Procedural Knowledge. Factor 3: Learning Environment.
*$p < 0.05$.
***$p < 0.001$.

4.2.2. Factor 1: Conceptual Emphasis

There was a significant difference across grade levels between CMP and non-CMP instruction related to the Conceptual Emphasis factor ($F(3, 575) = 53.43$, $p < 0.001$). The overall (grades 6–8) mean of the summated ratings on the Conceptual Emphasis factor for CMP lessons was 13.41, while the overall mean of the summated ratings on the Conceptual Emphasis factor for non-CMP lessons was 10.06. The summated ratings for the Conceptual Emphasis factor were obtained by summing the ratings on four items. That implies that the mean rating on the Conceptual Emphasis items is 3.35 (13.41/4) for CMP instruction and 2.52 (10.06/4) for non-CMP instruction. That is, CMP instruction was rated 0.35 points above the midpoint between low and high conceptual emphasis, while non-CMP instruction was rated almost a half point below the midpoint. The end result is that CMP instruction was rated an average of about 4/5 of a point higher (out of 5) on each Conceptual Emphasis item than non-CMP instruction, which is a significant difference ($t = 12.40$, $p < 0.001$).

4.2.3. Factor 2: Procedural Emphasis

There was also a significant difference across grade levels between CMP and non-CMP instruction related to the Procedural Emphasis factor. Specifically, the data for factor 2 reveals that the Procedural Emphasis ratings across grade levels for the non-CMP lessons are significantly higher than the Procedural Emphasis ratings across grade levels for the CMP lessons ($F(3, 575) = 37.77$, $p < 0.001$). Note that the direction of the difference is opposite to that of the Conceptual Emphasis factor. Also, the overall (grades 6–8) mean of the summated ratings on the Procedural Emphasis factor for non-CMP lessons (14.49) is significantly greater than the overall mean of the summated ratings on the Procedural Emphasis factor for CMP lessons, which is 11.61 ($t = -10.43$, $p < 0.001$). The summated ratings for the Procedural Emphasis factor were obtained by summing the ratings on four items. That implies that the mean rating on the Procedural Emphasis items was 3.62 (14.49/4) for non-CMP instruction and 2.90 (11.61/4) for CMP instruction. That is, non-CMP instruction was rated 0.62 points above the midpoint between low and high procedural emphasis, while CMP instruction was rated just slightly below the midpoint. The end result is that, on average, non-CMP instruction was rated about 7/10 of a point higher (out of 5) on each Procedural Emphasis item than CMP instruction, which is a significant difference.

4.2.4. Factor 3: Learning Environment

Finally, differences across grades 6–8 are significant ($F(3, 575) = 3.64$, $p < 0.05$) for the Learning Environment factor. These differences are mainly due to the fact that instruction differed significantly within grade 6 ($t = 4.25$, $p < 0.001$). In fact, in terms of Learning Environment, there are no significant differences within grades 7 or 8. The overall (grades 6–8) mean of the summated ratings on the Learning Environment factor for CMP lessons (34.70) is significantly greater than the overall mean of the summated ratings on the Learning Environment factor for non-CMP lessons, which is 33.47 ($t = 2.46$, $p < 0.05$). The summated ratings for the Learning Environment factor were obtained by summing the ratings on nine items. That implies that the mean rating on the Learning Environment items was 3.86 (34.70/9) for CMP instruction and 3.72 (33.47/9) for non-CMP instruction. That is, both CMP instruction and non-CMP instruction were rated above the midpoint between low and high Learning Environment. Even though overall there is a significant difference across grades 6–8 between CMP and non-CMP instruction for the Learning Environment, on average, the CMP instruction was rated only 14/100 of a point higher (out of 5) on each Learning Environment item than the non-CMP instruction.

4.2.5. Three overall ratings items

Table 7 shows results from three of the items that we used to rate the overall nature of instruction. These three overall ratings items were chosen because they highlight the important differences we observed between the CMP and non-CMP lessons. Table 7 shows that CMP teachers' instruction was rated higher for fostering conceptual understanding than non-CMP teachers' instruction was. On the other hand, CMP teachers' instruction was rated lower for fostering procedural ability than non-CMP teachers' was. Lastly, the CMP teachers' instruction was rated higher for fostering the ability to make mathematical applications than the non-CMP teachers' was. All three differences are significant ($p < 0.001$).

Table 7. Results from three items to describe the nature of instruction.

	CMP mean (*n* = 305)	**Non-CMP mean (*n* = 274)**	***T***
Rate the extent to which the teacher fostered students' conceptual understanding of algebraic ideas	3.44 (1.00)	2.66 (0.83)	10.17^{***}
Rate the extent to which the teacher fostered students' ability to carry out mathematical procedures	3.08 (1.06)	3.88 (1.01)	-9.27^{***}
Rate the extent to which the teacher fostered students' opportunity to learn how to apply a mathematical process/concept to a problem situation	3.19 (1.25)	2.19 (0.94)	10.75^{***}

$^{***}p < 0.001$.

5. Conclusion and discussion

In this article, we examined the impact of curriculum on instruction in *Standards*-based and traditional classrooms. The results of the study provide evidence that the kinds of instruction that transpired in classrooms using *Standards*-based and traditional mathematics curricula were different. Specifically, our research examined 14 types of lesson activities and the use of two types of teaching materials. Our research also examined three factors rating the nature of instruction in CMP and non-CMP lessons. We found that statistically significant differences existed between *Standards*-based and traditional classrooms in the frequency/duration of most of the 14 activities, in text usage, and in the mean ratings of all three factors. Statistical significance, however, does not necessarily imply educational significance. In this section, we discuss the activities, materials, and factors related to the differences from an educational perspective.

Historically, conceptual understanding and procedural ability have been highly valued learning goals in school mathematics (Resnick & Ford, 1981), and they continue to be important today (Hiebert and Grouws, 2007, Lappan et al., 2007). In fact, the question of how—and in what order—students should acquire conceptual understanding and procedural abilities is at the heart of the intense controversy that has been dubbed the "math wars" (Stein, Remillard, & Smith, 2007). Our research uncovered major differences between the levels of conceptual emphasis and procedural emphasis in the CMP and non-CMP instruction. CMP lessons emphasize the conceptual aspect of instruction to a greater extent than the non-CMP lessons. On the other hand, non-CMP lessons emphasize the procedural aspect of instruction to a greater extent than the CMP lessons. This finding is consistent with goals and features of *Standards*-based and traditional curricula (Hirsch, 2007, Senk and Thompson, 2003) as well as with the findings from our analyses of the CMP and non-CMP curricula (Cai et al., 2010, Nie et al., 2009). The CMP curriculum includes more cognitively demanding problems than the non-CMP curriculum (Cai et al., 2010). This finding is also consistent with findings from the analysis of instructional tasks in CMP and non-CMP lessons that we have reported elsewhere (Cai, Wang, Moyer, Nie, & Wang, submitted for publication). In fact, CMP teachers were more than three times as likely to implement high-level tasks during classroom instruction than non-CMP teachers (see article 5 in this special issue by Cai, Wang, Moyer, Wang, & Nie, 2011). These results are important, especially in light of existing research (Hiebert and Grouws, 2007, Schoen et al., 2003, Stein and Lane, 1996, Stigler and Hiebert, 2004) that shows that the implementation of cognitively demanding tasks (coupled with reform-oriented practices) are positively associated with student achievement.

The materials in the CMP curriculum are designed to be suitable for use in cooperative learning instructional formats (Lappan et al., 2007). Therefore, it is not surprising that more than twice as many CMP lessons as non-

CMP lessons implemented group work. The percent of time spent on group work during the CMP lessons was almost three times as great as during the non-CMP lessons. Although the relatively greater use of group work and student presentations during CMP lessons was not surprising, the small amount of time spent on group work (12.8%) and on student presentations (1.1%) during CMP lessons was unexpected, given the nature of the CMP curriculum. These results are aligned with the research discussed previously that documents the difficulty that teachers using reform curricula have implementing many of the practices that are consistent with reform. Our results seem to indicate that using the CMP curriculum does not necessarily persuade CMP teachers that group learning is as efficient and powerful as is often claimed by proponents of reform mathematics (Davidson & Kroll, 1991).

Non-CMP students spent significantly more class time working individually on their homework than CMP students. The difference between the 2 percentages of time spent was almost 7 percentage points. It is instructive to note that the difference between the total times that CMP and non-CMP teachers devoted to homework was much smaller. Specifically, the difference between the percentages of time spent on all homework-related activities was narrowed to about 2%, mostly because CMP teachers spent more class time going over homework than non-CMP teachers. The different allocations of time devoted to homework-related activities in CMP and non-CMP classrooms are aligned with the different philosophies of the two types of curricula. In the case of the non-CMP curricula, the solutions to homework problems are designed to be similar to the worked-out problems that the teacher demonstrates during the presentation of new material. Typically, the purpose of homework in non-CMP classes is for students to practice solving similar problems, using a previously demonstrated approach. By allowing students to work on homework during class time, non-CMP teachers are able to help them learn to apply the demonstrated techniques. Solutions to problems in the CMP curriculum, however, are not intended to be demonstrated by the teacher. Rather, students are expected to help one another learn to solve the problems during in-class activities. CMP homework assignments, too, usually involve true problem solving, rather than applications of demonstrated approaches. As a result, we found that the CMP teachers in our project needed to devote more class time to discussing the solutions to the homework problems than the non-CMP teachers, and less time was available for students to work on homework problems during class.

With respect to textbook use, an important result is that the CMP teachers followed the lesson laid out in the text 113 times as often as the non-CMP teachers, and the CMP students followed the text activity almost twice as often as the non-CMP students. These findings suggest that CMP teachers appeared more likely than non-CMP teachers to implement the curriculum as intended by the textbook authors. This is an especially relevant finding in light of the conclusion by Tarr et al. (2008) that "…what is needed is *coherence* between the textbook and implemented curricula; that is consistency between curriculum and instruction in order to actualize student learning in mathematics" (p. 275).

CMP teachers were more likely than non-CMP teachers to "work problems from the text" and CMP students were more likely to "read from the text," but non-CMP students and teachers were more likely than CMP students and teachers to "review examples or find formulas." In addition, CMP teachers were much more likely than non-CMP teachers to "review diagrams, charts or pictures." These findings are not surprising given that CMP is a problem-based curriculum that relies heavily on diagrams, charts, and pictures, while worked-out examples form the backbone of the non-CMP curricula.

In terms of the use of calculators and physical manipulatives, we found that CMP and non-CMP students were equally likely to use calculators. Specifically, the mean percent of lessons that the CMP students used calculators as an integral part of instruction is similar to that for non-CMP students. The same was true of CMP and non-CMP teachers' use of manipulatives. CMP and non-CMP students and teachers used manipulatives in about 10% of the lessons that we observed. Since the use of calculators and of physical materials to represent mathematical concepts are often considered hallmarks of *Standards*-based instruction, these results are unexpected.

In their comprehensive description of existing research on the influence of curriculum on student learning, Stein et al. (2007) "…call for studies that are designed to include both large-scale tests of curricular effectiveness and smaller, but embedded, observational studies of instructional practice" (p. 339). Importantly, this study answers their call. It is embedded in a large-scale investigation of curricular effectiveness (see article 5 in this special issue by Cai et al., 2011), and it provides long-term, detailed information about the similarities and differences between the ways that mathematics is taught in classrooms of a large urban district when *Standards*-based and traditional curricula are implemented. Previous studies of the role of curricula in mathematics education have focused chiefly on student outcomes, with little or no consideration of classroom instruction (NRC, 2004). The National Research Council (2004) identified 698 studies on 13 *Standards*-based and 6 traditional curricula. Only a few studies considered instruction and implementation issues when interpreting their outcome measures.

While research into the effect of curriculum on teaching is not uncommon, no study has looked at this level of detail into the effect of curriculum in classrooms of large urban districts, with so many teachers, over such a long period of time. The striking and clear differences that we found between the two types of instruction are of great interest and importance internationally, especially in those countries that are considering whether the aim of improving the mathematical education of their students can be accomplished by reforming their mathematics curricula. Our research strongly suggests that the curriculum has a significant effect on the frequency and duration of many of the activities that teachers use during instruction, as well as the level of emphasis they place on conceptual and procedural issues.

In the end, despite all the measures we took to ensure validity and reliability, our study—like all studies—has its limitations. Research limitations are acutely manifest in education research, partly because actions that one can take to control variables are limited by existing classroom, district, and societal constraints. In the LieCal Project, the district required us to choose existing CMP and non-CMP schools to participate in the project. Even though we randomly selected the participating schools, the prior existence of these CMP and non-CMP schools prohibited us from having a truly randomized allocation of students and teachers to the CMP and non-CMP treatment groups. Despite such limitations, the methodology, size, and duration of our longitudinal research provides the mathematics education community with unprecedented insights into the instruction that transpires in US urban classrooms when students use *Standards*-based or traditional mathematics curricula.

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[1]In this paper, the term 'curriculum' refers to the textbook and all the teaching, learning, and assessment materials marketed by the publisher to complement its use.