Effects of a Web-based Curriculum-based Measurement System (ECBM) on Math Achievement: A Dynamic Classwide Growth Model

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Abstract

The purposes of this study were: (1) to illustrate how a well-developed ECBM system can be used by general educators to enhance students' math achievements, and (2) to examine the effects of two types of math probes and two types of growth models on students' math achievement in general classrooms.

One hundred and thirty-four third-grade students in four classes of an elementary school located in Taiwan were randomly assigned into one of four conditions: control, single-type CBM probes and dynamic-growth modeling, mixed-type CBM probes and dynamic-growth modeling, and mixed-type CBM probes and linear-growth modeling. Teachers in experiment groups used ECBM system for twelve weeks.

Results of this study indicated that students in the dynamic-growth modeling group outperformed students in the linear-growth modeling group in CBM and Mathematics Concepts Test. It also established strong evidence that classwide dynamic-growth modeling was more effective for students in mixed-type CBM probes than it is for students in single-type CBM probes. Overall, both lower and higher CBM math students in the dynamic-growth modeling group significantly outperformed the students in the linear-growth modeling group.

This study expends previous research in developing dynamic features of ECBM, which is reliable and beneficial for students in the general classroom.

Keywords: Curriculum-based measurement, elementary mathematics, computerized measurement system

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Introduction

Accelerating the academic progress of students who, in the general classroom, either have or do not have disabilities becomes increasingly possible through the ongoing assessment and instructional interventions. Curriculum-based measurement (CBM) is a data-based, problem-solving model for the indexing of academic competence and progress through ongoing assessment (Deno, 1985; Green & Shinn, 1990). CBM integrates key concepts of traditional measurement theory and the conventions of behavioral and observational assessment methods (Deno, Fuchs, Marston, & Shin, 2001). The growth rate (slope) plays an important role in CBM by mimicking the progress that students typically make (Deno et al., 2001). Comparing an individual student's slope with the normative growth rate, teachers can effectively formulate their goals for the student, make instructional adjustments, or identify learning problems for the students with and without disabilities. The initial goal underlying CBM concerns CBM-based normative growth rates that, covering reading, spelling, and mathematics, are exhibited by students from school districts or nationally representative student populations (Deno et al., 2001). Teachers can use a CBM graph analysis to determine whether a goal adjustment is necessary. Research has documented that CBM graph analyses and slope comparisons are effective in revealing useful information about students' progress, information that enhances teachers' planning and student achievement (e.g., Fuchs, Deno, & Mirkin, 1984; Wesson, 1991; Shinn & Good, 1993; Allinder & Oats, 1997). Moreover, when teachers raise goal more often and develop higher expectations, they introduce more revisions to their instructional programs (Fuchs, Fuchs, & Hamlett, 1989) and reflect better achievement among their students (Fuchs, Fuchs, Hamlett, & Stecker, 1991). However, two problems concerning goal setting in the general classroom are raised: First, previous research has indicated that general educators have difficulties in deciding how much growth might be expected for their students when adjustment is necessary (Tsuei, 2001, 2004). Second, studies by Fuchs (1995, 1999) have shown that the effectiveness of instructional settings in the general classroom can vary dramatically. Thus, use of an individual's CBM slope data as classwide instructional decision-making criteria becomes problematic. It is necessary to establish goals for growth rates in relation to other students' acquisition of the same instruction. Consequently, there is a need in CBM research to establish an appropriate growth model that is based on classwide comparisons in the general classroom.

Mathematics is less concerned with content validity and technical adequacy in CBM research (Thurber, Shinn, & Smolkowski, 2002). Research has indicated that math achievement first increases quickly and then exhibits a declining growth rate

(Ding & Davison, 2005). Apparently, students' math scores do not increase in a linear mode. Previous research indicated that a linear relationship does not adequately model the academic growth across school years (Fuchs, Fuchs, Hamlett ,Walz, & Genmann,1993; Howard, 1999). Moreover, according to the same research, the linear relationship does not contribute significantly to the modeling of student progress for more than 50% of general students (Fuchs et al., 1993). Previous studies indicated that trend analyses with quadratic-curve or cube-curve estimates were more suitable to the modeling of an individual student's CBM performances in mathematics (p <.01) (Tsuei, 2001, 2004). Moreover, Deno (1985) argued that, because higher slopes make the detection of student growth relatively fast, higher slopes are a desirable feature of ongoing measurement systems. Therefore, how to establish appropriate classwide "ambitious goal" to model students' progress of mathematics learning, which describes weekly rates of improvement over time in general classrooms, appears to be necessary.

Computerized CBM system

Over the past decade, Fuchs et al. (1993, 1994, 1998) have developed a computerized system, Monitoring Basic Skills Progress (MBSP), that efficiently and accurately collects and manages students' ongoing CBM data in reading, math computation, math concepts and applications. Two components of MBSP in mathematics are the Basic Math Computation Program and Basic Math Concepts and Applications. Research indicated that the MBSP graphs can benefit teachers in their instructional program development and can result in better student achievement (Ferguson & Fuchs, 1991; Fuchs, Fuchs, Hamlett, & Stecker, 1991; Fuchs, Fuchs, Hamlett, & Ferguson, 1992; Fuchs, Hamlett, & Fuchs, 1998). Despite this strong research basis supporting MBSP, at least two limitations associated with MBSP in mathematics exist. The fist limitation concerns fixed-content and single problem-type of CBM probes; the second concerns the use of a single mathematics concept-skill on CBM math problems.

Fixed-content and single problem-type of CBM probes

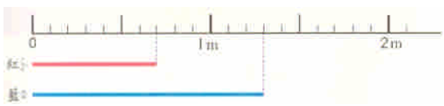
MBSP is standalone computer software with a fixed number of mathematics CBM probes at each grade level (e.g., 30 computation probes) (Fuchs, Hamlett, & Fuchs, 1998). Each CBM probe comprises a set of single mathematics problem-type. That is, computation and concept-application mathematics CBM probes are constructed separately. The single problem-type CBM probes in MBSP may decrease correlations between CBM and the general measures of mathematics (Helwig, Anderson, & Tindal, 2002). In previous CBM math validation studies, CBM computations, concepts, and applications and total math battery scores ranged from .64 to .81 for Grade 2 and 4 (Fuchs, Fuchs, Hamlett, & Thompson, et al., 1994).

Correlations between CBM math-application probes and two CTBS were .45 and .52 (Parke, 1995). Correlations between CBM math estimation tasks (20 computation and 20 one-step word problems) and the California Achievement Test ranged from .29 to .63 (Foegen & Deno, 2001). In CBM concept probes, research indicated that its correlation with CAT were .61 (students with learning disabilities) and .80 (general students)(Helwig et al., 2002). Apparently, most criteria for mathematics achievement tests integrate mathematics computations or application skills to measure mathematics proficiency, e.g. California Achievement Tests (Thurber, Shinn, & Smolkowski, 2002). Moreover, in the field of mathematics education, concept-driven curriculum that is meant to foster students' integrated mathematical competence was led by the teaching and assessment by the National Council of Teachers of Mathematics (NCTM, 2000). Thus, these results point to a need for more research on the utility arising from CBM math probes that focus on integrated mathematical competence. To date, no such research has focused on this particular issue.

Single mathematics concept-skill on CBM problem

The primary datum of CBM is the performance indicator, which represents students' overall proficiency in the annual curriculum. CBM provides an adequate database for judgments about treatment effectiveness, especially about the combination of CBM graphs and skill analyses, which can help teachers plan more effective instruction (Fuchs, Fuchs, & Hamlett, 1989; Fuchs, Fuchs, Hamlett, & Allinder, 1989). The CBM skill analysis provides teachers with qualitative information about which curricular skills have and have not been mastered. More than two decades of CBM research in MBSP mathematics focused on the use of one concept-skill to represent the concepts of one mathematics problem (e.g., M2 represents multiplying by 1 digit). However, the core of the NCTM's Principles and Standards for School Mathematics emphasizes mathematical reasoning rather than mastery of arithmetic procedures (NCTM, 2000). Mathematics curriculum can be divided into various domains, many of which overlap in relation to hierarchy or interconnectivity (Helwig et al., 2002). The single mathematics concept-skill is insufficient for the solution of multi-step concepts or application problems. For example: By how many centimeters is the blue line longer than the red one for?

Red
Blue



To answer the question above, students have to understand three concept-skills: Length measurement, subtraction of tenths-decimal numbers with one-step regrouping, and decimals comparison. If concept-skill analysis is to be considered a viable datum in CBM, investigating the effectiveness of analyzing students' mathematics competence by multi-skill problems must be documented.

Consequently, it is needed to expand the computerized CBM program that has dynamic features. Such a program will measure mathematical competence globally and effectively (e.g. multi-concept-skill math questions, mixed-type math probes, and randomly constructed CBM tests). To begin to address these problems, the researcher of this study developed a web-based curriculum-based measurement system (ECBM) by exploring the potentials for web-based technology since 2000. The potential contributions of computer networking technology to ECBM are enhanced in communications, planning, implementation, data entry, data display, progress monitoring, and decision making on program improvement. Moreover, teachers can use ECBM at anytime and in any place and can share instructional strategies in cyber space.

The current study was to examine the effectiveness of dynamic features of ECBM on students' mathematics achievement in general classrooms. The purposes of this study are: (1) to illustrate how a well-developed ECBM system can be used by general educators to enhance students' math achievement; (2) to examine the effects of mixed-type math probes of ECBM on students' math achievement; (3) to investigate the dynamic classwide growth model of ECBM on student's math achievement in general classrooms.

Method

Web-based CBM system

The web-based CBM system (ECBM) was developed on the Windows 2000 server and the Microsoft SQL 2000 server. Through ODBC techniques, ECBM can access various relational database systems through the active server page programming language, VB Script, ActiveX and JAVA languages. The ECBM system helps teachers to manage multiple CBM tasks such as the selecting of test stimuli from students' curriculum, the administrating and the scoring of tests, the analyzing of assessment information, the monitoring of progress, and the keeping of records on instruction strategies.

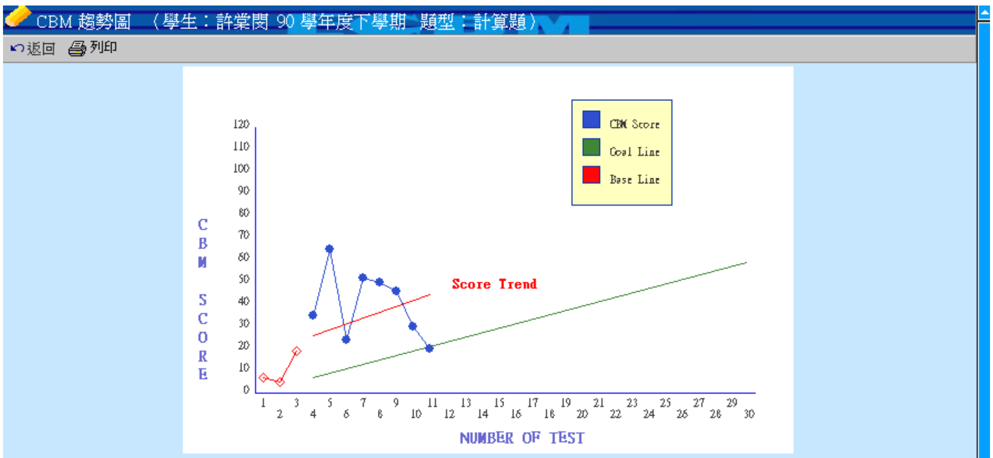
The main components of ECBM system are described as follows:

1. Mathematics CBM item bank: The item bank of the ECBM system included all questions of mathematics textbooks from the first grade to the sixth grade, published by Nan-Yi and Kung-Sheng company in Taiwan. The item bank was built according to the following processes: First, every math question in the textbooks was categorized into one of three types of mathematics problems (concept, computation, or application). Second, the basic information of each question was recorded into the database, and the information included instructional unit, unit objective, unit activity, and source page. Third, the mathematics concept-skill codes and the mathematics standards were used to analyze every math question. The mathematics concept-skill codes were expanded from a previous study (Fuchs, Fuchs, Hamlett, & Allinder, 1989) that includes 188 skill codes in nine mathematics domains (e.g., whole number computation, fractions, addition and subtraction with decimals, relationships between numbers). That is, every item of ECBM is comprised of at least one mathematics skill codes in different mathematics domains (Figure 1).

Figure 1. Mathematics item bank of ECBM

2. Test-related database: The proposed system includes four main databases: teachers' accounts and instructional strategy database, students' database, CBM probe database and item bank. Every teacher in the ECBM system has the unique privilege to generate CBM probes in dynamic ways according to grade level, version of textbook and problem type (single or mixed type of computation, concept and application). The selecting module of the ECBM system can randomly select a specific number of math questions form the item bank to form a CBM probe. Teachers can also administer CBM probes (delete and print) as well as maintain students' basic information and their CBM test scores. Using relational databases and web programming technique, teachers can implement CBM more accurately and effectively (Fuchs, Hamlett, Fuchs, & Ferguson, 1988) at anytime and in any place.

3. CBM performance diagnostic system: A core component of the ECBM system, the CBM performance diagnostic system enables teachers to monitor students' progress through direct and on-going assessments. The ECBM progress monitor includes the three following features: (1)Mathematics IEP: ECBM generates and individual student's annual IEP which specifies the level of students' mastery learning of instructional objectives at each grade level. (2)Graphed analysis of student progress: ECBM automatically generates an individual student's CBM graph, which features a baseline, a trend line and a goal line (dynamic or linear growth models). The proposed system also provides statistically analyzed data of each student's CBM mathematics performance, and the analysis includes a mean score, a slope and a linear equation. Figure 2 shows the CBM linear graph. (3)Mathematics concept skill profile: The skill analysis summarizes and individual student's mastery level on each concept skill during a specific number of CBM probes (default value=3). The mastery level was categorized into five levels according to the aggregated CBM concept score of total concept scores in every mathematics concept-skill code: non-mastered (less than 20%), partially mastered (less than 40%), nearly mastered (less than 60%), almost mastered (less than 80%), and mastered (above 80%) (Figure 3).



測驗次別(Test Number)	1	2	3	4	5	6	7	8	9	10	11
天數(Days)	1	2	7	9	14	16	20	23	27	28	30
分數(Score)	7	5	19	35	65	24	52	50	46	30	20

統計分析

平均每天成長分數(growth rate: score/day)： 0.88 分

平均每週成長分數(growth rate:score/week)： 6.16 分

回歸方程式爲(Linear Regression): Y= 17.9352396972246 + 0.879730866274179 X

CBM得分平均數(Mean of CBM scores):32.09

Figure 2. CBM linear graph

Figure 3. Mathematics concept skill profile

Participants

One hundred and thirty-four third-grade students in four classes of an elementary school located in Taipei, Taiwan participated in the study. Students were randomly assigned into three experiment groups and one contrast group: a CBM-single type and dynamic-growth modeling group (SD), a mixed-type CBM and dynamic-growth modeling group (MD), a mixed-type CBM and linear-growth modeling group (ML) and the contrast group, which featured single-type CBM and linear-growth modeling (SL). Demographics for all groups of students are displayed in Table 1.

Table 1 Demographics characteristic of participants

Variable	Treatment			
	MD	SD	ML	SL
Total	33	35	33	33
Sex				
Male	16	18	16	16
Female	17	17	17	17
LD student	1	0	1	1

Measures

Using the ECBM system, the teachers participated in this study administered to all students CBM tests for 12 weeks.

CBM. Teachers used the ECBM system to generate CBM tests every week in this study. According to (1) the specific grade level, (2) the version of mathematics textbooks and (3) the type of CBM probe (single or mixed), the selecting module of the ECBM system can generate CBM probes from the mathematics item bank in dynamic ways. That is, each CBM probe sampled every problem type in the proportions reflecting the curriculum (Fuchs et al., 1991). The algorithms of the ECBM system's selecting modules are as follows:

I. The single-type CBM probes generated by ECBM consisted of one of mathematics problem type: computation, concept, or application. A single-type CBM probes includes ten questions in computations, ten questions in concepts, or six questions in applications. The mixed-type CBM probes included five concepts, three computations, and two application questions.

II. Teachers input four parameters: version of textbook, semester, grade level, and problem type.

III. According to the types of the CBM probes (computation, concept, application) and parameters (step II), the ECBM system automatically and randomly selected non-repeated units from a specific item bank (e. g., 10 units as a single-type of CBM computation test).

IV. ECBM randomly selected a non-repeated question from every selected unit according to step III.

Thus, every CBM probe was an alternative form that sampled 10 non-repeated questions and thus reflected 10 different teaching objects in each semester's curriculum. ECBM also automatically saved related information onto CBM the probe database by linking to the relational database.

To examine the reliability and validity of single and mixed-type CBM probes generated by the ECBM system, we enlisted the participation of one hundred and sixty-three students in grades 4 and 5. During one week, all students were given three single-type and three mixed-types CBM probes, the Key-Math Diagnostic Test, the WISC III Test, and school math-achievement test. Results supported the adequacy of the reliability (r=.63 -.76, $p < .01$) and the validity (r=.40-.84, $p < .05$) of the ECBM system (Tsuei, 2001).

Achievement Measures. Basic Mathematics Concepts Test (BMCT) measured student performance in basic skill areas of mathematics. BMCT is developed for screening of students in relation to mathematics difficulties in Taiwan. Criterion validity with respect to the math-achievement test ranged from .43 to .83 for second to sixth grade subtests; international consistency reliability, .93. Each student took a paper and pencil group-administered BMCT. The test consisted of 120 mathematics concept and computation items. Students were given 30 minutes to complete the test.

Teacher Training

All teachers participated in three full-day workshops. We explained to them the CBM concepts, the students' feedback, and the teachers' reports. ECBM was used by teachers individually in the workshop for CBM administration and for the analysis of students' performance in accordance with their assigned group.

CBM treatment

Weekly CBM. All teachers implemented CBM for twelve weeks. Using ECBM and standard measurement tasks, teachers assessed students' performance weekly. Each time, an alternate form of the CBM probe that was generated by ECBM represented the grade-level curriculum. Students in the SD and the SL groups had to complete a single-type computation CBM probe in 4 minutes. And, 4 minutes for completing a CBM concept probe and six minutes for completing a CBM application probe. These three single-type CBM probes were administered in the SD and the SL group over the course of three days during a week. Students in the MD and the ML groups had to complete a mixed-type CBM probes in 6 minutes. Three mixed-type CBM probes were administered over the course of three days during a week.

Traditional linear-growth modeling was used as the expected CBM goal line for students in the ML and the SL groups. Previous studies indicated that the normative increasing CBM math scores for general students in Taiwan were 2 digits as weekly growth rate or 1 digit as growth rate of continuous CBM test (Tsuei, 2001). Consequently, we used 2 digits as weekly CBM growth rates as linear-growth modeling in the ML and the SL groups.

Classwide dynamic-growth modeling was used for students in the SD and the MD groups. Classwide dynamic-growth modeling was a way to anticipate each student's increasing scores of CBM, and it involved, as the normative comparison, a comparison between the student and his or her own classmates. This study used the larger number scores as next anticipated CBM growth rate between normative growth rate (1 digit) and the mean plus one standard deviation of the classwide growth rate in the previous CBM test.

For example, the mean score and the standard deviation of the third CBM test in the SD group were 2.34 and 0.34. Because 2.68 is larger than 1, the next anticipated growth rate of fourth CBM scores for students in the SD group was their third CBM score plus 2.68 digits. Therefore, the growth rates in the SD and the MD groups depended on the every classwide CBM scores. Therefore, the growth modeling was dynamic.

Periodic Evaluation. Teachers employed the ECBM-*performance diagnostics system* to track their pupils' progress toward mathematics goals, beginning in October, 2004, and continuing to January, 2005. ECBM also automatically recorded the frequencies of teachers by using each component of the ECBM system, including a mathematics IEP, a graphed analysis of student progress, and a mathematics concept-skill profile.

Every two weeks, I discussed with teachers individually about the performance of the class, including students' classwide progress and students' individual progress on the ECBM graphs, the classwide mathematics concept-skill profile, the classwide slopes, and the instructional procedures. Teachers constituted small groups for the upcoming two weeks' instruction according to each student's mathematics performance.

Every two weeks, teachers used the ECBM system in each group to teach students both to read and to interpret their mathematics performance individually by ECBM system. Teachers helped students to identify the strengths and weaknesses of their mathematics concept-skills. And, teachers asked students to compare their CBM score trend line with the goal-line in the CBM graph. A classwide dynamic-growth model graph was used in the MD and the SD groups. A linear-growth model was used in the ML and the SL groups.

Data Collection

To index achievement, the BMCT and the six mixed-type CBM probes that wres divided into two sets were administered as pre- and post-test proceedings and followed the study.

The ongoing CBM test scores for students were entered into the ECBM system by teachers.

Results

Fidelity of Treatment

The accuracy with which teachers implemented the treatment was assessed by direct observation along four dimensions: CBM, periodic evaluations by students, small group vs. whole group's instruction, and the number of ECBM interactions.

Four RAs were trained in two one-hour sessions to conduct and score observations along the first four dimensions. By checking yes o no bi-weekly, the RAs judged whether a teacher had conducted first two elements correctly. The RAs conducted observations on the time arrangement of mathematics group-instruction were conducted by randomly selecting one class (forty minutes) bi-weekly. Percentage of agreement, accessed by the first three observations, was 100.0, 100.0, and 99.6.

The results of the observations indicated that the teachers fully implemented CBM and the periodic evaluations (Table 2). Mathematics instruction performed comparably on both number of minutes for small-group and whole-group instruction between groups. In terms of ECBM interactions, teachers were more likely to navigate mathematics concept-skill profiles. An ANOVA was conducted on four dimensions of observations, and it revealed no significant difference between treatments.

Pre- to post-treatment changes in CBM mathematics performance

To assess the impact of the growth modeling and the CBM probes on students' CBM performance, a two-way ANCOVA was conducted in this study. The first factor had two levels corresponding to the dynamic- or linear-growth modeling of students' CBM performance. The second factor had tow levels that, by using the ECBM system, reflected the mixed-type or single-type CBM probes. All of the fundamental assumptions upon which the ANCOVA was based, including homogeneity of regression, were met. Descriptive statistics associated with the pre-test and the posttest and a summary of the two-way ANCOVA results for main effects and the interaction are displayed in Table 3.

Both the effects of growth modeling and the CBM probes, the analysis of ANCOVA for students' CBM mathematics scores yielded the following results: There was a significant main effect for growth modeling, $F_{(1,129)}=16.47$, $p<.001$, a significant main effect for CBM probe, $F_{(1,129)}=38.66$, $p<.001$, and a significant interaction between the growth modeling and CBM probe components, $F_{(1,129)}=13.36$, $p<.001$. The effect size for the CBM probe was .23. The growth modeling produced an efect size of .11. The effect size for the interaction between the growth modeling and CBM probe was .09. According to Huitema (1980), "If the interaction is significant, the interpretation of the main effects becomes ambiguous" (p. 220). A significant interaction indicated that differences across levels of growth modeling are not the same across levels of a CBM probe. Therefore, two sets of simple main effect of ANCOVA were performed by using formulas recommended by Huitema (1980) (see Table 4).

Under the effects of CBM probes, the adjusted means for students in the MD group($M^d=209.33$) outperformed statistically than the SD group($M^d=168.27$), $F_{(1,65)}=64.15$, $p<.001$. The effect size for the CBM probe was found to be .50. No such effects were found under the linear-growth modeling effect. In terms of growth modeling conditions, students who participated in the MD group outperformed statistically than the ML group ($M^d=177.13$), $F_{(1,63)}=31.30$, $p<.001$. The effect size for the CBM probe was found to be .33.

Pre- to post-treatment changes in the Basic Mathematics Concepts Test performance

A two-way ANCOVA was conducted on pre- and post-BMCT scores. Statistically significant main effects were obtained for the effects of growth modeling $F_{(1,129)}=4.93$, $p<.05$, with the dynamic-growth modeling group outperforming the linear-growth modeling. Statistically significant main effects were also obtained for CBM probes, $F_{(1,129)}=4.67$, $p<.05$, with the group in the mixed-type probes performing better. No reliable interactions were obtained between growth modeling and CBM probes.

Rates of improvement by different skill levels

Individual student's weekly CBM progress rate (slope) was calculated by a least squares regression between scores and calendar days. For comparing slopes by skill level, a subsample of students was selected from the participants, and it represented different skill levels. Because of the relatively small number of students per group, only students with CBM pretest scores below the 20th percentile (low ability group) and above the 80th (high-ability group) were analyzed by two separate ANCOVAs. The covariate was the students' CBM pre-test scores.

As displayed in Table 6, the statistically significant main effects of the CBM probes on the slopes of students who had different skill levels were obtained, $F_{(1,56)}=15.35$, $p<.001$; no reliable interaction effects were found on different skill level groups. Students with high- or low-skill levels in the mixed-type CBM probe group performed better than those in the single-type CBM probe group. The effect size for CBM probes was .22.

Significant main effects of growth modeling on students' CBM slopes were found by a two-way ANCOVA performed, $F_{(1,56)}=4.70$, $p<.05$. No significant main effect was found on different skill level groups. Overall, students who participated in the dynamic-growth modeling group significantly outperformed students in the linear-growth modeling group. For growth modeling, the effect size was relative low, .08.

Table 2 Fidelity of treatment for CBM teachers

Variable	Dynamic Growth Modeling				Linear Growth Modeling				F	P
	Mixed-Type Probe (MD)		Single-Type Probe (SD)		Mixed-Type Probe (ML)		Single-Type Probe (SL)			
	M	SD	M	SD	M	SD	M	SD		
CBM [a]										
CBM probes generation	12.00	0.00	12.00	0.00	12.00	0.00	12.00	0.00	0.00	1.00
Number of CBM measurement	12.00	0.00	12.00	0.00	12.00	0.00	12.00	0.00	0.00	1.00
Periodically evaluation [a]										
help students to read personal profiles	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	0.00	1.00
Group rearrangement	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	0.00	1.00
Mathematics group instruction [a]										
Small group instruction	13.29	0.68	12.92	0.54	13.13	0.72	13.21	0.66	0.36	0.78
Whole group instruction	22.46	0.70	22.13	0.70	21.96	0.73	22.04	0.27	0.70	0.56
Number of ECBM interactions [b]										
Mathematics IEP	9.00	3.74	9.17	4.22	8.67	3.20	8.50	3.51	0.04	0.99
Graphed analysis	17.50	3.39	16.83	3.92	17.50	3.40	17.50	3.37	0.53	0.98
Mathematics concept skill profile	20.17	2.99	19.83	2.56	20.50	2.95	20.33	2.94	0.59	0.98

[a] Each mean reflects the average number of four observers by bi-weekly basis

[b] Each mean reflects the average access number of ECBM system by bi-weekly basis

Table 3 ANCOVA analysis of pre-post CBM scores

Measures	Dynamic Growth Modeling				Linear Growth Modeling				F		
	Mixed-Type Probe (MD)		Single-Type Probe (SD)		Mixed-Type Probe (ML)		Single-Type Probe (SL)				
	M	SD	M	SD	M	SD	M	SD	Growth Modeling	CBM Probe	Growth modeling x CBM probe
N	33		35		33		33		16.47***	38.66***	13.36***
CBM Pretest	121.52	26.13	125.83	18.87	133.03	24.16	124.67	22.57			
CBM Posttest	205.33	28.69	167.91	25.21	182.85	37.65	165.30	30.52			
M^d	209.33		168.27		177.13		166.64				

****p* <.001 M^d= adjusted means

Table 4 ANCOVA analysis of simple main effect of treatments

Main effects	SS	df	MS	F	ES
CBM probes					
Dynamic growth modeling	27882.30	1	27882.30	64.15***	0.50
Linear growth modeling	1541.38	1	1541.38	2.14	0.03
Growth Modeling					
Mixed-type probes	17479.31	1	17479.31	31.30***	0.33
Single-type probes	55.35	1	55.35	0.95	0.00

****p* <.001

Table 5 ANCOVA analysis of pre-post BMCT

Measures	Dynamic Growth Modeling				Linear Growth Modeling				F		
	Mixed-Type Probe (MD)		Single-Type Probe (SD)		Mixed-Type Probe (ML)		Single-Type Probe (SL)				
	M	SD	M	SD	M	SD	M	SD	Growth Modeling	CBM Probe	Growth modeling x CBM probe
N	33		35		33		33		4.93*	4.67*	2.58
Pretest	85.85	11.81	88.64	9.92	88.90	11.05	91.28	7.39			
Posttest	91.83	7.85	87.03	9.78	90.62	10.08	91.73	6.76			
M^d	93.80		90.46		90.46		89.90				

*p <.05 M^d= adjusted means

Table 6 ANCOVA analysis of CBM slopes

Treatment		Group								F		
		LG				HG						
		N	M	SD	M^d	N	M	SD	M^d	Treatment	Group	Treatment x group
CBM probe	Mixed-type	(14)	1.66	.65	1.37	(16)	1.33	.39	1.58	15.35***	.22	0.07
	Single-type	(15)	1.13	.52	.90	(16)	.83	.44	1.04			
Growth modeling	Dynamic	(15)	1.64	.62	1.45	(17)	1.17	.58	1.31	4.70*	.01	1.60
	Linear	(14)	1.12	.56	.96	(15)	.98	.33	1.16			

Note. CBM pretest scores used as covariate *p <.05 ***p <.001

M^d= adjusted means LG= low ability group HG=high ability group

Discussion

ECBM, the web-based CBM system, represents a well-developed measurement and diagnostic system that generates the adequacy of the reliability and validity of CBM tests. The web-based technology provided more dynamic features in the CBM frameworks. As a corroboration of previous research on computerized CBM systems, the amount of time that teachers devoted to the mechanics underlying the implementation of CBM was eliminated, and satisfaction with the process increased (Fuchs, Hamlett, Fuchs, Stecker, & Ferguson, 1988). Moreover, teachers can gather the assessment information at any time and in any place. Teachers appeared to use mathematics concept-skill profiles more often than other features. More research needs to be conducted on the feasibility of ECBM system use for instructional information exchanging and on ECBM system effects on teachers' professional development.

Changes in CBM and BMCT mathematics achievement growth were found between students in classwide dynamic-growth modeling and those in linear-growth modeling. Students who participated in the dynamic growth modeling group had more math achievement gains than those in the linear growth modeling group on CBM and BMCT scores.

In addition to the main effects of the CBM probes and the growth modeling treatment, an interaction was found between the two on students' CBM scores. In the dynamic-growth modeling treatment, students in the mixed-type CBM probes group (MD) significantly performed better than those in the single-type CBM probes group (SD). This outcome was not seen in the linear-growth modeling treatment. In the mixed-type CBM probes treatment, the dynamic-growth modeling group (MD) significantly outperformed in achievement gains than the students in the linear-growth modeling group (ML). There was no such effect found in the single-type CBM probes treatment.

This research expanded on previous research in that, through the use of linear-growth modeling combined with CBM mixed-type probes, students performed better than they would have through the use of single-type CBM probes. The evidence pertaining to the content of mathematics tests is extensive. The previous study concerning the validity of CBM mathematics computation probes indicated that mathematics with computations and applications were distinct constructs, even through related (Thurber et al., 2002). CBM was designed so that teachers would measure students' mathematics "proficiency on the global outcomes toward which the entire curriculum is directed" (Fuchs & Deno, 1991, p. 493). The mixed-type CBM probes including computation, concept, and application are evident in the scope and sequence of typical math textbooks (Salvia & Ysseldyke, 1991) as well as in math assessment (Thurber et al., 2002; Helwig, Anderson, & Tindal, 2002). From this point of view, the use of mixed-type math CBM probes reflects “truly curriculum-based” assessment, and has much potentials for improvement in students’ mathematics proficiency in the general classroom. Such potential for special students still requires empirical testing.

Previous research indicated that the linear relationship adequately modeled math growth within an academic year (Fuchs, Fuchs, Hamlett, Walz, & Germann, 1993). However, the results of this study constitute strong evidence that the classwide dynamic-growth modeling was more effective for students in mixed-type CBM probes than it was for students in single-type CBM probes. Relative to their classmates, the students in the dynamic-growth modeling groups were aware of their mathematics performance, and this awareness thus promoted their self-expectations. Therefore, classwide dynamic-growth modeling holds the promise of peer-model effects. The peer model conveys information about the functional value of behaviors and serves to motivate individual’s behaviors and achievement (Jessor, 1993; Slaughter-Defoe, 1995; Ma, 2001). This study revealed a strong positive treatment effect concerning the classwide peer modeling by using more optimistic growth rates for general students. The classwide dynamic-growth modeling provided “ambitious goals” for math growth in the general classroom, particularly when using mixed-type CBM probes. Such an approach results in the accelerating of growth for students in the general classroom. These findings have been encouraging in light of the use of higher expectations in CBM for students with learning disabilities (Deno, Fuchs, Marston, & Shin, 2001) as well as for general classwide students.

With respect to vary with skill-level variance in the weekly rate of student progress, the main effects of both CBM probes and growth modeling were found for both low- and high-level students’ weekly CBM slopes. No statistical interactions were obtained between treatment and skill factors. The lack of interaction suggests that higher and lower levels of CBM math did not mediate treatment effects. Overall, both lower and higher CBM math students in the dynamic-growth modeling group significantly outperformed those in the linear-growth modeling group. Such effects were also found between the classwide dynamic-modeling groups and the linear-growth modeling groups. Consistent with previous research (Spicuzza, Ysseldyke, Lemkuil, Kosciolek, Boys, & Teelucksingh, 2001), these findings indicate that computerized CBM intervention was, in this case, effective for skill levels including high- and low-performing students in the general classroom. Because the effective size was moderate low, additional evidence is needed to test these findings.

Conclusions

ECBM promises benefits of quality and cost saving. Taking advantage of previously developed and validated components, computer networking technology adds value to CBM which is substantial and important. Relative to web technology, the relational database systems and network technology provide more advantages that feature dynamic techniques with which teachers can manage, implement, and interpret individual, as well as classwide, CBM performance.

Based on the analyses, it appears that students gain more mathematics proficiency by using mixed-type CBM probes than they do by using single-type CBM probes. From this point of view, the use of computation, application and concept components in CBM has the potential to generate significant instructional changes in classrooms.

The approach of the classwide dynamic-growth model in this exploration demonstrates optimistic weekly growth rates for students in the general classroom. That is, students can achieve higher growth rates through a classwide dynamic-growth model than through a linear-growth prediction model. Ambitious goals are important ingredients of effective programs. Teachers and students are likely to rise to expected levels of accomplishment (Deno et al., 2001).

This study expands previous research by exploring the dynamic features that inhere ECBM, which is reliable and beneficial for students in the general classroom.

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