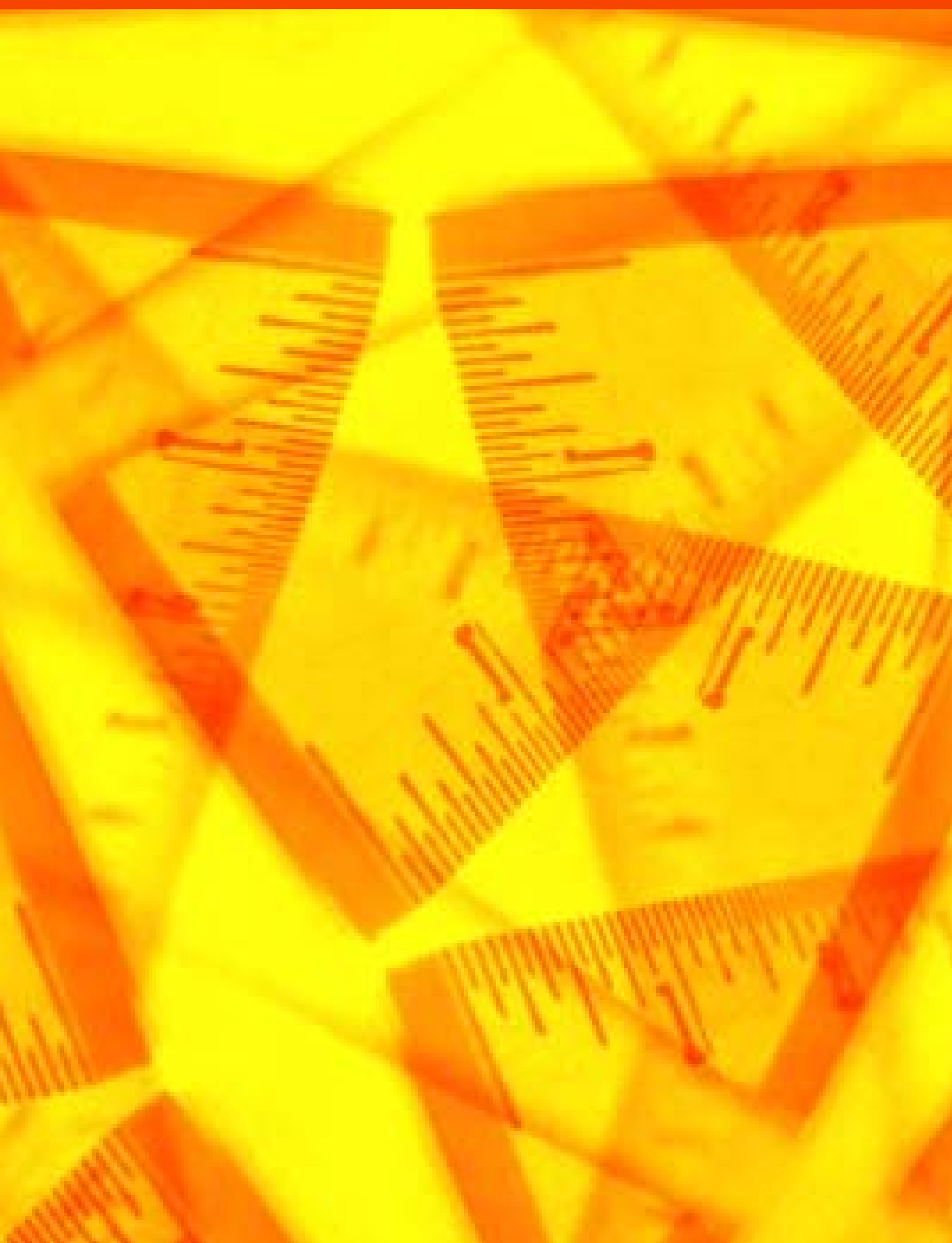
CURRICULUM-BASED MEASUREMENT IN MATHEMATICS

An Evidence-Based Formative Assessment Procedure



CENTER ON INSTRUCTION

CURRICULUM-BASED MEASUREMENT IN MATHEMATICS

An Evidence-Based Formative Assessment Procedure

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CENTER ON INSTRUCTION

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INTRODUCTION

Although schools have always been under pressure to produce positive outcomes for all students, the passage of the No Child Left Behind Act (NCLB, U.S. Department of Education, 2001) increased expectations that schools improve student performance and monitor student growth over time. With the NCLB mandate that states monitor the performance of all students in grades 3 through 8, most states now give standardized, high-stakes assessments to all students each year in mathematics and reading. By tying funding to performance, NCLB also encourages schools to better use data to inform and redirect instruction. Consequently, it is common to hear educators talk about being "data-driven," including making data-based instructional decisions designed to meet the needs of all students. However, these data-based decisions should not be made solely on tests that are administered infrequently (like the aforementioned standardized, high-stakes tests). Decisions should be made within an integrated system of data-driven decision-making. Schools need a gauge that provides frequent, timely estimates of student performance, so that decisions about instructional effectiveness and student performance can be made routinely, particularly for students who are at-risk.

These frequent measures should embody several characteristics:

- the measures need to be reliable and valid for the purposes for which they are used,
- they need to be short and easy to administer, and, most importantly,
- they need to be highly related to other measures of proficiency in academic areas.

These measures can then be used *formatively* to assess student performance on a frequent basis and to complement *summative* data that can be gained from yearly high-stakes assessments.

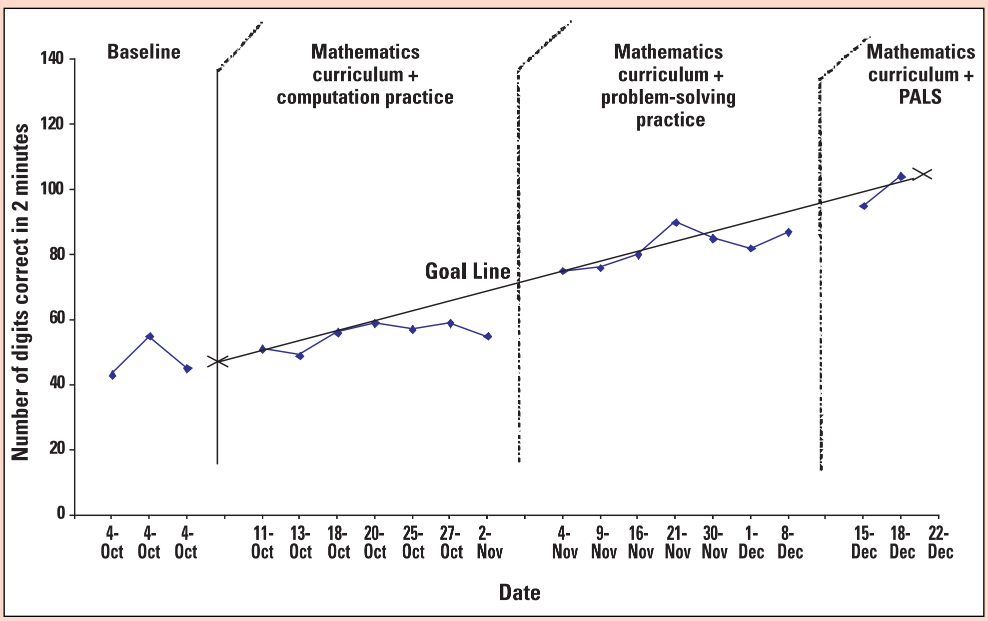
Formative assessments are akin to the weekly checks you might conduct on your health by stepping on the scale, reading your blood pressure, or taking your temperature. These quick and reliable health checks give you valid indicators of your overall well-being. A summative assessment might be your annual physical exam. This assessment is much more comprehensive, but one yearly check on critical health indicators is not enough.

In the same way, students need more routine checks on their *educational* health to make sure they are making progress and for their teachers to make instructional changes if they are not. One of the best methods of formative assessment in academic areas and a method that exemplifies the characteristics of good measures is Curriculum-Based Measurement (CBM; Deno, 1985).

Developed at the University of Minnesota in the early 1970's, CBM (see example below) has been researched in academic areas including mathematics computation, concepts, and applications; early numeracy; reading; early literacy; writing; spelling; science; and social studies. Administration time for each

CBM Graph in Mathematics – An Example

On this graph, the teacher has collected and graphed baseline data, established a long-range goal, and continued to collect two-minute samples of mathematics data. These two minute samples are graphed to inform changes in instruction using decision-based rules. Decision-making rules are determined prior to the beginning of data collection and are data examination guidelines that teachers use as they look at student graphs and determine whether instructional changes need to be implemented.



measure ranges from one to eight minutes, and these measures serve as indicators of academic performance in that as students' achievement in mathematics increases, there is subsequent growth on the mathematics CBM probes. The measures are timed to give teachers a quick snapshot of student performance. The results of the assessment are graphed to facilitate ongoing analysis of student progress. Teachers use decision-making rules to make changes in a student's instructional program if the data indicate that the student is not making sufficient progress. For instance, if the trend of a student's data indicates insufficient progress toward a long-term goal, the teacher would implement an instructional change to positively affect student performance. More details about CBM procedures, including a sample decision-making rule, are described in Tables 1 (page 5) and 2 (page 8), and in additional text, later in this document.

The following sections describe Mathematics-CBM (M-CBM), including a brief history, basic procedures, implications for practice, and further resources. In addition, this paper reviews the research that supports the use of M-CBM. The intended audience is practitioners or researchers who are seeking more information on M-CBM procedures and the research that supports the use of these procedures.

PROCEDURES FOR IMPLEMENTATION

CBM is an evidence-based system of screening and progress monitoring that teachers use on a frequent basis to screen all students in a school, grade, or class and to assess the effects of instruction on student performance. When using the measures for *screening*, individual teachers, schools, or districts typically administer measures to students in the fall, winter, and spring. Results from these tests are used to determine students' level of risk related to meeting benchmark goals. For students who achieve at average to above-average levels, screening provides data on effectiveness of the curriculum for meeting student needs, as well as a checkpoint three times a year to make sure these students continue to stay on target to meet benchmark goals. For students who achieve at below-average or low levels, screening provides data on curriculum effectiveness, including intervention effectiveness and growth towards meeting benchmark goals.

To gain a stable indicator of student performance, each student might be administered three two-minute mathematics probes during one or two sessions and the teacher would use the median score. Academic goals or points of reference called benchmarks are derived either from school or district data or from commercially available programs, and the teacher compares each student's median score to the grade-level benchmark. For those students whose scores indicate they are on track for meeting these goals at the fall, winter, and spring testing period, no additional M-CBM data need be collected between testing periods. However, the students' instructional routines should be examined to make sure they are challenging enough.

For students whose scores indicate that they are not on track to meet critical outcomes at the fall, winter, and spring testing periods, *progress monitoring* may be implemented on a more routine basis prior to the next school-wide screening. This progress monitoring might take place as infrequently as once a month for students whose performance is below benchmark or as often as once or twice a week for students who need intensive intervention, based on the screening data. When progress monitoring, teachers administer alternate forms of mathematics probes on a frequent basis, score these probes, and then graph the results to use in decision-making. In essence, an assessment system is designed that matches the frequency of assessment to the degree of student need. Students who are on-track are assessed three times per year to ensure that they are making expected progress. For students who are not on-track, more frequent assessment occurs to allow educators to monitor students' growth in mathematics towards critical outcomes. Table 1 shows a list of steps in progress monitoring.

Table 1: Steps involved in data-based decision-making

Decide on level of implementation	Individual, small group, classroom, grade-level, school-level, or district-level
Decide on which measures to use	Reading, mathematics, written expression, spelling, or content-area
Collect screening or baseline data	Best practice is to administer three probes and use the median score
Decide on short-term objective or end criteria	Use weekly growth criteria or a benchmark level
Set long-range goal	Connect median baseline point to ending level to establish goal line
Decide how often to monitor	For students who are slightly below the benchmark level and in need of strategic intervention, progress is monitored at least monthly. For students at-risk or in need of intensive intervention, or those students identified with special needs, progress is monitored one to three times weekly.
Administer timed, alternate measures	Be consistent in your administration, timing, and scoring
Graph data	Use paper/pencil or a computerized graphing program
Make instructional changes using decision-making rules	For example, after collecting four weeks of data and at least eight data points, the teacher may compare the trend of the current data path to the goal line. *If the trend of the data is less steep than the goal line, implement a change in instruction. If the trend of the data is steeper than the goal line, perhaps raise the goal. If the trend of the data fell close to the goal line, perhaps continue the same instruction.*
Continue monitoring	Continue to collect, graph, and examine data, applying decision-making rules.

MEASURES

Teachers use mathematics probes to monitor students in elementary school, middle school, and high school. The measures that have undergone the most extensive development and refinement are for students in grades 1 through 6, although more research is being conducted to identify mathematics measures for students in kindergarten and in middle and high school. The measures are not necessarily created to align with district curricula, or to match state standards, as the probes are meant to be used with any student in any state. While it is essential that schools are documenting progress towards success in curricula or on standards, CBM mathematics measures do not provide specific information on whether particular standards are being met. Rather, CBM mathematics measures provide information on whether students are on track to meet performance goals, whether instruction is effective for students, and whether instructional modifications are necessary. States or districts might choose to examine the relationship between CBM measures and their state standards or high stakes outcomes, but this would be an individual state decision.

Similar to a basketball game, having students meet state standards is like winning the game and CBM measures are like points that are scored along the way. When points are not being scored, a team is not on track to win their game, so the coach needs to examine the plays that are put into place (similar to district curricula) or diagnostic information on how individual players are doing on particular skills like shooting or rebounding (like chapter tests or weekly quizzes) to see where changes need to be made. Following changes to the plays or changes for individual players, the coach hopes the team will start scoring points again. Particular measures can be used diagnostically and states or districts should consider diagnostic information that might be provided as they select measures. A more thorough discussion of robust versus curriculum-sampled measures appears later in this paper to help as a guide when selecting CBM mathematics measures.

In elementary school, both computation and concepts and applications measures are available. Computation measures include single or mixed basic facts or multi-step addition, subtraction, multiplication, or division problems. Concepts and applications measures include problems that ask students to apply their mathematics knowledge, including problems that address concepts such as greater than/less than, measurement, money, and temperature. Examples of pre-computation measures for students in kindergarten and first grade include quantity discrimination, missing number, and number identification. At the secondary level, measures include estimation in middle school and algebra in high school. While students may not be able to answer all of the problems on a given probe the first time it is administered, they will perform better on the probes as they learn more about mathematics strategies and skills. Students should be encouraged to move through the problems, solving those that they know, and skipping those that are too difficult at that time.

Each measure is administered for one to eight minutes, depending on grade level and type of measure, with a majority of the measures completed independently by students. While a lengthier and more detailed measure could give the teacher greater diagnostic information, the purpose of these measures is to provide teachers a quick glimpse of student performance on a regular basis.

Measures can either be scored by counting the number of correct problems, number of correct digits in the answer, or, in the case of concepts and applications problems, number of blanks correctly filled-in. The score that the student attains during the allotted time is then graphed to use for decision-making. Tables 2 (page 8) and 3 (page 9) provide examples of some basic instructions and a sample scored probe.

Once all students have been screened, and students who are at-risk have been identified for progress monitoring, the most important aspect of CBM is how a teacher uses the data. The first step is to graph the data. A teacher establishes a goal line based on the student's initial baseline performance (the median of three probes administered) and sets either a weekly growth criterion or a long-range goal. Once a goal line is set, the teacher collects data at regular intervals based on the severity of student need. For students who are slightly below the benchmark level and in need of strategic intervention, progress is monitored at least monthly. For students at-risk, in need of intensive intervention, or identified with special needs, progress is monitored one to three times weekly. As the teacher continues to graph and examine data, patterns may emerge that indicate that the student is experiencing or not experiencing success using the current instructional program.

Table 2: Sample Administration Directions, Basic Computation

Materials:	Teacher copy of mathematics probe with correct answers written to use as a key Pencil Student copy of the problems Stopwatch
Directions:	1. Place the mathematics page in front of the student. 2. Say to the student: **"When I say begin, I want you to complete these mathematics problems. Do your best to answer them correctly. Start here** (point to problem in upper left hand corner) **and go across the page** (demonstrate by moving finger across the page), **trying each problem. If you come to a problem that you don't know, put an X on it and move on to the next problem. Do you have any questions?** (pause). **Begin.** (start your stopwatch.) 3. At the end of 2 minutes, place a bracket after the last problem solved and say to the student **"Stop. Thank you."**
Scoring:	Score the probe, putting a slash over either any problems that the student did not get correct or any digits that the student did not get correct. Count the number of problems or the number of digits the student got correct. This result is the number that is graphed.

Table 3: Scored Basic Computation Mathematics Probe

11 + 35 $\cancel{2}\cancel{1}$	23 - 19 $\cancel{2}\cancel{2}$	36 + 45 81
51 - 9 $\cancel{6}\cancel{0}$	89 + 41 $1\cancel{1}0$	40 - 13 27
37 - 5 $\cancel{1}\cancel{3}\cancel{7}$	90 + 35 $1\cancel{0}5$	16 + 57 73
50 - 14	91 + 34	71 - 56

Number graphed—10 digits correct or 3 problems correct

The teacher uses decision-making rules when examining graphed data to determine if instructional modifications are necessary. For example, after collecting four weeks of data and at least eight data points, the teacher may compare the trend of the current data path to the goal line. If the student's data trend is far below the goal line, the teacher implements a change in instruction. If the trend was significantly above the goal line, the teacher might raise the goal. If the trend of the data fell close to the goal line, the teacher might continue the same instruction.

Lowering the goal line should not be considered an instructional change. Teachers can analyze and interpret data on their own, or better yet, with other colleagues. In some schools, this is done at weekly grade-level or team meetings. Student, class, or grade-level data is examined, using decision-making rules to compare data to established goals. Individual, class, or grade-level changes are made when a decision-making rule is applied. As the teacher considers an intervention to implement, he or she should draw on resources (like the current National Council of Teachers of Mathematics [NCTM] Linking Research and Practice Initiative) that are supported by research for the population with whom the teacher is working. More suggestions for assessing the effectiveness of practices can be found in documents such as "Identifying and implementing educational practices supported by rigorous evidence: A user friendly guide" (http://www.ed.gov/rschstat/research/pubs/rigorousevid/rigorousevid.pdf); "Using research and reason in education: How teachers can use scientifically based research to make curricular and instructional decisions" (http://www.nifl.gov/partnershipforreading/publications/html/stanovich/); and "Using research-based practices to support students with diverse learning needs in general education settings" (Lembke & Stormont, 2005). Implementing these evidence-based strategies and interventions as the data indicate will help maximize instruction and outcomes for students.

IMPLICATIONS FOR PRACTICE

CBM serves as an excellent model for general and special educators alike because of its important components, including selecting and administering reliable and valid measures, using consistent administration procedures, and making data decisions to changes instruction. Another strength of CBM is flexibility: it can be used to screen all students in a school and monitor the progress of individual students. Research has examined CBM in subjects such as reading, mathematics, spelling, and written expression, so similar methods may be used across many academic areas. CBM can be used to monitor the effectiveness of the core curriculum, the progress of a small group, or an individual's responsiveness to instruction. CBM can be used as a tool to monitor the effects of enrichment being provided to high achieving students, prereferral interventions, and (as one measure) the progress of student subgroups toward adequate yearly progress. Most importantly, a recent research review published by Stecker, Fuchs, and Fuchs (2005), showed evidence that the use of CBM can contribute to increases in student achievement.

SUMMARY OF SELECTED RESEARCH

How do we know that CBM in mathematics is an effective way to estimate student performance and to monitor student progress for all learners? Although the literature supporting mathematics CBM is not as extensive as that of CBM in reading, many key studies have been completed that address critical issues for teachers who may be implementing, or considering, M-CBM:

- identifying reliable and valid measures to use in screening and progress monitoring at a variety of grade levels,
- progress monitoring for students with special needs,
- skills analysis using M-CBM data,
- using M-CBM as part of a class wide peer tutoring system, and
- the effects of instructional consultation with teachers.

Researchers have compared M-CBM measures to other measures of mathematics proficiency, such as standardized tests, teacher ratings, and high stakes state assessments. When there is a strong relationship between the M-CBM measures and other commonly recognized mathematics measures, teachers can be confident that the M-CBM data that they are collecting is related to overall mathematics proficiency. Table 4 (page 17) summarizes some of the significant studies on the use of CBM in mathematics with learners in early elementary through secondary grades.

Identifying Reliable and Valid Measures for Screening and Progress Monitoring

When developing measures of mathematics performance as part of a CBM model, researchers examine mathematics tasks that might serve as proxy measures for mathematics performance while also attending to the characteristics of an effective CBM measure (e.g., reliability, validity, efficiency of administration, and the ability to use the data in decision-making.) While M-CBM would not take the place of more detailed diagnostic measures, the data that are collected and graphed on a frequent basis can help teachers monitor growth in mathematics over time. Very few diagnostic measures can provide this growth data.

In mathematics, CBM measures include those developed using a *curriculum-sampling* approach or a *robust indicator* approach (Fuchs, 2004). Both types of measures have been examined in the literature. Curriculum-sampling measures incorporate content that should represent the curriculum expectations for the student across the year. For example, if a teacher monitors a student who is at the third grade level, CBM mathematics computation probes might include single-digit multiplication, double-digit multiplication, and addition and subtraction with regrouping problems randomly placed on each probe. Resources for M-CBM probes and computer-based systems are in the Appendix.

Mathematics measures that utilize the robust-indicator approach provide a similar indicator of mathematics proficiency, just as the curriculum-sampled measures do, but are developed using a task that is "robustly" related to many mathematics component skills. Initial research in mathematics (Skiba, Magnusson, Marston, & Erickson, 1986) identified the number of digits correct in two minutes on grade-level probes with mixed basic facts as a good measure of mathematics proficiency for students in grades 1 through 6 (see Table 3 for an example of scoring using correct digits). Students were given a page of mixed addition, subtraction, multiplication, and division facts targeted at the specified grade level, and two minutes in which to complete the task. After two minutes, the administrator scored the probe according to number of correct digits, giving credit for each digit that was written correctly and located in the correct place, and graphed the number of correct digits. This graphed data served as an overall indicator of the student's proficiency in mathematics.

Measures of early numeracy, like number identification, quantity discrimination, and missing number, have been studied as CBM indicators for students in kindergarten and first grade (Clarke & Shinn, 2004; Lembke & Foegen, 2005). These measures are individually administered and students respond orally, in writing, or by pointing when prompted to name the number that is bigger (quantity discrimination) or name the number that is missing (missing number), for example.

At the secondary-school level, Foegen and Deno (2001) have examined the use of estimation tasks as a robust indicator for middle school students, and Foegen (2005) has researched the use of algebra measures with middle and high school students. Estimation tasks—multiple choice tasks administered for three minutes—provide students with problems involving either computation or word problems (e.g., 915 - 320 = ? or "Each month I earn $56. How much will I earn in three months?", in Foegen & Deno, 2001). Students circle the best estimate of the answer. Algebra tasks have included measures based on curriculum sampling (e.g., problems that represent key concepts in the chapters of a particular textbook series) and measures that serve as robust indicators (e.g., "standard" algebra skills such as graphing slope and intercept or evaluating equations), with no clear evidence favoring one type of measure over the other at this time.

Using Progress Monitoring with Students with Special Needs

Progress monitoring using CBM has been demonstrated to be equally effective with general education and special education students, as can be seen in the samples of students in Table 4 (page 17), adding to its utility as an important technique to consider. In a recent study with 120 special education students with learning disabilities (Shapiro, Edwards, Zigmond, 2005), students were monitored weekly using both computation and concepts and applications probes. More than two-thirds of the students achieved their goals in computation and more than one-third in concepts and applications, with levels of improvement comparable to those of general education students.

Skills Analysis Using CBM Data

A common question about CBM is how the measures relate to skills that the students have or have not mastered. Several articles have sought to examine the effects of skills analysis when using CBM data in mathematics (Bentz & Fuchs, 1993; Fuchs, Fuchs, Hamlett, & Allinder, 1989; Fuchs, Fuchs, Hamlett, & Stecker, 1990). All of these studies were conducted using the *Monitoring Basic Skills Progress* (Fuchs et al., 1990) computer program, which includes a component that analyzes student work from the computerized probes and provides individual or class feedback for skills tested by level of mastery, so teachers can easily see skills on which students need to improve. Results of one of these studies indicated that special education teachers made more specific instructional changes and students with mild to moderate disabilities made greater achievement gains with the use of skills analysis (Fuchs, Fuchs, Hamlett, & Stecker, 1990). Also, the skills analysis software provided reliable and valid information to support instructional decision-making (Fuchs, Fuchs, Hamlett, & Allinder, 1989).

Using CBM with Classwide Peer Tutoring

CBM has also been examined when paired with a highly effective method of instructional delivery (peer tutoring). The evidence supports the use of CBM measures to monitor the effectiveness of peer tutoring strategies in mathematics. Fuchs, Fuchs, Phillips, Hamlett, and Karns (1995) implemented classwide peer-assisted learning strategies (PALS) in 20 general education classrooms, contrasted with 20 general education classrooms that were not receiving PALS. The performance of average achieving students, low achieving students, and low achieving students with learning disabilities was monitored using weekly CBM mathematics measures. Effect sizes for students who were low achieving and low achieving with learning disabilities in the PALS condition ranged from .30 to .95, indicating strong treatment effects, and effect sizes for the average achieving students were moderate, ranging from .32 to .34 on mathematics acquisition and transfer measures.

In a related study (Phillips, Fuchs,& Fuchs, 1994), twenty elementary general education teachers implemented classwide peer tutoring along with CBM. Both students and teachers received weekly skills feedback and a graph of student performance from a computerized CBM system (*MBSP*, Fuchs et al., 1990). In addition, the teachers received a summary report for the class. Teachers reported heightened academic achievement with the implementation of the peer tutoring-CBM procedures. Eighteen of the teachers reported that the tutoring-CBM model helped better prepare students for standardized tests, and all teachers reported that the model encouraged students to help each other more. Teachers also reported that their expectations of students had increased.

Effects of Instructional Consultation with Teachers

Instructional consultation with teachers, provided by either computerized systems or knowledgeable consultants, seems to have a positive effect on the frequency and effectiveness of instructional changes that teachers make in students' programs, leading to gains in student achievement. With respect to computerized feedback, Fuchs, Fuchs, Hamlett, Phillips, and Bentz (1994), worked with 40 elementary general education teachers, with half of the teachers using CBM and half not using CBM. Of those using CBM twice each month half received both instructional recommendations and class wide, computerized feedback, while the other half received only computerized feedback. Students whose teachers received both instructional recommendations and class wide feedback performed better on mathematics computation problems taken from the statewide curriculum, and the teachers reported more diversification of their instruction.

A study with 22 special education teachers (Stecker & Fuchs, L.S., 2000) found that it is not merely implementing instructional changes that is important, but implementing instructional changes based on individual student data. Teachers of 42 students with mild to moderate disabilities in grades 2 through 8 made instructional changes based on students' individually graphed data, and made the same changes for a matched peer. Achievement gains on a mathematics achievement test were greater for the students receiving individualized intervention, indicating that it is not just frequency of intervention that is important, but intervention tailored to student needs and based on data.

Table 4: Selected studies in mathematics curriculum-based measurement

Study	Participants	Findings
Early Numeracy		
Chard, D.J., Clarke, B., Baker, S., Otterstedt, J., Braun, D., & Katz, R. (2005). Using measures of number sense to screen for difficulties in mathematics: Preliminary findings. *Assessment for Effective Intervention, 30(2),* 3-14.	168 K and 207 1st grade students	Fall, winter, and spring, students were administered three counting measures, number identification (NI), number writing, verbal quantity discrimination (QD), and missing number (MN) measures, along with a criterion measure, the Number Knowledge Test. Correlations with the criterion measure, growth across time, and amount of variance accounted for were examined and the three strongest measures were NI, QD, and MN.
Early Numeracy		
Clarke, B. & Shinn, M.R. (2004). A preliminary investigation into the identification and development of early mathematics curriculum-based measurement. *School Psychology Review, 33(2),* 234-248.	52 1st grade students	Participants were administered four CBM measures (oral counting, NI, QD, and MN) and three criterion measures (Woodcock Johnson Applied Problems subtest, the Number Knowledge Test, and a CBM computation probe). Alternate form and test-retest reliabilities were adequate, concurrent validity coefficients were moderate to very strong, with the largest coefficients for QD, and all measures had moderate to strong predictive validity (fall to spring), with QD effecting the strongest correlations.
Early Numeracy		
Lembke, E.S. & Foegen, A. (2005). *Creating measures of early numeracy.* Presentation at the annual Pacific Coast Research Conference. San Diego.	56 K and 32 1st grade students in Missouri and 63 K and 86 1st grade students in Iowa	Students were administered measures including quantity array, QD, NI, and MN between 1 and 3 times during the school year. Alternate form and test-retest reliability was strong and criterion validity with teacher ratings, the Mini Battery of Achievement, the Test of Early Mathematics Ability (TEMA), and the Stanford Early Achievement Test varied by measure and grade, but generally ranged from moderate to moderately strong.
Early Numeracy		
Foegen, A., Deno, S.L., & Lembke, E.S. (2006). ***Progress monitoring measures in mathematics: Do they show progress?*** Presentation at the annual Pacific Coast Research Conference. San Diego.	77 K and 30 1st grade students in Missouri, 56 K and 75 1st grade students in Iowa	Students were administered measures including QD, NI, and MN in the fall, winter, spring in Iowa and monthly in Missouri. Correlations with criterion variables including teacher ratings and the TEMA varied by measure and grade but were moderate to moderately strong overall. Monthly administration of the measures in Missouri indicated significant growth on all measures.

(continued)

Table 4: (continued)

Study	Participants	Findings
Elementary Fuchs, L.S., Fuchs, D., Hamlett, C.L., Thompson, A., Roberts, P.H., Kubek, P., Stecker, P.M. (1994). Technical features of a mathematics concepts and applications curriculum-based measurement system. *Diagnostique, 19(4),* 23-49.	140 elementary students in six classrooms	Six general educators implemented both the CBM concepts and applications and CBM computation probes on a weekly basis for 20 weeks. Weekly growth rates and the reliability and validity of the CBM graphed scores and skills analysis feedback are discussed.
Elementary Shapiro, E.S., Edwards, L, & Zigmond, N. (2005). Progress monitoring of mathematics among students with learning disabilities. *Assessment for Effective Intervention, 30(2),* 15-32.	120 students in grades 1-6, 113 of whom were LD and 7 of whom were EBD	The majority of the students were administered both a computation and concepts and applications probe once every two weeks over 7 months. Rates of improvement on both types of mathematics probe were .38 digits per week. 66% of the students in computation and 37% in concepts and applications achieved their expected goals. These levels of improvement were comparable to general education students.
Elementary Fuchs, L. S., Fuchs, D., Hamlett, C. L., & Walz, L. (1993). Formative evaluation of academic progress: How much growth can we expect? *School Psychology Review, 22(1),* 27-48.	All students in grades 1-6. Year 1: 117 students in reading, 252 in spelling, 177 in mathematics. Year 2: 257 in reading, 1046 in spelling, 1208 in mathematics	In Year 1, students were monitored weekly and in Year 2 at least monthly, in reading, mathematics, and spelling, using CBM. Weekly rates of academic growth (or slopes of achievement) were calculated.
Elementary Phillips, N. B., Hamlett, C. L., Fuchs, L. S., & Fuchs, D. (1993). Combining classwide curriculum-based measurement and peer tutoring to help general educators provide adaptive education. *Learning Disabilities Research & Practice, 8(3),* 148-156.	40 elementary mathematics classes	Study that describes and evaluates the efficacy of a combination of curriculum-based measurement and peer tutoring incorporated into 40 elementary education mathematics classes, to differentiate instruction and improve student achievement. The evaluation indicated that students with low achievement, average achievement, and learning disabilities achieved significantly better than students in control classrooms.

(continued)

Table 4: (continued)

Study	Participants	Findings
Elementary/Middle School		
Fuchs, L. S., Fuchs, D., Hamlett, C. L., & Stecker, P. M. (1991). Effects of curriculum-based measurement and consultation on teacher planning and student achievement in mathematics operations. *American Educational Research Journal, 28(3),* 617-641.	33 teachers of 63 students in grades 2-8	Teachers were divided into three groups—those implementing M-CBM with computerized instructional consultation, those implementing M-CBM without consultation, and those not implementing M-CBM. Students whose teachers were implementing CBM with expert system consultation had significantly greater achievement on a mathematics computation test at the end of 20 weeks.
Elementary/Middle School		
Fuchs, L.S., Fuchs, D., Hamlett, C.L., & Stecker, P.M. (1990). The role of skills analysis in curriculum-based measurement in math. *School Psychology Review, 19(1),* 6-23.	30 special education teachers of students in grades 1-8	Teachers assessed each students' mathematics performance at least twice weekly using computation probes. Teachers in the experimental group entered the data into a computer program that graphed the data, applied data evaluation rules to the graphed performance, provided feedback to the teachers regarding the decisions, and performed a skills analysis of the student's performance. Teachers who received both the graphed performance of their students and a skills analysis planned more specific instructional programs for their students and the students achieved better than students in the control group or students in the group whose teacher got only graphed data.
Elementary/Middle School		
Stecker, P. M., & Fuchs, L. S. (2000). Effecting superior achievement using curriculum-based measurement: The importance of individual progress monitoring. *Learning Disabilities: Research & Practice, 15(3),* 128-134.	22 special education teachers of 42 students in grades 2-8	Teachers of students with mild to moderate disabilities made instructional changes for their students based on the students' individually graphed data, and made the same changes for a matched peer. Achievement gains on a mathematics achievement test were greater for the students that were receiving individualized intervention based on their graphed data, indicating that it is not just frequency of intervention that is important, but intervention tailored to student and based on data.

(continued)

Table 4: (continued)

Study	Participants	Findings
Middle School		
Foegen, A. & Deno, S.L. (2001). Identifying growth indicators for low-achieving students in middle school mathematics. *The Journal of Special Education, 35(1),* 4-16.	100 students in 7th and 8th grades	This study examined the validity and reliability of CBM estimation probes as a method to monitor the progress of middle school students. Students were administered 4 types of measures (basic mathematics operations, basic estimation, and two types of modified estimation tasks). Results indicated that all four measures were reliable, and that all were promising indicators of overall mathematics proficiency.
Middle School		
Helwig, R., Anderson, L., & Tindal, G. (2002). Using a concept-grounded, curriculum-based measure in mathematics to predict statewide test scores for middle school students with LD. *The Journal of Special Education, 36(2),* 102-112.	171 8th grade students	The validity of a CBM test created from a larger pool of field-tested mathematics items was assessed by comparing the results of the CBM scores with a computer adaptive test designed to mimic a state mathematics achievement test. Correlations between the two measures were moderate for students with LD and strong for general education students.
High School		
Foegen, A. (2006). *Monitoring student progress in algebra.* Presentation at the annual Pennsylvania Technical Assistance Network conference: University Park, PA.	217 students in secondary grades	Two of three different types of algebra probes were administered twice each month, with students demonstrating growth on all three probes, but the most growth on the content analysis probes.

SUMMARY

More than 30 years of research supports the use of Curriculum-Based Measurement to aid in screening and progress monitoring in academic areas. CBM provides a standardized set of procedures that produce reliable, valid data that verify which students are at-risk, and identifies when instructional changes need to be made. It is a key component in instructional delivery, as data must drive the amount, type, and intensity of instruction. CBM is a multi-faceted tool that can be used to screen all students in a district, school, grade-level, class, or small group; monitor the effectiveness of instruction for general education students and students in special education; monitor the effectiveness of prereferral interventions that are implemented prior to referral to special education; and utilize as an easy-to-understand way to communicate student growth to parents.

The basic steps for CBM implementation are summarized in Table 1 and resources for materials, directions, and interventions are provided in Appendix A. As described previously, CBM is a tool that can be used with one student or 100 students, which makes it extremely flexible. It also is easy to learn and implement, which makes it a time-efficient tool for all teachers. Educators will continue to be held accountable for the progress of their students, and CBM is an important tool that can be utilized to examine student progress.

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APPENDIX

Resources for CBM Information

National Centers

National Center on Student Progress Monitoring

http://www.studentprogress.org

- Web site that provides information and technical assistance on progress monitoring for elementary students.
- Watch for conference notices, as this technical assistance center funded by OSEP offers training in progress monitoring.

Research Institute on Progress Monitoring

http://www.progressmonitoring.org

- Web site that provides information regarding the OSEP-funded project to evaluate the effects of individualized instruction on access to and progress within the general education curriculum.
- Provides information on current and previous research in CBM, including a comprehensive literature review.

Computer or Web-based Resources and Software Systems

Intervention Central—www.interventioncentral.org

- A web site developed by Jim Wright, a school psychologist from Syracuse, NY. This site contains numerous tools for creation, administration, and graphing of CBM measures, and includes ideas for research-based interventions (free).

Algebra Assessment and Instruction—www.ci.hs.iastate.edu/aaims

- Provides details on ongoing research into algebra assessment tools that can be used for monitoring the progress of students with and without disabilities as they learn algebra.

Assessing the Effectiveness of Interventions

- *Identifying and implementing educational practices supported by rigorous evidence: A user friendly guide*
  http://www.ed.gov/rschstat/research/pubs/rigorousevid/rigorousevid.pdf
- *Using research and reason in education: How teachers can use scientifically based research to make curricular and instructional decisions*
  http://www.nifl.gov/partnershipforreading/publications/html/stanovich/
- *Lembke, E.S. & Stormont, M. (2005). Using research-based practices to support students with diverse learning needs in general education settings. Psychology in the Schools, 42(8), 761-763.*

CBM Tutorial

- Lembke, E., & Espin, C. (2005). Curriculum based measurement: Using progress monitoring to affect change in the classroom. In G. D. Sideridis & T. A. Citro, (Eds.), Research to practice: Effective interventions in learning disabilities, (pp. 150-171). Boston, MA: LDW.

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