TECHNICAL REPORT #2:

Seamless and Flexible Progress Monitoring: Age and Skill Level Extensions in Math, Basic Facts

Christine A. Espin, Teri Wallace, Anne Foegen, Xiaoqing Du, Renata Ticha, Miya Miura Wayman, and Hilda Ives Wiley

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Note: The participants and data collection methods are the same as Technical Report #1 and #10.

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Seamless and Flexible Progress Monitoring: Age and Skill Level Extensions in Math, Basic Facts

The acquisition of basic skills in mathematics is an important foundation for students' academic development. Proficiency in mathematics is closely related to students' success at school and in careers (Fuchs & Fuchs, 2002; Fuchs, Fuchs, Hamlett, Thompson, Roberts, Kubek, & Slecker, 1994). Today's students will be tomorrow's citizens applying mathematics to solve practical problems every day. At the elementary school level, progress monitoring tools have been developed to track students' proficiency in basic math facts. Foegen and her colleagues (Foegen, 2000; Foegen & Deno, 2001) have investigated the use of a basic facts measure at the middle school level and found acceptable levels of reliability and criterion validity. Little is known about whether such a measure could be used in a seamless and flexible system to track students' development of mathematical proficiency across multiple grade levels. This study examines the technical adequacy of two forms of a basic facts probe used to measure K-12 students' basic skills in addition, subtraction, multiplication, and division.

Although mathematics has always been a core subject in the K-12 curriculum, learning outcomes in mathematics are still not optimal. In the late 80s, the United States ranked at the bottom in the international comparisons among developed countries (Fuchs et al., 1994). American 8th grade students' performance in the International Evaluation of Educational Achievement was more than 2 years behind high-scoring countries (Fuchs & Fuchs, 2001). The report of the Trends in International Mathematics and Science Study in 2003 showed that the mathematics performance of American 8th-grade students fell behind that of 15 of the 46 participating countries (National Center for Education

Statistics, 2003). Recent studies reveal that the current math performance level of American students has not met the challenging needs of the job market yet (Clarke & Shinn, 2004). Therefore, students' performance in mathematics has caused concern among educators in the United States.

In 2001, the U.S. Department of Education issued the No Child Left Behind Act (NCLB) which requires each state to adopt challenging standards for reading, mathematics, and science, as well as improved outcomes for students' academic achievement in these areas. Many states have established regulations mandating the use of standardized tests to measure students' achievement. Examples of state tests include measures such as the Minnesota Basic Skills Test (MBST; Minnesota Department of Education, 2007), the Northwest Achievement Level Tests (NALT), and the computerized version of NALT, which is called Measures of Academic Progress (MAP; Northwest Evaluation Association, 2003). These tests are used to measure the performance of different student reference groups to meet NCLB mandates and to assess the effectiveness of instruction. However, these tests are not appropriate for monitoring student progress as they are only administered once or twice a year.

The NALT/MAP is used by some states in the mid-west and western areas such as Minnesota, Oregon, and California. The NALT/MAP mathematics tests cover the areas of (a) number sense, (b) measurement and geometry, (c) algebra functions, (d) statistics, data analysis probability, and (e) mathematical reasoning. For the purpose of validity and reliability, the scales for NALT are created based on the Item Response Theory (IRT; Thorndike, 2005) which guides the math tests by estimating the probability that a student answers a question, the difficulty level of the question given to the student, and the achievement level of the student (Northwest Evaluation Association, 2003). The results of the NALT/MAP are designed to assist teachers as they make instructional planning for individual students or an entire class.

To assure internal consistency, NWEA calculates the marginal reliability coefficient using IRT to obtain test information and the underlying scale (Northwest Evaluation Association, 2003). Test information indicates the inverse of the measurement error of the test – the smaller the measurement error, the more information is obtained. Since the amount of information obtained is at the maximum around the middle of the test, measurement error is minimal for the underlying scale at the middle of the test. To achieve content validity, NWEA produces a test blueprint based on existing content standards from districts and states (Northwest Evaluation Association, 2003). Test items are identified fro a specific test according to their match to the content standards and the difficulty level of the test being developed.

The MBST includes standardized tests in reading, math, and writing that students in Minnesota must take and pass to receive a diploma from a public high school (Minnesota Department of Education, 2007). The test is first administered in grade 8 and can be repeated if students do not pass. The MBST in math is a minimum competency test of basic skills and knowledge in mathematics. The test covers 8 content areas which include (a) problem solving with while numbers, fractions, decimals, and integers; (b) problem solving with percents, rates, ratios, and proportions; (c) number sense, place value, and number relationships; (d) estimation of the context of real-life problems; (e) measurement concepts; (f) tables and graphs; (g) chance and data; and (h) shape and space. Although the state has set up a passing score, it is the school districts' responsibility to determine whether a student has met the MBST requirement for graduation. If a student does not pass the MBST, the district needs to provide appropriate remediation services. A new policy from Minnesota specifies that students who enter Grade 8 in 2005-2006 or later will not take the MBST. Instead, they will take the Minnesota Comprehensive Assessment II (Minnesota Department of Education, 2005).

The MCA tests are state-wide tests that the Minnesota schools give to students at Grade 3, 5, 7, and 11 in 2005 (Minnesota Department of Education, 2005). The MCA includes five performance levels from the lowest to the highest, I. IIa, IIb, III, and IV. Student performance is measured on the RIT scale, which estimates student achievement based on individual item difficulty values. There is no passing score for students. The MCA only provides information about students' performance level.

The purpose is to measure student performance at their grade level on the Minnesota Academic Standards (Minnesota Department of Education, 2005). The test results indicate the effectiveness of existing district curriculum and Adequate Yearly Progress (AYP) of schools under the No Child Left Behind Act (NCLB). The test results are also used to inform districts and schools of their performance in terms of decision making for the improvement of teaching and learning. The 2004 and 2005 administrations of the MCA tests provides schools and districts the opportunity to transition to new academic standards required by NCLB. Each student receives a report about the level of performance as well as a state percentile rank showing the student's performance compared to that of other students in Minnesota (Office of Educational Accountability, 2000).

Standardized tests provide little evidence of students' achievement in a specific area within a period of time as the scores can only indicate students' performance level within a reference group. Standardized tests only employ limited measures of constructs and tend to obtain incomplete assessments of students' proficiency (Koretz, 2002), which are technically inadequate for making specific instructional decisions for individual students (Deno, 1985). To make decisions concerning student placement or instructional improvement, educators need to employ an assessment tool that can monitor student progress in a specific area on a regular basis.

Curriculum-Based Measurement (CBM) is considered an efficient assessment method to monitor students' progress within basic skills curriculum (Deno, 1985, Fuchs & Fuchs, 1990). Initially, educators used CBM in special education particularly in the areas of reading fluency, spelling, writing expression, and mathematics as CBM is a "technically adequate formative evaluation system" for teachers to modify instructional programs by monitoring student progress (Yell, Deno, & Marston, 1992). Over the years, CBM has been used extensively in monitoring student progress as general outcomes (Nolet, 1997). For example, CBM has been used to monitor progress in reading at the secondary level (Espin & Deno, 1993), modify academic interventions (Fuchs, Fuchs, & Hamlett, 1993), and develop norms for decision making (Deno, et al. 2001). All these studies reveal that administering CBM on a regular basis can help provide information about students' rate of learning which can be used by teachers to modify their instruction (Fuchs, 2004).

CBM math measures have been found to be effective with preschoolers (Vanderheyden, Broussard, Fabre, Stanley, Legendre, & Creppell, 2004), elementary school students (Thurber, Shinn, & Smolkowski, 2002), middle school students (Foegen

& Deno, 2001), and special education teachers (Fuchs & Fuchs, 1990). A study of early math measures was conducted particularly on the reliability, validity, and sensitivity to 52 first-grade students using four experimental measures including Oral Counting, Number Identification, Quantity Discrimination, and Missing Number (Clarke and Shinn, 2004). Data were collected during one academic year with approximately 13-week intervals. The results show that all the measures which display moderately high to high reliability and validity can be used as indicators in mathematics for early identification and formative evaluation. Although there is evidence suggesting that CBM math measures are useful to monitor progress within a grade level, there is no conclusive evidence supporting the use of CBM math measures to gauge general outcomes of students across grades in general education. Developing such a tool can serve as a standard for K-12 students and help teachers to monitor students' growth within and across grades.

The purpose of this study was to investigate the validity and reliability of CBM math fact probes for students across grade levels. We addressed the following research questions in the study:

1. What are the validity and reliability of a 1-minute math fact probe?
    a. Do reliability and validity differ by grade level?
    b. Do validity and reliability differ by skill level within grade?
2. What are the relative contributions of math probes for predicting performance on state standards tests and standardized achievement tests?

Method

Participants and Setting

Participants were 509 students from two Midwestern school districts, one rural, and one urban. Students from the rural district came from two K-5 schools - one middle school and one high school. Students from the urban district came from one K-8 school and one high school.

As seen in Table 1, the participants were 109 3rd graders (56% female and 44% male), 130 5th graders (48% female and 52% male), 90 8th graders (61% female and 39% male), and 178 10th graders (51% female and 49% male).

Table 1
Information about the participants

	3rd Grade		5th Grade		8th Grade		10th Grade	
District	Male	Female	Male	Female	Male	Female	Male	Female
1	23	29	33	31	21	26	31	41
2	25	34	35	31	14	29	55	51
Percent	43%	57%	52%	48%	39%	61%	48%	52%
Total	111		130		90		178	

The rural district had 3,540 students, with 17% qualifying for free/reduced lunch, 10% receiving special education services, and 1% receiving English Language Learner services. One percent of the students were American Indian, 2% Asian Pacific American, 1% African or African American, 1% Hispanic/Latino/Chicano, and 95% White.

The urban district had 40,499 students, with 68% qualifying for free/reduced lunch, 15% receiving special education services, and 23% receiving English Language Learner services. Four percent of the students were American Indian, 12% Asian Pacific American, 42% African or African American, 14% Hispanic/Latino/Chicano, and 27% White (see Tables 2.1 – 2.3).

Table 2.1
Gender, Languages, Special Education, and Free/Reduced Lunch (%)

		Gender		Languages				Free/Reduced Lunch			
District	Grade	Male	Female	English	Others	ELL	Special Education	Free	Reduced	Full Price	Not Sure
1	3	44.2	55.8	100	0	0	13.7	9.6	3.8	84.6	1.9
	5	51.6	48.3	100	0	0	9.4	7.8	4.7	87.5	0
	8	44.7	55.3	100	0	0	8.9	4.4	8.9	86.7	0
	10	43.1	56.9	98.6	1.4	0	8.3	9.7	5.6	84.7	0
2	3	44.1	55.9	79.9	20.3	18.6	3.4	49.2	6.8	5.1	39
	5	53	47	56.1	43.9	31.8	9.1	51.5	4.5	3	40.9
	8	32.6	67.4	81.4	18.6	14	9.3	41.9	4.7	4.7	48.8
	10	52.8	47.2	70.5	29.5	19	1.9	39	9.5	4.8	46.7

Table 2.2
Ethnicity (%)

District	Grade	Asian American	African American	Hispanic American	Native American	White	Missing
1	3	0	0	0	2	98	
	5	3.1	6.3	0	0	90.6	
	8	0	0	2.1	0	93.6	4.3
	10	1.4	0	0	0	98.6	
2	3	1.7	27.1	23.7	3.4	44.1	
	5	6.1	24.2	40.9	0	28.8	
	8	0	37.2	20.9	7	34.9	
	10	7.3	30.3	21.5	2.2	38.3	

Table 2.3
Primary Handicap (%)

District	Grade	Autism Spectrum	EBD	SLD	Speech and language	Early Childhood Speech & Language	Deaf and Hard Hearing	Physical Impairment	Other Health Disability
1	3		1.9	3.8	3.8	1.9	1.9		
	5		1.6		4.7				
	8		4.3		2.1			2.1	
	10			4.2				1.4	
2	3	1.7			1.7				
	5	1.5	1.5		1.5				
	8		2.3	7					
	10			0.9					0.9

Measures

CBM basic fact probes were taken from the Basic Academic Skills Samples (BASS; Espin, Deno, Maruyama & Cohen, 1989). Students took two parallel forms of the probes. Each probe had 20 single digit addition, subtraction, multiplication and division problems (see Appendix A). Problems were placed in a random order on the probe. For example, the problems in the probes included 12 – 7 = (?), or 12 / 3 = (?). Participants were given one minute to complete as many problems as possible on each probe.

Criterion Variables

Criterion variables included (a) a standardized achievement test, Northwest Achievement Level Test (NALT), (b) state standards test, the Minnesota Comprehensive Assessment (MCA), and (c) the Minnesota Basic Skills Test (MBST). As displayed in Table 2, the two districts made different decisions regarding standardized tests or state test that students should take. Students in District 1 took the MAP test, a computer version of the NALT while students in District 2 took the paper-pencil NALT test. For the MCA, there was only information about 3^{rd}- and 5^{th}-grade students in 2005 in District 1. In District 2, 8^{th}-grade students took the MCA in 2004; 3^{rd}- and 5^{th}-grade students took the MCA in 2005. Information about the MBST in 2005 was obtained on 8^{th}-grade students in both districts and 10^{th}-grade students in District 2 (see Table 3).

Table 3
Criterion variables

	District 1	District 2
MAP	Grade	Grade
Spring 04	3, 5, 8	
Fall 04	3, 5, 8	
Spring 05	3, 5, 8	
NALT		
Spring 04		3, 5, 8, 10
Spring 05		3, 5
MCA		
2004		8
Spring 05	3, 5	3, 5
MBST		
2005	8	8, 10

Procedure

Training of data collectors. Data collectors were 4 graduate research assistants on the Research Institute on Progress Monitoring (RIPM) Age Skill Level Study group at University of Minnesota and 5 data collectors who were either graduate students in educational programs or had years of teaching experience. Training of data collecting was conducted across two days. The training covered the administration of all reading and math probes as well as the scoring methods. Training was provided by the graduate research assistants who had experience in administering and scoring the probes.

Training of scorers. All the scorers participated in a 2-hour training session which covered scoring for reading and math. For the math part, scorers first went through the directions and then practiced on 2 math probes. Afterwards, they checked the scores on the same two probes against each other under the supervision of an experienced trainer. The reliability agreement was between 80% and 90%.

Administration. Data were collected in the fall, winter, and spring of the 2004-

2005 academic year. At each testing session, participants completed the two math probes one after the other. The order in which participants completed the probes was counterbalanced across students. Participants were given 1 minute to complete each probe, and were instructed to begin at the top left corner and work from left to right in order, putting an “X” over any problems they could not answer.

All the 3rd- and 5th-grade students participated in the study in their classrooms. Depending on the agreement of the class teachers, the 8th- and 10th-grade students took part in the study in their classrooms, the hallway, or the media resource center.

Scoring. The number of correct answers was scored. Scoring accuracy was checked by a graduate research assistant that re-scored one scored sheet for every 20 completed. Interscorer agreement ranged from 67% to 100% with an average interscorer agreement of 88.8% in Fall 2004, 87% in Winter 2005, and 93.81% in Spring 2005. Detailed information is displayed in Table 4.

Table 4
Interscorer Agreement for Math Facts (%)

Season	Mean	Range
Fall, 04	88	67-100
Winter, 05	87	67-100
Spring, 05	93.81	67-100

Data Analysis

When data scoring and data entry were finished, three steps were taken for data analysis. Step 1 was to obtain descriptive data of the two math facts probes and of all criterion measures. The descriptive data were run by the sequence of Fall 2004, Winter 2005, and Spring 2005 from the combined districts and separate districts. Step 2 was to list all histograms and scatterplots of the descriptive data. Step 3 was to obtain correlations coefficients for (a) checking reliability of alternate forms and test-retest, and (b) obtaining evidence of concurrent validity and predictive validity. The number of correct problems was used for all analyses.

Results

Descriptive data

CBM. Data of math mean and standard deviation of CBM math facts probes in Fall 2004, Winter 2005, and Spring 2005 are listed across grades (see Table 5 and Figure 1). Data for District 1 are displayed in Appendix B; data for District 2 are displayed in Appendix C. As is shown in Table 5, the mean scores of the CBM probes increased as grade level increased in each season. The mean scores for each grade increased across the three seasons: Fall 2005, Winter 2005, and

Table 5
Descriptive Data of CBM math probes (Number of Correct Problems)

Season	Grade	*M*	*SD*	*n*
Fall 04	3	9.57	3.33	111
	5	18.83	8.66	130
	8	26.48	11	89
	10	27.56	10.24	178
Winter 05	3	11.5	3.99	107
	5	21.69	10.08	129
	8	27.52	10.86	86
	10	30.80	12.15	168
Spring 05	3	14.1	5.2	106
	5	22.95	11.53	125
	8	28.54	11.28	82
	10	32.12	13.12	162

Spring 2005 (see Figure 2). The growth gaps between each grade varied. The gaps between Grades 3 and 5 across the three seasons (8.46 in Fall 2004, 10.19 in Winter

2005, and 8.85 in Spring 2005) were bigger than the gaps between Grades 5 and 8 (7.65, 5.83, and 5.59) and between Grades 8 and 10 (1.08, 3.08, and 3.58). The mean scores for each grade are graphed in Figure 5.

The standard deviations for Grade 3 across seasons (3.33-5.2) were smaller than those for Grades 5, 8, and 10 (8.66-13.12). Grade 10 showed the largest standard deviations across seasons (10.24, 12.15, and 13.12). The sample size varied across grades and across seasons. In each season, Grade 8 had the smallest sample size (89, 86, 82); Grade 10 had the largest sample size (178, 168, 162). For the three seasons, Grade 3 had the sample size between 106 and 111; Grade 5 had the sample size between 125 and 130.

Figure 1
CBM Math Performance in Three Seasons by Grade

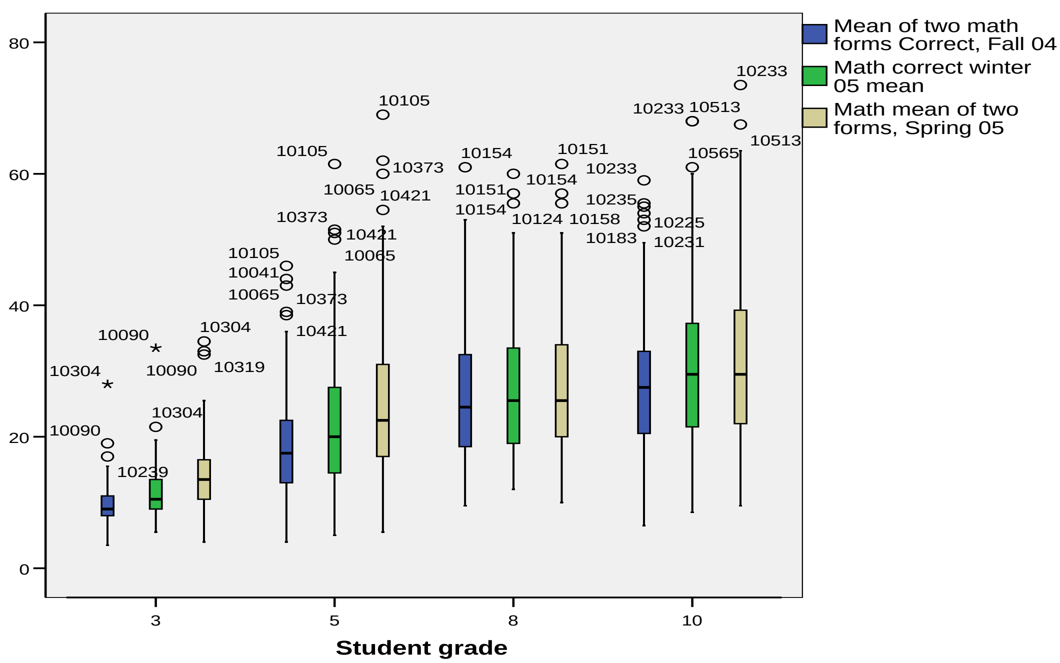
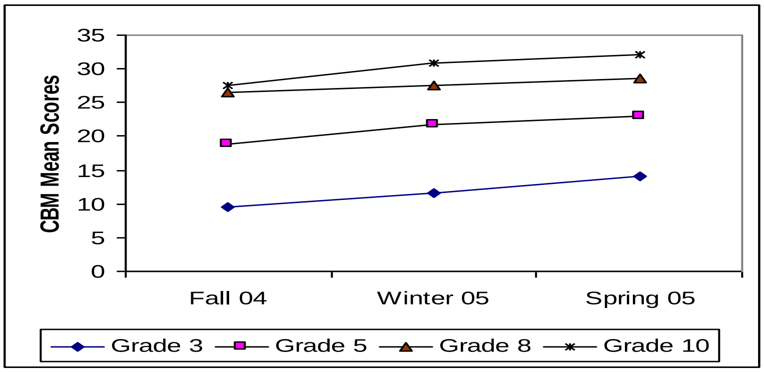


Figure 2

CBM Mean Scores (Number of Correct Problems)



NALT/MAP. In Spring 2004, students in Grades 3, 5, and 8 of District 1 took the MAP test; students in Grades 3, 5, 8, and 10 took the NALT test (in Table 6). In Spring 2004, 3rd-, 5th-, and 8th- grade students in Districts 1 and 2 took the NALT/MAP; only 10th-grade students in District 2 took the NALT/MAP. In Spring 2005, 3rd- and 5th-grade students in both districts took the NALT/MAP; only 8th-grade students in District 1 took the NALT/MAP. No 10th-grade students took the NALT/MAP in 2005.

Data indicate that the mean scores tended to increase as grade increased in both 2004 (193.93 to 234.98) and 2005 (207.77 to 240.67). From 2004 to 2005, the mean scores seemed to increase for Grades 3 (193.93 to 207.77) and Grade 5 (215.13 to 223.73). However, the sample size was not similar across grades. The largest sample size was in Grade 5 (*n* = 120, in 2004; *n* = 126, in 2005); the smallest sample size was in Grade 8 (*n* = 80, in 2004; *n* = 42, in 2005).

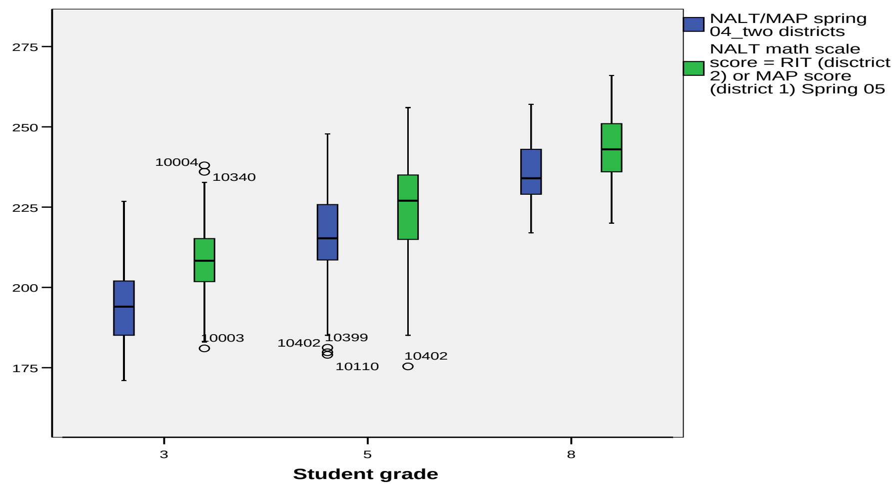
Table 6

Descriptive Data of NALT/MAP

Year	Grade	*M*	*SD*	*n*
Spring, 04	3	193.93	11.14	104
	5	215.13	15	120
	8	234.07	13.02	80
	10 (District 2 only)	234.98	18.44	96
Spring, 05	3	207.77	12.28	103
	5	223.73	16.18	126
	8 (District 1 only)	240.67	12.82	42

Figure 3

Student Performance on NALT/MAP by Grade



MCA. Only students in District 2 took the MCA in 2004 and 2005 (in Table 7). In 2004, 8th-grade students in District 2 took the MCA. In 2005, 3rd- and 5th-grade students in District 2 took the MCA. In 2005, the mean score of Grade 3 seemed to be higher than the mean score of Grade 5. The standard deviation of Grade 8 in 2004 was approximately 4 times smaller compared to that of Grades 3 and 5 in 2005. The sample size of Grade 8 was the small (*n* = 39); the sample size of Grade 5 was larger (*n* = 66) than that of Grade 3 (*n* = 57).

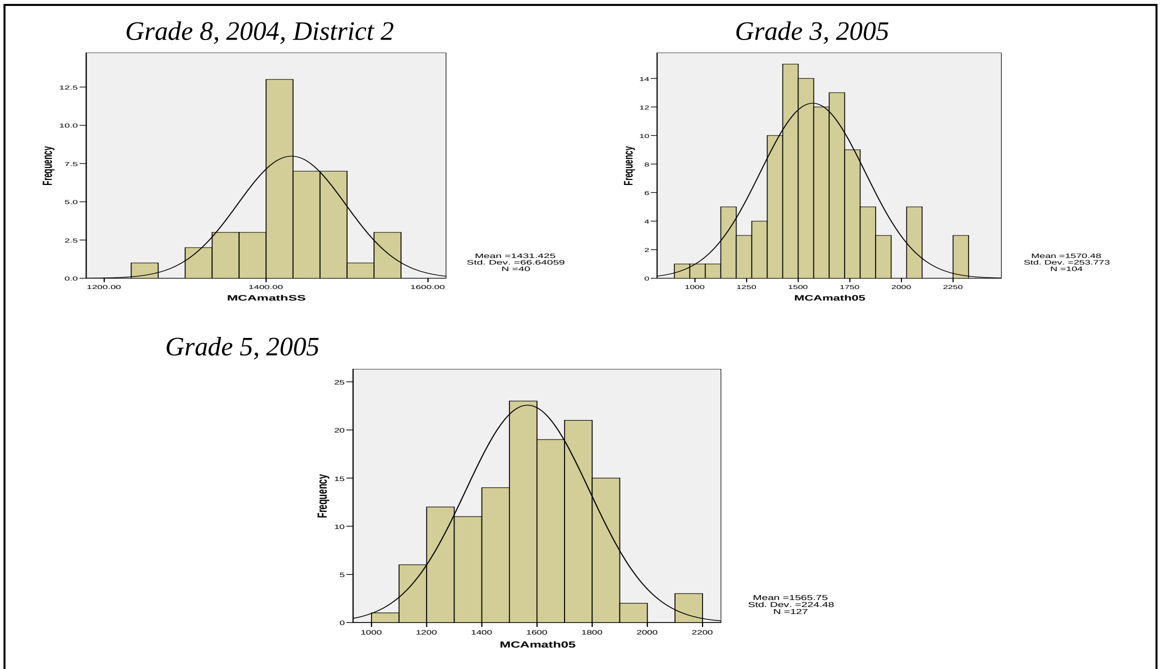
Table 7

Descriptive Data of MCA and MBST

	Year	Grade	*M*	*SD*	*n*
MCA	2004	8 (District 2 only)	1436.33	59.74	39
	2005	3	1570.48	253.77	104
		5	1565.75	224.48	66
MBST	2005	8	631.66	55.34	86
	2005	10 (District 2 only)	574.94	24.17	34

Figure 4

Student Performance on MCA



The mean was 631.66; the standard deviation was 55.34. In 2005, only 10th-grade students in District 2 took the MBST. The mean was 574.94; the standard deviation was 24.17. Descriptive data of MAP and MBST for District 1 are in Appendix B-2; descriptive data of NALT, MCA, and MBST for District 2 are in Appendix C-2.

Figure 5

Student Performance on MBST

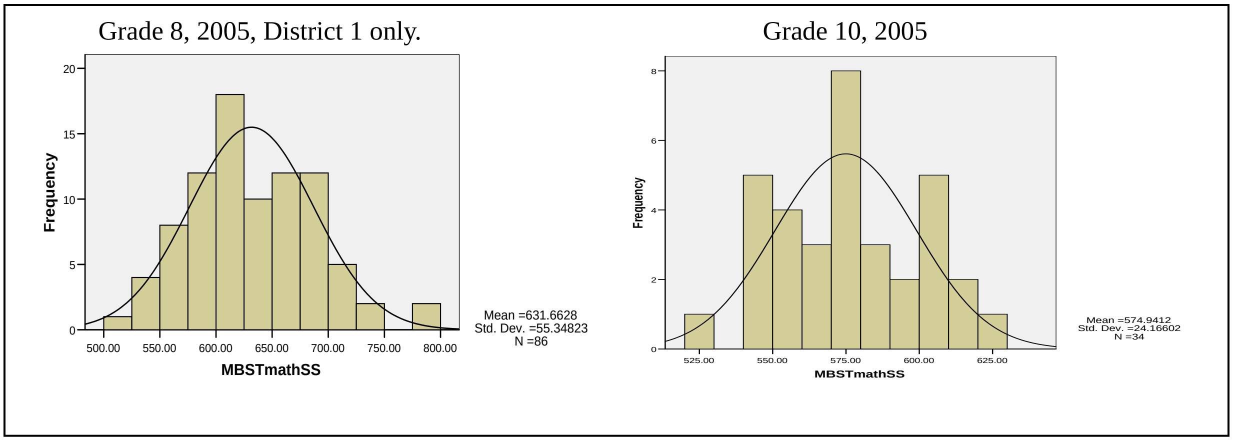


Table 8

Inter-Item Correlation

Fall 2004	Probe	*r*	*M*	*SD*	*n*
	1	.90**	21.39	11.97	508
	2		21.08	11.35	508
Winter 2005	Probe				
	1	.92**	23.98	13.02	489
	2		23.31	12.34	489
Spring 2005	Probe				
	1	.90**	26.00	13.77	475
	2		25.01	12.71	475

Note. ***p* < .01

Reliability

Inter-item correlation. Reliability of CBM math probes 1 and 2 were examined using the method of inter-item correlation. Correlation coefficients (in Table 8) between probes 1 and 2 across grades in Fall 2004, Winter 2005, and Spring 2005 were strong (.90, .92, and .90, respectively). These coefficients indicated that difficulty level in probe 1 was similar to that of probe 2 from the performance of the participants.

Alternate-form reliability. Alternate-form reliability of the CBM math probes 1 and 2 for each grade level was tested using Pearson product moment correlation (see

Table 9). Means and standard deviations of each probe were also listed. Overall correlation coefficients for each grade across Fall 2004, Winter 2005, and Spring 2005 appeared to be strong. The range was between *r* = .64 and .92 across grades and across seasons. The correlations for Grades 5, 8, and 10 seemed to be similar across the three seasons. The correlations for Grade 3 increased from Fall 2004 (*r* = .64) to Winter 2005 (r = .73), and to Spring 2005 (*r* = .82).

Table 9
Alternate-form Reliability of CBM Math Probes (Number of Correct Problems)

Season	Grade	*r*	Probe 1		Probe 2		*n*
			M	*SD*	*M*	*SD*	
Fall 04	3	.64**	9.21	3.75	9.93	3.6	111
	5	.88**	18.64	8.85	19.03	9.01	130
	8	.85**	26.87	11.39	26.08	11.49	89
	10	.85**	28.24	10.89	26.88	10.43	178
Winter 05	3	.73**	11.3	4.23	11.76	4.37	106
	5	.92**	22.3	10.72	21.52	9.93	125
	8	.87**	28.11	11.48	27.68	11.22	82
	10	.88**	31.91	12.83	30.61	12.44	160
Spring 05	3	.82**	14.34	5.4	13.86	5.51	106
	5	.89**	25.14	12.38	24.84	11.34	125
	8	.85**	29.21	12.48	27.88	10.93	82
	10	.87**	33.41	13.98	31.14	13.21	160

Note. ***p* < .01

Furthermore, the correlation coefficients for each grade increased from fall 2004 to spring 2005. The correlation coefficients for Grade 5 seemed to be stronger across the three seasons (*r* = .88, *r* = .92, and *r* = .89) than those for all other grades. The correlation coefficients for Grade 3 seemed to be the lowest across seasons (*r* = .64, *r* = .73, and *r* = .82).

Table 10
Concurrent Validity Evidence CBM Math and Criterion Measures

	CBM Math			
NALT/MAP	Grade 3	Grade 5	Grade 8	Grade 10
2004	.58**	.60**	.42**	.495** (District 2 only)
Spring 05	.60**	.61**	.50** (District 1 only)	
MCA				
2004			.23 (District 2 only)	
Spring 05	.51**	.52**		
MBST				
2005			.51**	.38* (District 2 only)

Note. $**p < .01$

Validity Evidence

Concurrent validity. Concurrent validity of the CBM math probes was examined using the criterion measures (in Table 10). Mean scores of CBM math probes in Fall 2004 were used to correlate with mean scores of NALT/MAP in 2004. Mean scores of CBM math probes in Spring 2005 were used to correlate with mean scores of NALT/MAP in Spring 2005. Correlations were moderate to moderately strong for Grades 3, 5, and 8 (r = .42 - .61). In both 2004 and 2005, correlations for Grades 3 and 5 seemed stronger than those for Grade 8. For Grades 3 and 5, correlations in 2005 (.60, .61) seemed to be a little bit stronger than those in 2004 (.58, .60). Correlations for Grade 10 in 2004 are based on students' performance in District 2. Correlations for Grade 8 in Spring 2005 are based on students' performance in District 1.

Validity evidence of the MCA was obtained from Grades 3, 5, and 8. In 2004, only 8^{th}-grade students in District 2 took the MCA. The correlation coefficient for Grade 8 in 2004 was not statistically significant. In Spring 2005, 3^{rd}- and 5^{th}-grade students in both districts took the MCA. The correlation coefficients for Grades 3 and 5 were similar (.51, .52).

Validity evidence with MBST was obtained from Grades 8 and 10 in 2005. In Grade 10, only students in District 1 took the MBST. The coefficient for Grade 8 seemed to be moderately strong (r = .51); the coefficient for Grade 10 was not as strong as that of Grade 8 (r = .38).

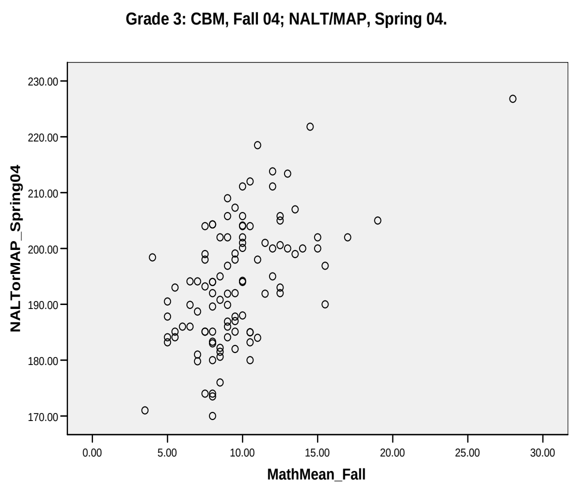
Evidence of the concurrent validity for the NALT/MAP, MCA and MBST in 2004 and 2005 is graphed in Figure 6, 7, and 8. Figure 6 displays correlations for Grades 3, 5, 8, and 10 between CBM math scores in Fall 2004 and NALT/MAP in Spring 2004. There seemed to be more linearity for Grade 5 than for Grades 3 and 8. The trend in the data for Grade 3 seemed to be linear, but was influenced by an outlier that was far away from the majority on both the CBM and NALT/MAP. Grade 8 showed quite a few outliers in all directions. Data for Grade 10 were obtained only from District 2.

Figure 7 displays correlations for Grades 3, 5, and 8 between CBM math scores in Spring 2005 and NALT/MAP in Spring 2005. Grades 3 and 5 showed linearity although there were a few outliers. Grade 8 (District 1 only) showed more outliers, some of which seemed to score low on the CBM math but high on the NALT/MAP, or vice versa.

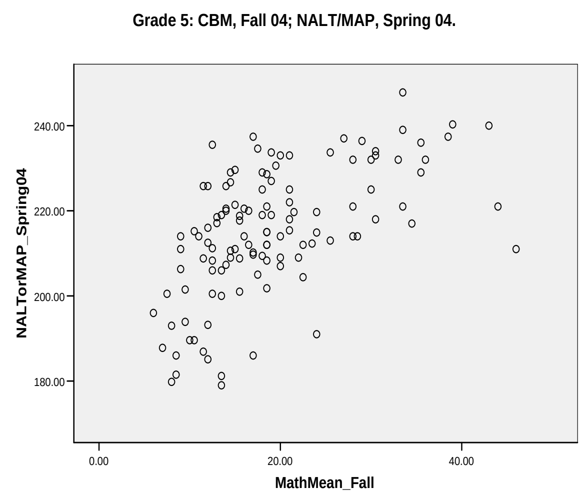
Figure 6

Correlations Between CBM (Fall, 04) and the NALT/MAP (Spring, 04)

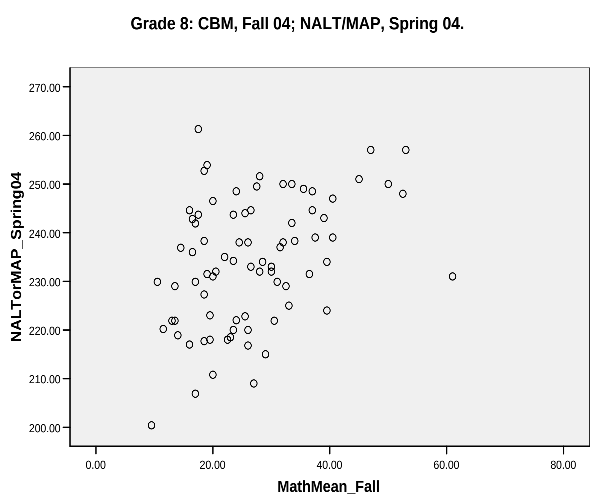
Grade 3: CBM, Fall 04 and NALT/MAP, Spring 04



Grade 5: CBM, Fall 04 and NALT/MAP, Spring 04



Grade 8: CBM, Fall 04 and NALT/MAP, Spring 04



Grade 10: CBM, Fall 04 and NALT/MAP, Spring 04
(District 2 only)

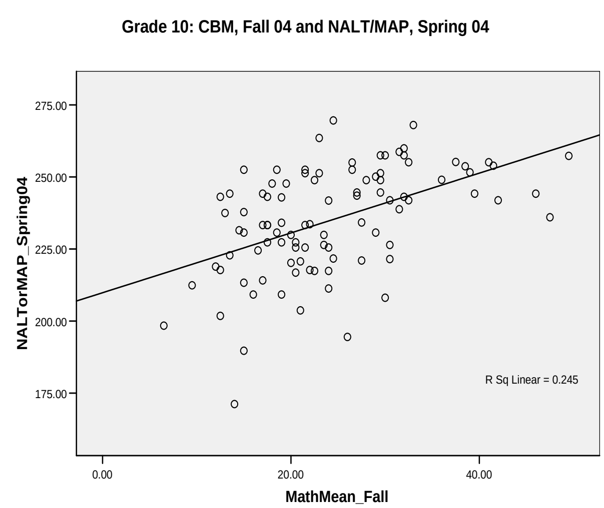
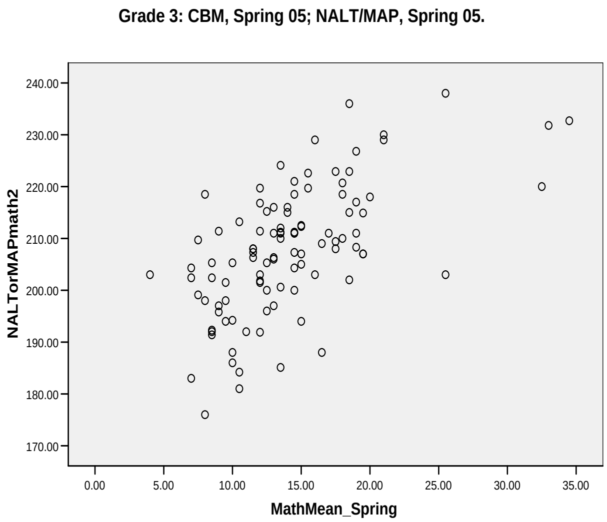


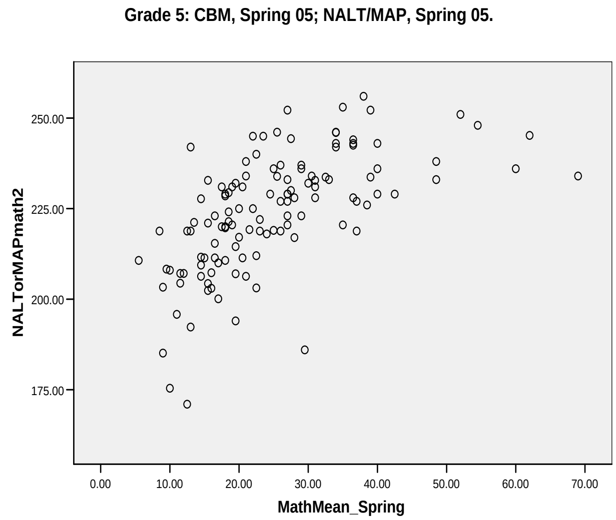
Figure 7

Correlations Between CBM (Spring, 05) and the NALT/MAP (Spring, 05)

Grade 3: CBM, Spring 05 and NALT/MAP, Spring 05



Grade 5: CBM, Spring 05 and NALT/MAP, Spring 05



Grade 8: CBM, Spring 05 and MAP, Spring 05

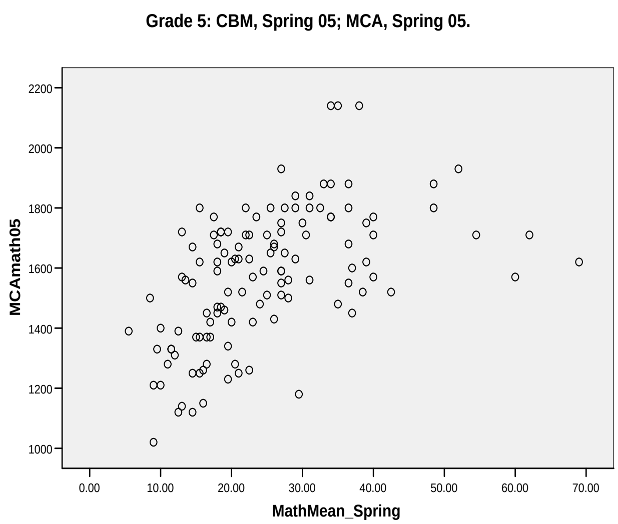
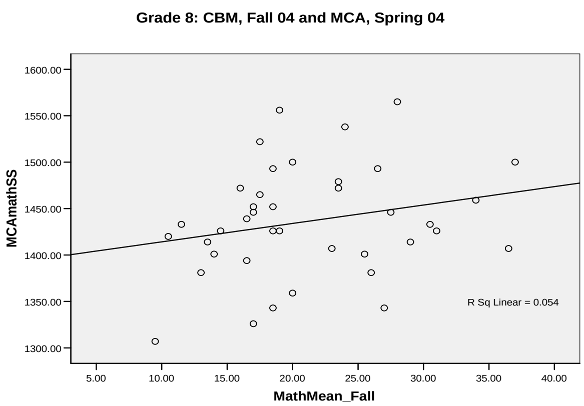


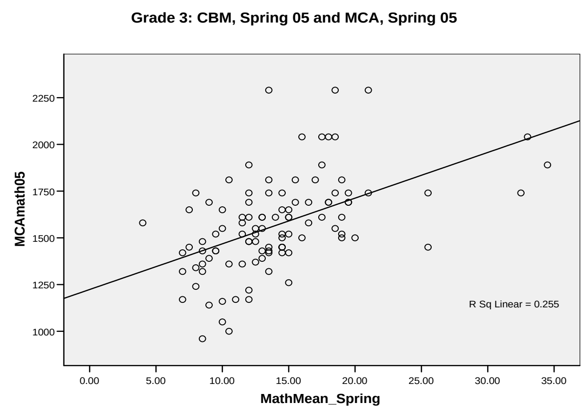
Figure 8

Correlations Between CBM scores and MCA and MBST scores

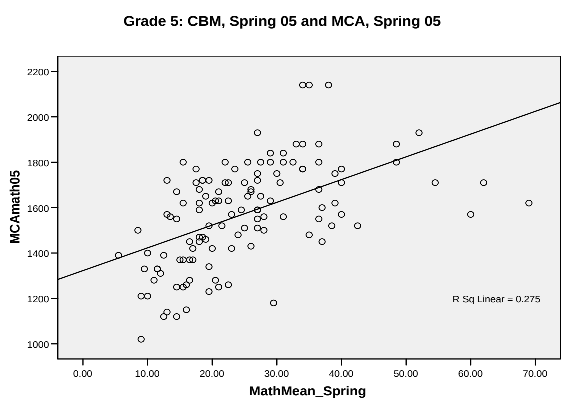
Grade 8: CBM, Fall 04 and MCA, 2004
(District 2 only)



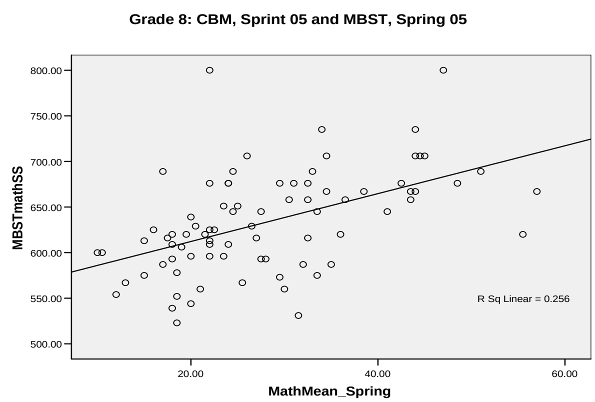
Grade 3: CBM, Spring 05 and MCA, Spring 05



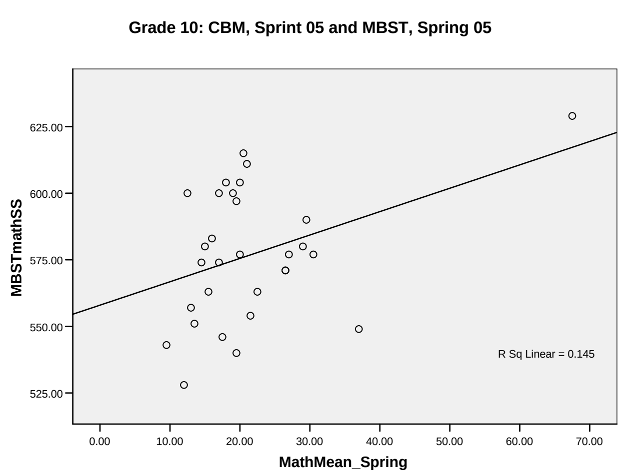
Grade 5: CBM, Spring 05 and MCA, Spring 05



Grade 8: CBM, Spring 05 and MBST, Spring 05
(Districts combined)



Grade 10: CBM, Spring 05 and MBST, Spring 05
(District 2 only)



34 students took MBST;
92 students took CBM.

Figure 8 displays correlations between (a) CBM and MCA, and (b) CBM and MBST. The scatterplot of the correlations between CBM and MCA in 2004 is obtained from the scores of Grade 8 in District 2 (*n* = 39). There was little linearity in the graph. Quite a few students scored high on the CBM but low on the MCA. As shown in the graphs of correlations between CBM and MCA in 2005 for Grades 3 and 5, there was linearity in both graphs. In both Grades 3 and 5, there were some outliers that scored either high on the CBM but low on the MCA, or vice versa. As shown in the graphs of correlations between CBM and MBST in 2005 for Grades 8 and 10, there was more linearity in the graph for Grade 8 (*n* = 86) than in the graph for Grade 10. The graph for Grade 10 is based on the scores of 10th-grade students in District 2, where 34 students took the MBST and 92 students took the CBM.

Table 11
Predictive Validity Evidence CBM Math and Criterion Measures

	CBM Math—Fall 2004			
NALT/MAP	Grade 3	Grade 5	Grade 8	Grade 10
Spring 05	.48**	.61**	.59** (District 1 only.)	
MCA				
Spring 05	.50**	.55**		
MBST				
2005			.53**	.44** (District 2 only.)
	CBM Math—Winter 2005			
NALT/MAP	Grade 3	Grade 5	Grade 8	Grade 10
Spring 05	.45**	.61**	.50**	
MCA				
Spring 05	.44**	.54**		
MBST				
2005			.49**	.46** (District 2 only.)

Note. ***p* < .001

Predictive validity. Predictive validity of the CBM math probes in Fall 2004 and

Winter 2005 was examined using the criterion measures of NALT/MAP (2005), MCA (2005), and MBST (2005). Data are displayed in Table 11. Using the CBM math scores from Fall 2004 to predict performance of NALT/MAP, MCA, and MBST in 2005, the range of correlation coefficients were between r = .44 and r = .61.The correlations for Grade 5 (r = .55 - .61) and Grade 8 (r = .53 - .59) seemed a little bit stronger than those for Grade 3 (r = .48 - .50) and Grade 10 (r = .44). Using the CBM math scores from Winter 2005 to predict performance of NALT/MAP, MCA, and MBST in 2005, the range of correlation coefficients were between r = .44 and r = .61. Again, the correlations for Grade 5 (r = .54 - .61) and Grade 8 (r = .49 - .50) seemed a little bit stronger than those for Grade 3 (r = .44 - .45) and Grade 10 (r = .46). Evidence of predictive validity is graphed in Figure 5, 6, and 7 on pages 23, 24, and 25.

Figure 9 displays graphs of predictive validity between the CBM math in Winter 2005 and Spring 2005 with the NALT/MAP in Spring 2005. The CBM math scores from Fall 2004 showed higher correlations for Grades 5 and 8 than for Grade 3. There were quite a few outliers in Grade 3. The CBM math scores in spring 2005 showed higher correlations for Grade 5 than for Grades 3 and 8. Again, there were quite a few outliers in Grade 3. The scores from Grade 8 were only based on District 2.

Figure 10 displays graphs of predictive validity between the CBM math in Winter 2005 and Spring 2005 with the MCA in Spring 2005. Overall, there was more linearity in Grade 5 than in Grades 3, 8, and 10. However, Grade 10 and Grade 3 showed more linearity than Grade 8.

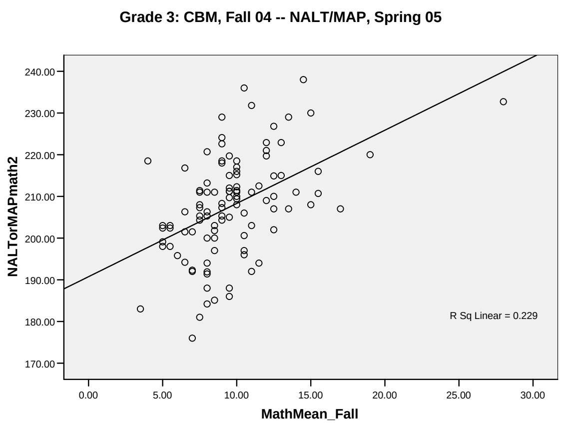
Figure 11 displays graphs of predictive validity between the CBM math in Winter 2005 and Spring 2005 with the MBST in Spring 2005. The CBM scores of Fall 2004 and

Spring 2005 showed linearity in Grade 8. Scores of Grade 10 are from District 2.

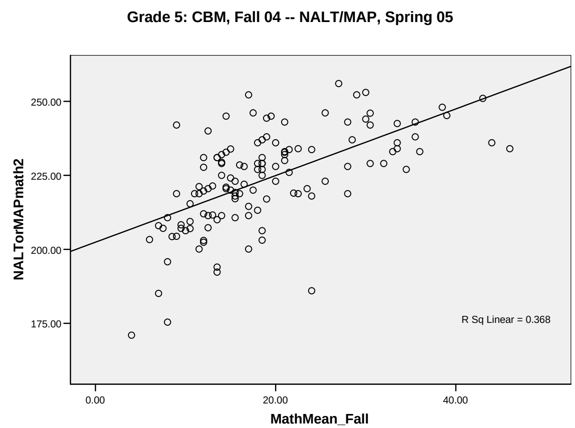
Figure 9

Evidence of Predictive Validity Between CBM Math and NALT/MAP

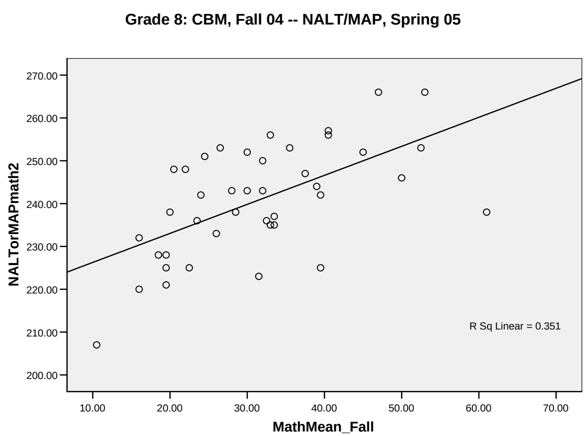
Grade 3: CBM, Fall 04 – NALT/MAP, Spring 05



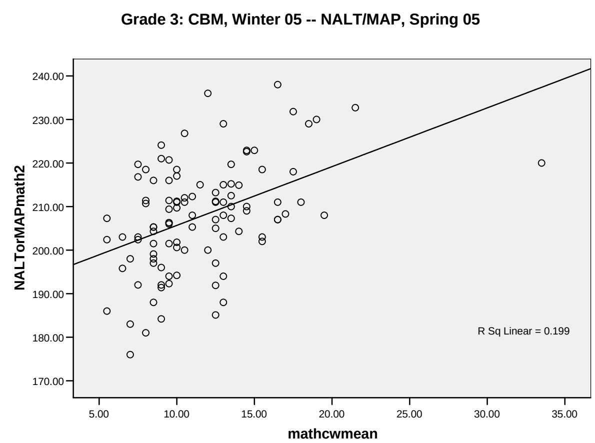
Grade 5: CBM, Fall 04 – NALT/MAP, Spring 05



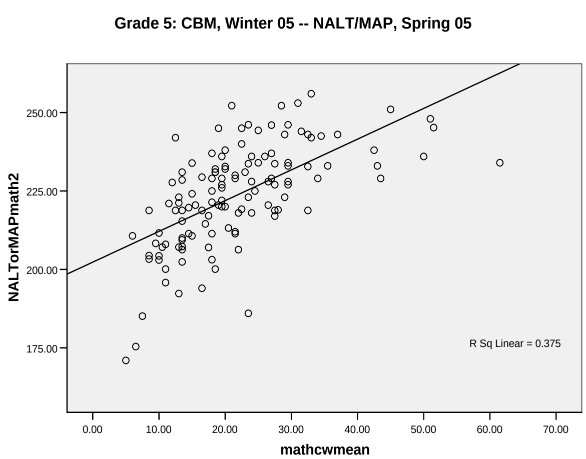
Grade 8: CBM, Fall 04 – NALT/MAP, Spring 05
(District 1 only)



Grade 3: CBM, Winter 05 – NALT/MAP, Spring 05



Grade 5: CBM, Winter 05 – NALT/MAP, Spring 05



Grade 8: CBM, Winter 05 – NALT/MAP, Spring 05

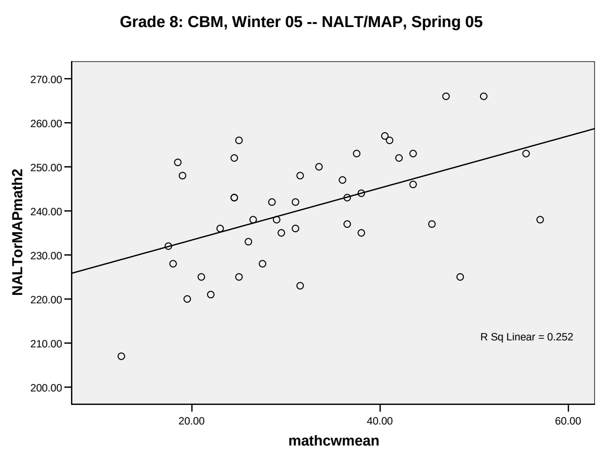
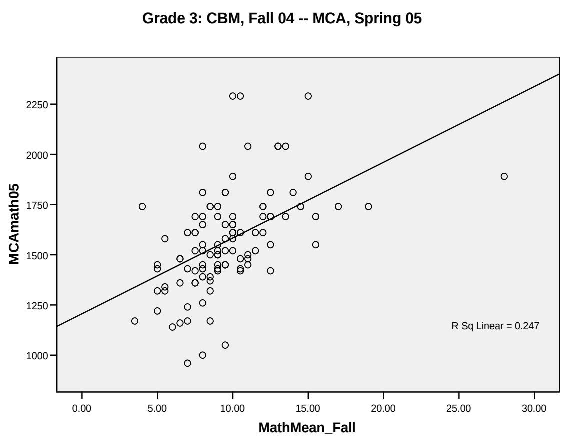


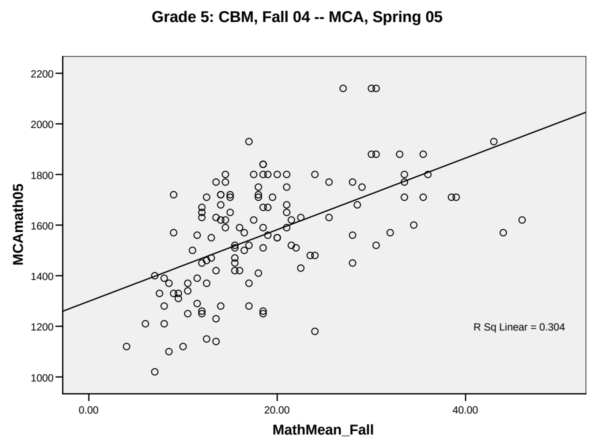
Figure 10

Evidence of Predictive Validity Between CBM Math and MCA

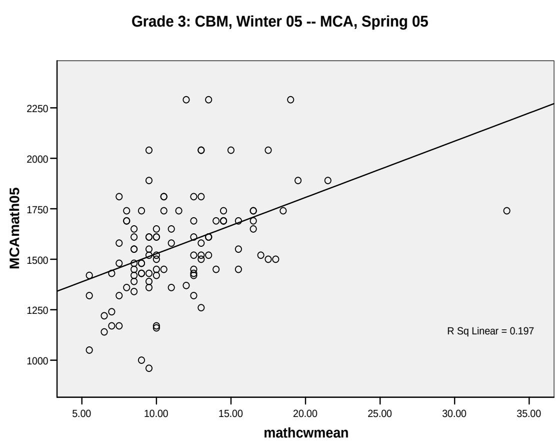
Grade 3: CBM, Fall 04—MCA, Spring 05



Grade 5: CBM, Fall 04—MCA, Spring 05



Grade 3: CBM, Winter 05—MCA, Spring 05



Grade 5: CBM, Winter 05—MCA, Spring 05

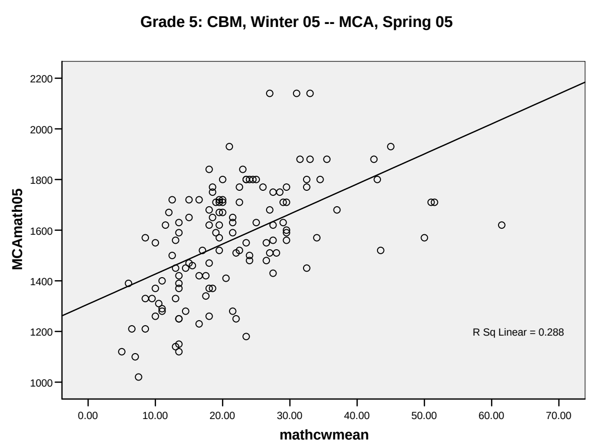
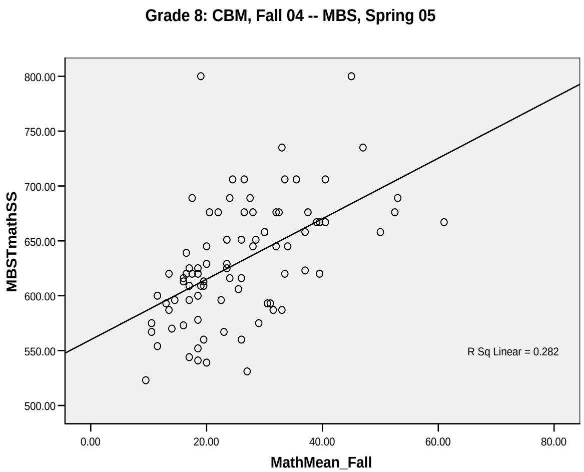
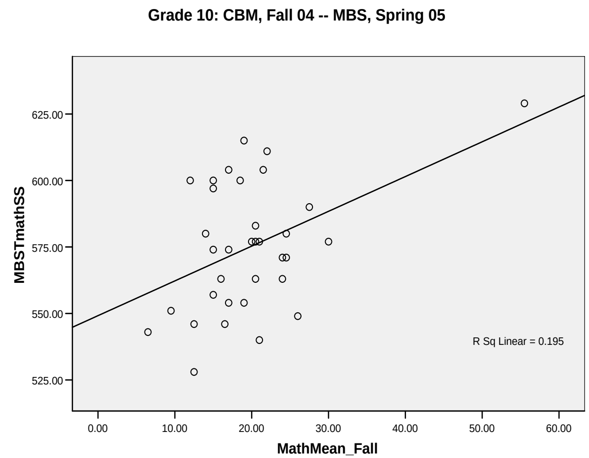


Figure 11
Evidence of Predictive Validity Between CBM Math and MBST

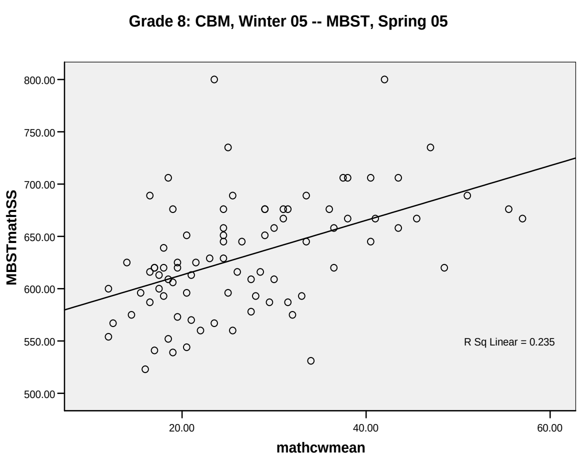
Grade 8: CBM, Fall 04—MBST, Spring 05



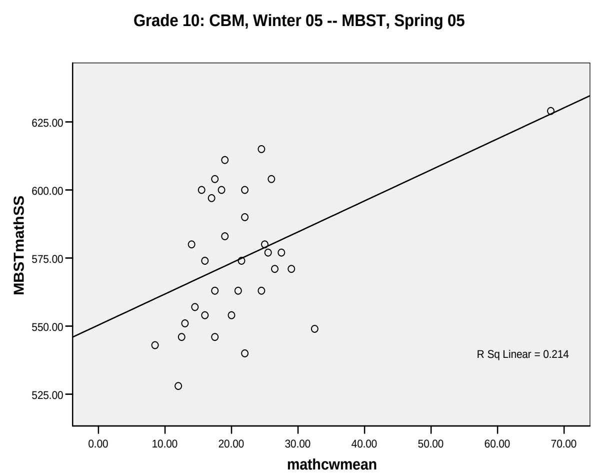
Grade 10: CBM, Fall 04— MBST, Spring 05
(District 2 only)



Grade 8: CBM, Winter 05— MBST, Spring 05



Grade 10: CBM, Winter 05— MBST, Spring 05
(District 2 only)



Discussion

The purpose of this study was to investigate the validity and reliability of CBM math fact probes for students across grade levels. We addressed two research questions in the study:

1. What are the validity and reliability of a 1-minute math fact probe?
    a. Do reliability and validity differ by grade level?
    b. Do validity and reliability differ by skill level within grade?
2. What are the relative contributions of math probes for predicting performance on state standards tests and standardized achievement tests?

To answer the first question regarding reliability, we conducted inter-item correlation analysis (in Table 8) and alternate-form reliability analysis (in Table 9). Data on inter-item correlation show that the two CBM math probes have moderately strong to strong correlations. These results indicate that the two math probes are based on the same content and have the same difficulty level. In other words, these two probes can reliably assess students' basic math skills.

The descriptive data in Table 5 show that mean scores of the two probes of each grade increase across the four grades from Grade 3 to grade 10. Furthermore, mean scores of the two probes of each grade increase across the three seasons from fall to spring. Therefore, either probe or both probes can be used for single administration on math performance.

However, descriptive data also show that the difference in the performance level of two adjacent grades decreases as the grades increase across seasons. The difference in performance level from Grade 8 to Grade 10 is not as big as the growth from Grade 3 to

Grade 5 and Grade 5 to Grade 8, implying that the CBM math probes might be more appropriate for students in elementary and middle school, but not for students in high school. It could also be that students at lower grades have more practice in basic math facts as they have just learned this skill. Students at higher grades may vary in their performance because of different math levels. Another possibility is that students in lower grades are more interested in completing the basic-skill oriented math probes as basic skills are directly related to their school curriculum. For students in higher grades, basic math facts tests might be too easy causing some students to lose interest in the task. This phenomenon was noticed during data collection at Grades 8 and 10, where some students' disruptive behaviors and low motivation affected the administration process and may have affected students' scores.

Regarding concurrent validity, students' performance on the NALT/MAP and MCA (in Table 10) provides evidence of the validity of the CBM math probes in assessing students' basic skills at lower grades. For students at higher grades, the basic facts tests are not able to comprehensively assess their math skills as they are moving to advanced topics. The CBM math probes only provide basic facts problems in addition, subtraction, multiplication, and division; standardized tests assesses students' basic math levels of knowledge in more complex aspects of mathematics such as fractions, decimals, and the application of geometric knowledge.

As only students in Grade 8 and 10 took the MBST, it was difficult to differentiate students' performance by grade level, especially between lower grades and higher grades. However, the fact that some students scored low on the CBM but high on the MBST indicates that the basic fact probes might not accurately reflect their mathematics proficiency.

Data on predictive validity indicate that CBM math probe could predict more of 5^{th}-grade students' performance on the NALT/MAP and MCA than that of students in Grades 3, 8, and 10. Students in Grades 8 (districts combined) and 10 (District 2 only) took the MBST in Spring 2005. Predictive performance of Grade 8 on the MBST was quite impressive.

Sample size of Grades 8 and 10 could affect the study results. All the participants in Grades 3, 5, 8, and 10 across the two districts completed the CBM math fact probes across the three seasons. Participants who took the NALT/MAP, MCA, and MBST differed by grade level and by district (see Table 3). For example, in Fall 2004, 178 students in Grade 10 from the two districts completed the CBM math probes. However, in Spring 2004, only 96 10-grade students from District 2 took the NALT, producing a correlation between the mean score of CBM math fact probes and the mean score of the NALT of $r = .50$. This fact reduced the sample size of a particular grade on a particular standardized test. It is not known whether these participants could represent the whole population. A similar phenomenon existed when looking at the MCA and MBST data.

The above findings help to answer the second research question regarding the relative contributions of reading and math probes are for predicting performance on state standards tests and standardized achievement tests. It can be concluded that the CBM math probes, which are based on single digits facts, are appropriate to measure what is measured by the state standardized test at lower grades.

In summary, this study explores the validity and reliability of two forms of a CBM math fact probe for students across grade levels. According to the results, the CBM math probes were reliable and valid indicators of math performance, especially for Grades 3 and 5, suggesting that the CBM math probes appear to be more appropriate for students in lower grades than for students in higher grades.

To implement the use of the CBM math probes at lower costs, either probe or both math probes can be used for single administration on lower-grade students because both probes are found to at the same difficulty level (see Table 9). For students in higher grades, future studies should examine 3 factors. The first factor is the length of time. A one minute administration might be too short to measure the real performance of students at higher grades because of their complicated math skills. It is expected that by having students complete a 2-min or a 3-min math probe instead of a 1-min probe, more variance will emerge in students at higher grades.

The second factor is the sample size. Although sample size with random sampling may not affect the research results, a larger sample size in a quasi-experimental design will more accurately represent the whole population (Hintze et al., 2002). Ideally, future studies should obtain an adequate number of participants from different schools across grades.

The third factor is the validity evidence appropriate for the research. To check concurrent validity or predictive validity, the standardized test used as a criterion should be measured on the same construct as the test used in the research. It is important that a standardized test used for validity evidence be appropriate for the research in terms of contents. When two tests are measuring the same traits, it is possible to obtain validity evidence.

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Appendix A

Math Probes—Form A

1 × 7	5 - 0	5 + 2	14 - 8	4 + 7	1 × 3	4 - 2	$3\overline{)3}$	4 + 1	$7\overline{)14}$

0 + 2	$5\overline{)35}$	13 - 9	3 × 3	16 - 9	$4\overline{)20}$	9 × 6	5 + 5	$5\overline{)25}$	$9\overline{)72}$

7 × 5	7 × 4	15 - 7	7 + 1	7 × 3	$6\overline{)12}$	2 + 7	$6\overline{)54}$	6 - 1	8 × 6

5 + 9	11 - 9	0 × 2	$1\overline{)5}$	14 - 5	$4\overline{)32}$	6 × 4	8 - 5	6 + 6	1 + 9

6 × 9	8 - 4	2 × 8	$5\overline{)30}$	2 + 4	14 - 9	$5\overline{)20}$	1 + 5	$4\overline{)16}$	$3\overline{)6}$

1 + 0	9 - 3	10 - 5	9 + 8	7 × 6	6 × 2	0 + 7	$1\overline{)6}$	$4\overline{)8}$	2 × 7

12 - 4	11 - 8	$8\overline{)72}$	3 + 6	$7\overline{)56}$	6 × 7	$9\overline{)45}$	10 - 4	5 + 0	0 + 6

6 - 2	6 - 0	6 × 0	0 × 3	10 - 3	0 × 7	$8\overline{)32}$	6 + 3	3 + 8	7 × 4

Math Probes—Form B

8 - 7	6 + 8	8 - 1	5 + 3	$7\overline{)56}$	9 - 0	0 + 9	$4\overline{)8}$	3 + 7	6 × 3

2 × 4	8 × 7	$1\overline{)5}$	5 + 8	13 - 5	2 × 3	8 - 0	3 × 0	$2\overline{)6}$	$4\overline{)28}$

$6\overline{)24}$	8 - 5	5 + 7	$3\overline{)12}$	$1\overline{)4}$	4 - 2	0 + 5	3 + 1	0 × 9	$3\overline{)3}$

$6\overline{)6}$	9 × 5	$6\overline{)24}$	6 + 2	9 + 5	0 × 7	$4\overline{)36}$	8 × 2	1 + 2	1 + 7

$6\overline{)0}$	$8\overline{)72}$	6 - 0	7 + 4	6 + 4	7 - 6	$7\overline{)49}$	2 × 8	9 - 2	11 - 2

9 × 8	$8\overline{)16}$	4 + 9	$2\overline{)6}$	0 × 8	7 + 7	3 - 2	8 - 8	5 + 6	$5\overline{)45}$

9 × 7	0 + 3	$4\overline{)32}$	14 - 9	17 - 8	3 × 1	11 - 6	2 × 1	7 + 3	11 - 5

$4\overline{)0}$	18 - 9	7 × 8	4 × 4	8 × 8	1 + 0	9 × 9	5 - 4	15 - 9	9 × 4

Appendix B: Tables and Figures of District 1

Appendix B-1:
Descriptive Data of CBM Math Probes for District 1

Season	Grade	*M*	*SD*	*n*
Fall 04	3	10.15	3.09	52
	5	22.09	9.08	64
	8	31.46	11.61	42
	10	32.01	10.28	72
Winter 05	3	12.47	4.53	50
	5	25.33	9.97	63
	8	32.33	11.69	45
	10	35.63	12.31	71
Spring 05	3	14.86	4.80	50
	5	28.86	11.16	63
	8	33.94	11.59	44
	10	37.64	13.40	70

Appendix B-2
Descriptive Data of Criterion Measures of District 1

		Grade	*M*	*SD*	*n*
MAP	Spring 04	3	193.88	10.25	48
		5	218.71	12.06	56
		8	235.53	10.97	40
	Spring 05	3	207.51	12.15	45
		5	230.57	12.68	53
		8	242.08	11.67	37
MCA	Spring 05	3	1619.15	257.48	47
		5	1656.72	196.30	61
MBST	2005	8	653.11	48.71	44

Appendix B-3

Correlation Coefficients of Alternate Forms

Grade	Fall 04	Winter 05	Spring 05
3	.55**	.85**	.78**
5	.88**	.92**	.88**
8	.84**	.85**	.82**
10	.80**	.87**	.88**

Note. **p < .01

Appendix B-4

Concurrent Validity Evidence Between CBM Math and Criterion Measures

	CBM Math		
NALT/MAP	Grade 3	Grade 5	Grade 8
2004	.46**	.48**	.63**
Spring 05	.56**	.45**	.50**
MCA			
2005	.39**	.34**	
MBST			
2005			.52**

Note. **p < .01

Appendix B-5

Predictive Validity Evidence Between CBM Math and Criterion Measures

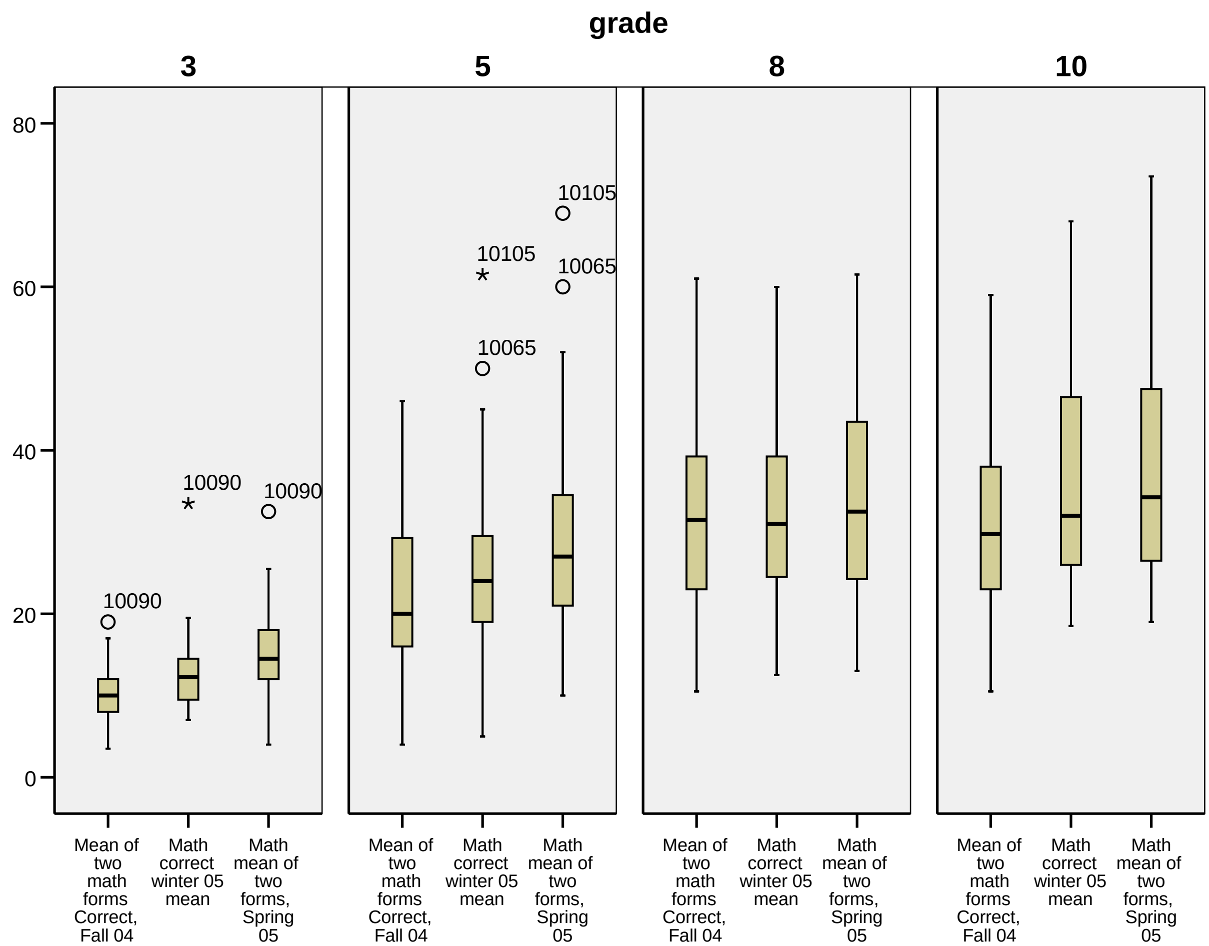
	CBM Math—Fall 2004			
NALT/MAP	Grade 3	Grade 5	Grade 8	Grade 10
Spring 05	.48**	.51**	.59**	
MCA				
Spring 05	.51**	.43**		
MBST				
2005			.55**	.44**

	CBM Math—Winter 2005			
NALT/MAP	Grade 3	Grade 5	Grade 8	Grade 10
Spring 05	.46**	.47**	.50**	
MCA				
Spring 05	.40*	.36**		
MBST				
2005			.48**	.46**

Note. * p < .05**p < .01

Appendix B-6

Distributions of CBM Math Facts Scores



Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Mean of two math forms Correct, Fall 04	226	96.2%	9	3.8%	235	100.0%
Math correct winter 05 mean	226	96.2%	9	3.8%	235	100.0%
Math mean of two forms, Spring 05	226	96.2%	9	3.8%	235	100.0%

Appendix C: Tables and Figures of **District 2**

Appendix C-1
Descriptive Data of CBM Math

Fall 04	Grade	*M*	*SD*	*n*
	3	8.95	3.38	56
	5	15.83	7.10	62
	8	20.54	6.71	38
	10	25.19	9.51	92
Winter 05	3	10.70	3.28	56
	5	18.42	9.07	62
	8	22.36	6.95	38
	10	27.69	11.05	92
Spring 05	3	13.42	5.48	56
	5	21.06	10.60	62
	8	22.29	6.89	38
	10	28.10	11.34	92

Appendix C-2
Descriptive Data of Criterion Measures of District 2

NALT	Spring 04	Grade	*M*	*SD*	*n*
		3	193.97	11.94	56
		5	211.99	16.62	64
		8	232.62	14.79	40
		10	234.98	18.44	96
	Spring 05	3	208.83	11.93	55
		5	219.1	16.32	65
MCA	2004	8	1436.33	59.74	39
	2005	3	1530.35	245.7	57
		5	1481.67	217.18	66
MBST	2005	8	609.19	53.4	42
		10	574.94	24.17	34

Appendix C-3

Correlation Coefficients of Alternate Forms

Grade	Fall 04	Winter 05	Spring 05
3	.71**	.60**	.84**
5	.84**	.90**	.89**
8	.76**	.81**	.79**
10	.86**	.87**	.82**

Note. ***p* < .001

Appendix C-4

Concurrent Validity Evidence Between CBM Math and Criterion Measures

	CBM Math			
NALT/MAP	Grade 3	Grade 5	Grade 8	Grade 10
2004	.56**	.62**	.20	.450**
Spring 05	.68**	.68**	.50**	
MCA				
2004			.23	
2005	.57**	.57**		
MBST				
2005			0.21	.38*

Note. ***p* < .001

Appendix C-5

Predictive Validity Evidence Between CBM Math and Criterion Measures

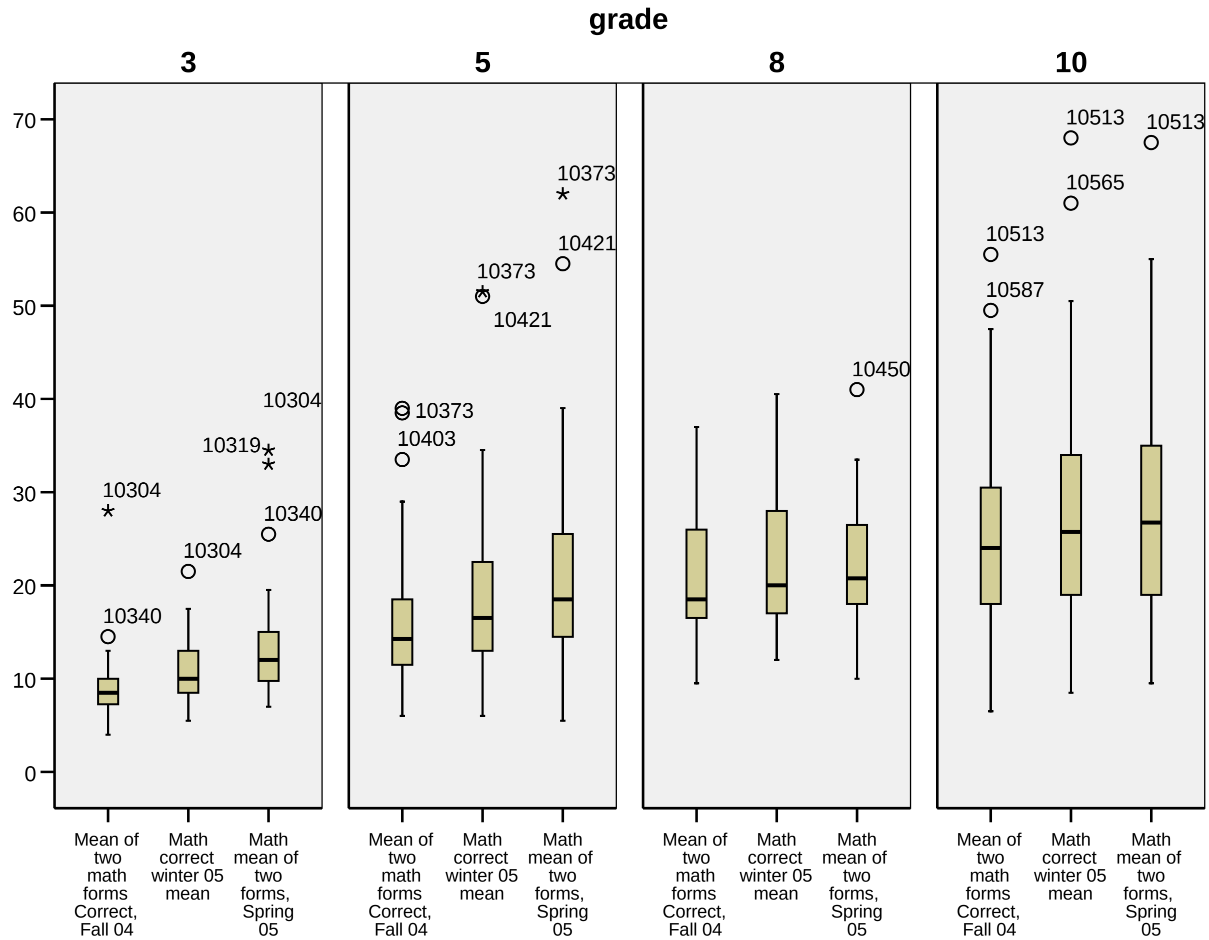
	CBM Math—Fall 2004			
NALT/MAP	Grade 3	Grade 5	Grade 8	Grade 10
Spring 05	.35**	.41**		
MCA				
2004			.19	
Spring 05	.51**	.56**		
MBST				
2005			.27	.44**

	CBM Math—Winter 2005			
NALT/MAP	Grade 3	Grade 5	Grade 8	Grade 10
Spring 05	.53**	.67**		
MCA				
Spring 05	.44**	.54**		
MBST				
2005			0.24	.46**

Note. ***p* < .001

Appendix C-6

Distributions of CBM Math Facts Scores



Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Mean of two math forms Correct, Fall 04	246	89.8%	28	10.2%	274	100.0%
Math correct winter 05 mean	246	89.8%	28	10.2%	274	100.0%
Math mean of two forms, Spring 05	246	89.8%	28	10.2%	274	100.0%