Assessing Calculators as Assessment Accommodations for Students with Disabilities

Emily C. Bouck
Aman Yadav
Purdue University

Abstract: This study explored the performance of 75 seventh-grade students with and without disabilities, educated in inclusive mathematics classes, on open-ended, problem-solving mathematics assessments. In the study, approximately half of the students used a graphing calculator on the first assessment and not on the second assessment (*n* = 35; 46.7%), whereas the other half used it on the second assessment and not on the first (*n* = 40; 53.3%). The results indicate that all students did better when using a graphing calculator, regardless of the order of calculator use (i.e., Assessment 1 or 2). The results also suggest that calculators may not be a valid accommodation for some students with disabilities on assessments. This study has implications for providing calculators as accommodations on mathematics assessments.

Keywords: Mathematics, Calculators, High incidence disabilities

Accountability is at the forefront of education and so is its 'sidekick'- assessment. Federal policy requires that all students be tested yearly in literacy and mathematics in grades 3 through 8 and once again between grades 10 and 12 (No Child Left Behind Act of 2001 [NCLB]). Although all students are to be tested, students are not all the same. Students with disabilities, for example, often struggle with content areas, such as mathematics, and therefore perform worse on assessments (Fuchs, Fuchs, & Capizzi, 2005). One way to better measure the performance of students with disabilities on assessments is to provide an accommodation or set of accommodations.

Accommodations are a right of students with disabilities on assessments and in daily class activities (Individuals with Disabilities Education Improvement Act of 2004 [IDEIA]; Koening & Bachman, 2004). A valid accommodation does not alter the construct of an assessment, but rather alters the presentation, type of response, setting, timing, or the provision of technology or other supports, according to a student's individual needs (Fuchs et al., 2005; Ysseldyke, Thurlow, McGrew, & Shriner, 1994). Accommodations help 'level the playing field' for students with a disability (Fuchs & Fuchs, 1999). Examples of common accommodations for students with disabilities, particularly students with a high incidence disability, include: tests read aloud, allowing oral responses, calculators, individual administrations, and extended time (Thurlow, Elliott, & Ysseldyke, 2003).

While accommodations for students with disabilities are varied and can be expansive, not every accommodation is a valid accommodation for assessments. Elbaum (2007) defined a valid accommodation as one that results in the performance of students with disabilities increasing to a greater extent than the performance of students without disabilities when provided with the same accommodation on the same assessment. Given the proliferation of assessing students in the era of accountability, research exploring the validity of accommodations has increased. Yet, even with this increased attention, there

is still a dearth of research. Additional studies are needed to understand the validity of different accommodations, specifically on mathematics assessments, and calculators are a natural option given their frequent appearance as accommodations on individual education programs (IEPs; Maccini & Gagnon, 2000; Thurlow, Lazarus, Thompson, & Morse, 2005; Tindal & Ketterlin-Geller, 2004).

Accommodations for Mathematics Assessments

Researchers have studied the validity of particular accommodations relevant to mathematics assessments, such as extended time, oral presentation, and calculators. The research on extended time has shown to be mixed and dependent on the type of mathematics problems being assessed (Fuchs, Fuchs, Eaton, Hamlett, & Karns, 2000). Fuchs and colleagues found that extended time is not a valid accommodation on computation mathematics assessments or those involving application problems, as students with disabilities did not benefit on Curriculum-Based Measurement assessments more than students without disabilities when provided with this accommodation (i.e., did not improve scores more). However, the researchers did find statistically significant benefits for extended time when students with and without disabilities took a problem-solving assessment, favoring students with disabilities. (Note: This suggests that extended time is a valid accommodation for problem-solving assessments.)

Researchers also have found mixed results for the oral presentation of mathematics assessments as an accommodation for students with disabilities. Similar to the extended time accommodation, Fuchs et al. (2000) found no benefit in the area of mathematics for students with disabilities on application assessments, but did find statistically significant benefits for this accommodation on the problem-solving assessments. Tindal, Heath, Hollenbeck, Almond, and Harniss (1998) found that students with disabilities benefited when a mathematics assessment was read aloud by a teacher as opposed to students with disabilities themselves reading the test but this was not the case for students without disabilities, making oral presentation an appropriate accommodation.

Finally, and similar to the other accommodations examined with respect to mathematics assessments, inconsistent results have been found for calculators as an accommodation. Fuchs et al. (2000) examined the use of a calculator as an accommodation for fourth- and fifth-grade students with learning disabilities on curriculum-based measurements (CBMs). Their research involved 181 students without disabilities and 192 students with learning disabilities. Students were given computation, concepts and applications, and problem-solving CBMs. The researchers found that students with learning disabilities benefited more than their peers without disabilities when using a calculator on problem-solving CBMs. However, the students with disabilities did not benefit more than students without disabilities on the concepts and application CBMs. (Note: Fuchs et al. study examined several different types of accommodations and the overarching study was to compare teacher-alone vs. data-support accommodation decisions.)

Shaftel, Belton-Kocher, Glasnapp, and Poggio (2003) also studied the impact of calculators as an accommodation for students with and without disabilities. Specifically, they studied 570 fourth graders with disabilities and 244 sixth graders without disabilities. Shaftel and colleagues found the use of a calculator benefited students with disabilities but not students without disabilities and concluded that calculators were an appropriate

accommodation for students with disabilities. However, the results were not conclusive as the assessments used for students with disabilities in the study were presented in simpler English in addition to students being provided a calculator. Furthermore, students with and without disabilities were not tested at the same grade levels.

Recent research has explored calculators–both four-function and graphing calculators–as an accommodation on open-ended problem-solving assessments. Bouck and Bouck (2008) studied four-function calculators as a mathematics assessment accommodation. The research involved 89 sixth graders with and without disabilities on open-ended, problem-solving, number and operation, time-limited assessments. They found that the use of a standard four-function calculator resulted in both students with and without disabilities answering more questions correctly when they had access to the calculator on the assessment than when not. However, students with disabilities did not benefit more than students without disabilities when provided with this accommodation.

Similar results were found by Bouck (in press) in examining graphing calculators as an assessment accommodation by students with and without disabilities. This study analyzed the performance of 47 seventh-grade students with and without disabilities, in inclusive mathematics classes, on an open-ended, problem-solving, number and operation, time-limited mathematics assessment. While the data showed that on the problem-solving assessments, students with disabilities answered more problems correctly when given access to a graphing calculator, these gains were not statistically significant when compared to students without disabilities.

This specific research project sought to continue and extend the research on calculators as an accommodation on assessments. It focused on graphing calculators and the order in which students were allowed access to a calculator (first assessment or second assessment). In particular, it sought to answer the following question: Does the use of a graphing calculator result in performance differences on standards-based, open-ended, problem-solving assessments for students with and without disabilities?

Method

Participants

Seventy-five seventh-grade students participated in this study. All participants came from two schools in one large rural district in a midwestern state. The district was selected because it had been using a problem-centered mathematics curriculum which encouraged calculator use for over a decade. It also educated the majority of its students with a disability in inclusive mathematics classes. The two schools had a combined student population of 2,577 students, an average rate of 93.1% Caucasian students, an average rate of 78% passing the state mathematics assessment, and an average rate of 88.3% passing the state reading assessment (School Matters, 2006). The district as a whole had a 28% economically disadvantaged rate and 13.8% of its students identified with disabilities (School Matters).

Four inclusive classes and two teachers (both general education mathematics teachers) participated in this study. Fifty-three percent of the students had Teacher A (n = 40) and 47% Teacher B (n = 35). The students were relatively evenly dispersed across the four classes. Of the 75 students who completed both assessments, 74.7% (n = 56) were students without disabilities and 25.3% (n = 19) were students with high incidence disabilities. The majority of the students with disabilities were diagnosed with a learning

disability (n = 13; 68.4%) (NOTE: The schools did not indicate the type of learning disability students had, such as a learning disability related to reading, writing, mathematics, and other subject areas); however, others included students with Attention Deficit Hyperactivity Disorder (ADHD; n = 5; 26.3%) and students with behavior disorders/emotional impairments (n = 2; 10.5%). Slightly more than half of all the students were female (n = 40; 53.3%), yet only 31.6% (n = 6) of the students with disabilities were female.

Materials

All students in the study completed the same two assessments in the same order (instruments available upon request from the author) as well as used the same type of calculator (a TI-82 graphing calculator), which was the standard calculator for these students and all students were familiar with it and had used it previously. The two assessments were similar but not identical. Both assessments consisted of 28 open-response, problem-solving questions that focused on the number and operation strand from the National Council of Teachers of Mathematics (2000) *Principles and Standards for School Mathematics.* The number and operation strand was chosen for both assessments because the majority of the standards for sixth grade students in this midwestern state came from this strand. The state's sixth-grade standards were chosen as students were tested at the beginning of their seventh-grade year and testing students on the sixth grade standards would reflect what students were suppose to have learned following the completion of their previous year of schooling. The assessment questions represented adaptations of released items from the state's general large-scale assessment (Michigan Department of Education, 2006) and released items from the National Assessment of Educational Progress (n.d.).The assessments were reviewed by well-known mathematics education specialists in the state for clarity, appropriateness, and alignment to state standards.

Procedure

The study involved two assessments taken about four weeks apart. Both assessments were timed, in that students had one class period to complete the assessment (50 minutes across all classes). About half of the students (n = 35; 46.7%) were assigned to Condition 1, meaning that they had access to a graphing calculator on the first assessment (Assessment 1) but not the second. The other students (n = 40; 53.3%) were assigned to Condition 2, in which they had access to a graphing calculator on the second assessment (Assessment 2) and not on the first. The students were randomly assigned to a condition (i.e., order of calculator use) at the level of teacher, which means that students themselves were not randomly assigned to use a calculator or not, but a class was assigned to use a calculator or not on the assessment (see Figure 1 for graphical depiction of conditions).

Data Analysis

The mathematics assessment data were analyzed multiple ways. First, the data was analyzed using a 2 × 2 ANOVA (Ability status × Condition). The dependent variable was students' raw change score from Assessment 1 to Assessment 2 and was computed by subtracting the number of questions students answered correctly on the first assessment (out of 28) from the number students answered correctly on the second assessment (out of 28). The change score was selected as the dependent variable following Richards's (1975) argument that change scores representing the difference between pretest and posttest are appropriate, easier to compute, and have greater meaning to non-researchers. Ability status (students with

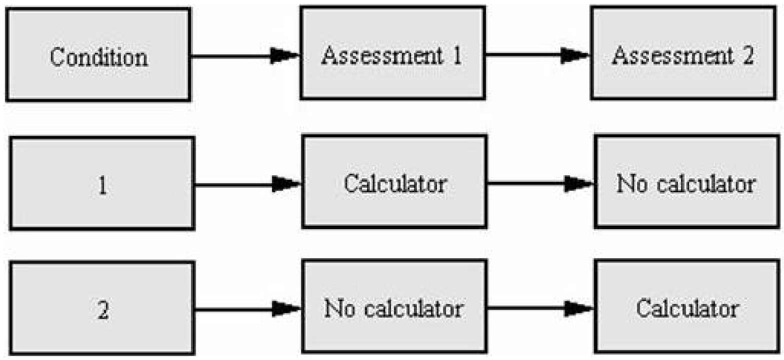

Figure 1: Graphical representation of study conditions.

disabilities and students without disabilities) and condition (calculator use on Assessment 1 or calculator use on Assessment 2) were the two factors in the ANOVA.

Independent t-tests were also completed for each condition with ability status as a factor. For Condition 1 (access to a calculator on Assessment 1), the dependent measure was students' scores on the first assessment when the graphing calculator was used. For Condition 2, the dependent measure was scores on the second assessment when students had access to a graphing calculator. The mathematics assessments data also were analyzed using frequency distributions.

Results

Analyzing students' change scores on the mathematics assessments from the first assessment to the second assessment revealed no statistically significant interaction for ability status and condition, $F_{(1,71)} = .573$, $p = .452$. However, a main effect for condition (graphing calculator use on Assessment 1 vs. graphing calculator use on Assessment 2) was found, $F_{(1,71)} = 26.118$, $p < .000$, $\eta_p^2 = .269$; $\beta = .999$. This suggests that students who had access to a graphing calculator on the second but not the first assessment showed greater gains (from Assessment 1 to Assessment 2) than students who had access to a graphing calculator on the first assessment but not the second. A main effect for students' gain scores was not found for ability status (students with disabilities vs. students without disabilities), $F_{(1,55)} = .904$, $p = .345$, suggesting that students with disabilities did not differ from students without disabilities on their change scores from the first assessment to the second assessment.

Figure 2 depicts the graphical representation of the data of change scores for students with and without disabilities by condition. The graph indicates illustrates the change in scores from Assessment 1 to Assessment 2 for the two groups of students (students with and without disabilities) via the two conditions (calculator and then no calculator and no calculator and then calculator). It indicates that students who had a calculator on Assessment 2 had positive change scores – they did better on Assessment 2 than Assessment 1, regardless of ability (although students with a disability were slightly higher), whereas students who had a calculator on Assessment 1 had a negative change score, meaning they did better on Assessment 1 than Assessment 2.

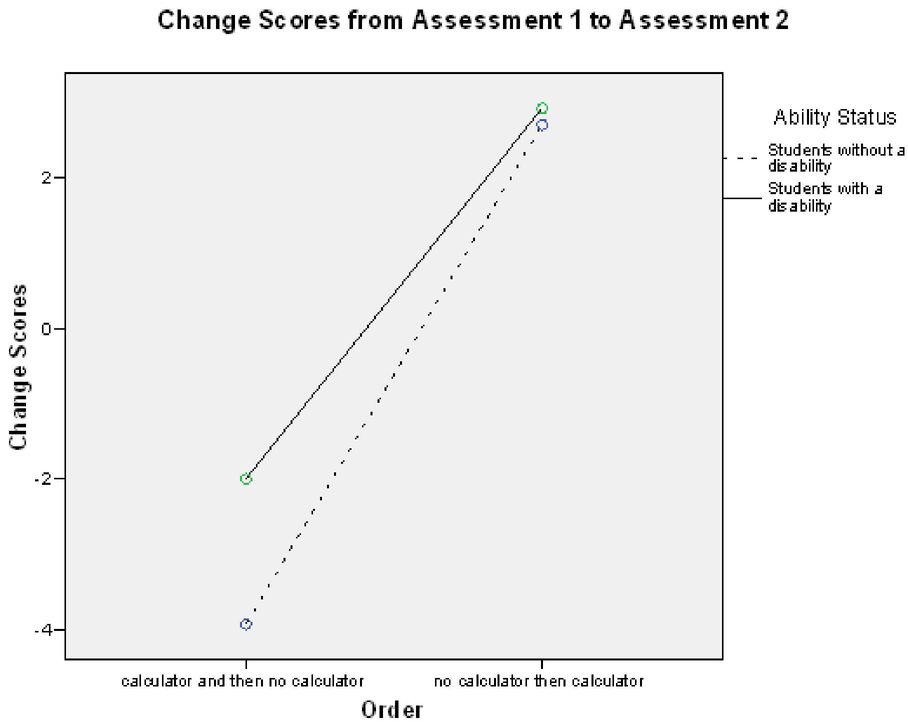

Figure 2: Change score from first assessment to second assessment across condition and ability.

All students, regardless of ability, answered more problems correctly on the mathematics assessment when they had access to a graphing calculator. For those who had access to a graphing calculator on Assessment 1, students with disabilities answered an average of 3.17 questions correctly and students without disabilities answered an average of 8 questions correctly (see 1 for means). This is in contrast to students who did not have access to a graphing calculator on the first assessment, in which students with disabilities averaged 2.31 correct responses and students without disabilities averaged 5.93 correct responses. Similarly on Assessment 2, students with disabilities who had access to a graphing calculator answered an average of 5.23 questions correctly and students without disabilities answered an average of 8.63 correctly, as opposed to students who did not have access to a graphing calculator (average of 1.17 correct for students with disabilities and 4.07 for students without disabilities). The change score in Condition 1 for students with a disability was a -2.0 and -3.93 for students without disabilities. However, in Condition 2 the change score for students with disabilities was +2.92 as compared to +2.7 for students without disabilities (refer to Table 1).

The *t*-tests for each condition with ability status (students with disabilities and students

Table 1
Means for Scores by Ability Status and Condition

	Condition 1		Condition 2	
	SWD (6)	SWOD (29)	SWD (13)	SWOD (27)
Assessment 1	3.17	8	2.31	5.93
Assessment 2	1.17	4.07	5.23	8.63
Change score	-2.0	-3.93	+2.92	+2.7

Note: SWD refers to students with disabilities; SWOD refers to students without disabilities

without disabilities) as a factor suggest that graphing calculators are not a valid accommodation. The independent *t*-test for Condition 1, with the dependent variable of scores on Assessment 1 and ability as a factor, was significant, $t_{(33)} = 2.453$, $p = .02$, favoring students without disabilities. The independent t-test for Condition 2, with the dependent variable of scores on Assessment 2 and ability as a factor, was significant, $t_{(38)} = 2.508$, $p = .017$, also favoring students without disabilities. The significant *t*-tests suggest that students with disabilities did not benefit more than students without disabilities when given access to a graphing calculator as an accommodation; in fact, students without disabilities benefited more.

Discussion

This study sought to answer the question: Does the use of a graphing calculator result in performance differences on standards-based, open-ended, problem-solving assessments for students with and without disabilities? The results indicate that both students with and without disabilities answered more open-ended, problem-solving questions correctly with access to a graphing calculator than without. However, the results further suggest that graphing calculators are not a valid assessment accommodation, given the definition of a valid accommodation, as one in which students with disabilities benefit to a greater extent than students without disabilities (Elbaum, 2007).

The findings of this study indicate that both students with and without disabilities performed better on standards-based, open-ended, problem-solving mathematics assessments when they had access to a graphing calculator. This is not necessarily surprising given that a calculator can reduce students' mental math mistakes. These findings both support and extend previous research regarding calculator use on mathematics assessments and students with disabilities (Bouck, in press; Bouck & Bouck, 2008; Fuchs et al., 2000; Shaftel et al., 2003). The results support previous research by replicating that access to a calculator can result in performance gains by students with and without disabilities; yet do not support calculators as a valid accommodation on mathematics assessments. The lack of students with disabilities benefiting more from a calculator might suggest that, while calculators help minimize the mental math mistakes of these students, they do not compensate for lower conceptual understanding. Lower conceptual understanding by some students with disabilities as compared to some students without disabilities might explain the statistically significant benefit to students without a disability when given a calculator. However, this interpretation from this limited research is not intended to be used as a rationale for denial of services to students with disabilities or a dismissal of calculator use by either population.

Outcomes and Benefits

Students with disabilities have historically performed worse in mathematics than students without disabilities. For example, students with disabilities often struggle with automaticity of basic facts, computation problems, and problem-solving (Cawley, Parmar, Fley, Salmon, & Roy, 2001; Jitendra, DiPipi, & Perron-Jones, 2002; Montague, 1992; Woodward & Montague, 2002). The data from this study suggest that calculators as an assistive technology tool cannot solve all the mathematical challenges faced by students with disabilities. A lack of conceptual understanding of a mathematical idea cannot be overcome through the use of a calculator. While calculators can reduce mental mistakes or students' struggle with basic facts, which is a positive result, they cannot generate an

understanding of a mathematical concept if a student does not possess it.

Hence, a need exists to increase the mathematical conceptual understanding of students with disabilities. Additional instruction focused on making sense and understanding mathematical ideas rather than efficiency with procedures is needed for students with disabilities. This is not to say that students with disabilities should not be given access to a calculator, as clearly these students benefited from having access (i.e., answered more correctly with a calculator than without). Allowing students with disabilities access to a calculator has the potential to give teachers greater insight into students' true mathematical knowledge bases when they are not hung-up by mental math or basic facts mistakes.

In conclusion, the data from this study on calculators as an assistive technology accommodation on mathematical assessments suggested all students, regardless of ability status, performed better on the open-ended, problem-solving assessments aligned to state standards when they had access to a graphing calculator. Yet, the data also suggested that graphing calculators are not a valid accommodation when using Elbaum's (2007) definition of a valid assessments accommodation, as students with disabilities did not benefit to a greater extent than students without disabilities from access to this tool. This is of particular importance given that 14 states within the United States of America allow calculators as accommodations on large-scale assessments, 14 allow them under certain circumstances, 1 allows them but with implications for scoring, 7 allow them under specific circumstances and with implications for scoring, and 5 consider them a non-standard accommodation but with no implications for scoring (Lazarus, Thurlow, Lail, Eisenbraun, & Kato, 2006). Educators and policymakers need to consider the research when deciding if and/or when calculators are a valid accommodation and should be allowed on assessments (Fuchs et al., 2005).

Limitations

This study has a few limitations in that only one school district was involved. It was conducted with a limited number of students in total and specifically students with disabilities. Another limitation involved missing data, which was a result of the length of the assessments. Twenty-eight open-response, problem-solving questions were too many for students with and without disabilities to complete in one class period. Students who did not finish either assessment employed different test-taking strategies, such as starting at the beginning and finishing as much as one could or skipping around and answering questions the student thought s/he knew. Finally, data was not analyzed at the level of type of disability, rather disability classifications were aggregated together. Data also was not aggregated for students with disabilities who were indicated to need a calculator as an accommodation versus those students whose IEP did not specify as such. While accommodations are meant to be determined on an individual student level given a student's strengths and challenges, this study sought to begin to examine calculators as assessment accommodations. Future research should address the limitations of this study.

Future Directions

Additional research is needed regarding mathematics assessment accommodations, particularly for standardized tests following mandates under NCLB. Specifically, additional research is needed to examine graphing calculators as valid accommodations–both in the classroom for daily use and on assessments. Future research

should replicate studies like this as well as extend the ages examined (i.e., elementary and high school). Finally, research should explore calculators as accommodations on a range of assessment types, such as computation problem, problem-solving questions, and in situations simulating standardized testing situations as well as other mathematics strands (i.e., geometry).

References

Bouck, E. C. (in press). Calculating the value of graphing calculators for seventh grade students with and without disabilities: A pilot study. *Remedial and Special Education.*

Bouck, E. C., & Bouck, M. K. (2008). Does it add up? Calculators as accommodations for sixth grade students with disabilities. *Journal of Special Education Technology, 23*(2), 17-32.

Cawley, J., Parmar, R., Fley, T. E., Salmon, S., & Roy, S. (2001). Arithmetic performance of students: Implications for standards and programming. *Exceptional Children, 67*, 311-328.

Elbaum, B. (2007). Effects of an oral testing accommodation on the mathematics performance of secondary students with and without learning disabilities. *Journal of Special Education, 40*, 218-229.

Fuchs, L. S., & Fuchs, D. (1999). Fair and unfair testing accommodations. *School Administrator, 10*(56), 24-29.

Fuchs, L. S., Fuchs, D., & Capizzi, A. (2005). Identifying appropriate test accommodations for students with learning disabilities. *Focus on Exceptional Children, 37*(6), 1-8.

Fuchs, L. S., Fuchs, D., Eaton, S. B., Hamlett, C. L., & Karns, K. M. (2000). Supplementing teacher judgments of mathematics test accommodations with objective data sources. *School Psychology Review, 29*, 3-24.

Individuals with Disabilities Education Improvement Act, 20 U.S.C. § 1400 *et seq.* (2004)

Jitendra, A., DiPipi, C. M., & Perron-Jones, N. (2002). An exploratory study of schema-based word – problem - solving instruction for middle school students with learning disabilities: An emphasis on conceptual and procedural understanding. *Journal of Special Education, 36*, 23-38.

Koenig, J. A., & Bachman, L. F. (Eds.). (2004). *Keeping score for all: The effects of inclusion and accommodation policies on large-scale educational assessments.* Washington, DC: National Academies Press.

Lazarus, S. S., Thurlow, M. L., Lail, K. E., Eisenbraun, K. D., & Kato, K. (2006). *2005 state policies on assessment participation and accommodations for students with disabilities* (Synthesis Report 64). Minneapolis, MN: University of Minnesota, National Center on Educational Outcomes. Retrieved March 5, 2006, from http://education.umn.edu/NCEO/OnlinePubs/Synthesis64.

Maccini, P., & Gagnon, J. C. (2000). Best practices for teaching mathematics to secondary students with special needs. *Focus on Exceptional Children, 32*(5), 1-22.

Michigan Department of Education. (2006). *Mathematics grade level content expectations* v.12.05. Lansing, MI: Author. Retrieved February 12, 2006, from http://www.michigan.gov/documents/MathGLCE_140486_7.pdf.

Montague, M. (1992). The effects of cognitive and metacognitive strategy instruction on the mathematical problem-solving of middle school students with learning disabilities. *Journal of Learning Disabilities, 25,* 230-248.

National Assessment of Educational Progress. (n.d.). NAEP questions. *IES National Center for Educational Statistics.* Retrieved February 8, 2008, from http://nces.ed.gov/nationalreportcard/ITMRLS/startseearch.asp

National Council of Teachers of Mathematics. (2000). *Principles and NCTM standards for school mathematics.* Reston, VA: Author.

No Child Left Behind Act, 20 U.S.C. 6301 *et seq*. (2001)

Richards, J. M. (1975). A simulation study of the use of change measures to compare educational programs. *American Educational Research Journal, 12*, 299-311.

School Matters. (n.d.). *Welcome to School Matters*. Retrieved February 11, 2008, from http://www.schoolmatters.com/

Shaftel, J., Belton-Kocher, E., Glasnapp, D. R., & Poggio, J. P. (2003). *The differential impact of accommodations in statewide assessment: Research summary*. Minneapolis, MN: University of Minnesota, National Center on Educational Outcomes. Retrieved March 5, 2006, from http://education.umn.edu/NCEO/TopicAreas/Accommodations/Kansas.htm.

Thurlow, M. L., Elliott, J. L., & Ysseldyke, J. E. (2003). *Testing students with disabilities: Practical strategies for complying with district and state requirements.* Thousand Oaks, CA: Corwin Press.

Thurlow, M. L., Lazarus, S. S., Thompson, S. J., & Morse, A. B. (2005). State policies on assessment participation and accommodations for students with disabilities. *Journal of Special Education, 38*, 232-240.

Tindal, G., Heath, B., Hollenbeck, K., Almond, P., & Harniss, M. (1998). Accommodating students with disabilities on large-scale tests: An experimental study. *Exceptional Children, 64*, 439-450.

Tindal, G., & Ketterlin-Geller, L. R. (2004, January). *Research on mathematics test accommodations relevant to NAEP testing.* Washington, DC: National Assessment Governing Board. Retrieved June 20, 2006, from http://www.nagb.org/pubs/conferences/tindal.pdf.

Woodward, J., & Montague, M. (2002). Meeting the challenge of mathematics reform for students with LD. *Journal of Special Education, 36*, 89-101.

Ysseldyke, J. M., Thurlow, M. L., McGrew. K. S., & Shriner, J. G. (1994). *Recommendations for making decisions about participation of students with disabilities in statewide assessment programs* (Synthesis Report 15). Minneapolis: University of Minnesota National Center on Educational Outcomes. Retrieved March 5, 2006, from http://cehd.umn.edu/nceo/OnlinePubs/SynthesisReport015.pdf