American Printing House for the Blind
Mathematics Research Analysis[1]

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The No Child Left Behind Act of 2001 (NCLB) focused the nation's attention on the need for educational research to confirm and corroborate the teaching methodologies used in schools. NCLB uses the term *scientifically-based research* 110 times in the statute (Slavin, 2002) and specifically defines the term at 20 U.S.C. 7801, Section 9101(37)):

> (37) . . . The term "scientifically based research"—
> (A) means research that involves the application of rigorous, systematic, and objective procedures to obtain reliable and valid knowledge relevant to education activities and programs; and
> (B) includes research that—
> (i) employs systematic, empirical methods that draw on observation or experiment; adequate to test the stated hypotheses and justify the general conclusions drawn;
> (ii) involves rigorous data analyses that are adequate to test the stated hypotheses and justify the general conclusions drawn;
> (iii) relies on measurements or observational methods that provide reliable and valid data across evaluators and observers, across multiple measurements and observations, and across studies by the same or different investigators;
> (iv) is evaluated using experimental or quasi-experimental designs in which individuals, entities, programs, or activities are assigned to different conditions and with appropriate controls to evaluate the effects of

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the condition of interest, with a preference for random-assignment experiments, or other designs to the extent that those designs contain within-condition or across-condition controls;

(v) ensures that experimental studies are presented in sufficient detail and clarity to allow for replication or, at a minimum, offer the opportunity to build systematically on their findings; and

(vi) has been accepted by a peer-reviewed journal or approved by a panel of independent experts through a comparably rigorous, objective, and scientific review.

In the education of students with visual impairment, it is not always possible to meet these strict criteria when conducting research. The low-prevalence of visual impairment within the school-age population often hampers efforts to recruit homogeneous subjects and consequently makes randomization both costly and difficult. When strong scientifically-based research does not exist, Valentine and Cooper (2004) suggest that researchers produce syntheses of research summarizing the evidence pertaining to the effectiveness of educational interventions and approaches. The What Works Clearinghouse was established in 2002 by the U.S. Department of Education to identify and disseminate the effectiveness of various educational interventions, primarily by conducting meta-analyses of the literature. The low prevalence of visual impairment makes it unlikely that the Clearinghouse will examine the body of literature in visual disabilities, and in fact, none of the topics currently under study involve students who are blind or visually impaired (see http://www.whatworks.ed.gov/topics/current_topics.html).

One method often used for synthesizing a body of literature is meta-analysis. Meta-analysis is a statistical procedure used to identify trends in the statistical results of a set of existing studies examining the same research problem (Gall, Borg, & Gall, 2003). Through such a procedure, effects, which are hard or impossible to discern in the original studies because the sample sizes are too small, can be made visible, as the meta-analysis is equivalent to a single study with the combined size of all original studies. Meta-analytic reviews go beyond narrative reviews in the sense that they are systematic, explicit, and utilize quantitative methods of analysis (Rosenthal, 1984). Because of these features, meta-analytic reviews are considered to provide more thorough, comprehensive, and precise summative evaluations that entail greater objectivity than narrative reviews. Moreover, meta-analysis is consistent with American Psychological Association publication guidelines (2001) that call for reporting effect sizes, which allows for an evaluation of the practical significance of differences.

The American Printing House for the Blind asked the National Center on Low-Incidence Disabilities to conduct a meta-analysis of the literature in mathematics instruction for students with visual impairment. Consequently, the purpose of this research was to conduct an exhaustive review of the literature and a meta-analysis of mathematics research in the field of blindness and low vision. This report presents the results of the analysis.

Method

A three-step literature search strategy identified pertinent studies published from 1955 to 2005. First, computer searches in ERIC and PsychINFO were conducted. The search terms used were *blind*, *deaf blind*, *deafblind*, *deaf-blind*, *eye disorders*, *optical aids*, *partially sighted*, *vision disorders*, *visual disabilities*, *blindness*, *visual impairment*, *large type*, *partial vision*, *low vision aids*, each paired with *math*, *mathematics*, *arithmetic*, *Nemeth*, *calculator*, and *abacus*.

Second, the reference list from every item identified in these searches was reviewed for any additional references that were not found in the computer search. Third, manual searches for articles related to mathematics and visual impairment were conducted of all issues of the *International Journal for the Education of the* Blind, *Journal of Visual Impairment & Blindness* (formerly the *New Outlook for the Blind*) and *RE:view* (formerly *Education of the Visually Handicapped*) from 1955 - 2005. *Dissertation Abstracts International* was also searched for relevant theses and dissertations. Reports submitted to the ERIC database were excluded from further analysis, but Appendix A provides a list of those citations.

Study Criteria

The resulting 125 articles, theses, and dissertations located by this search process were then reviewed to determine whether they met the criteria for inclusion in this analysis. Publications were classified by applying these seven criteria, in this order:

1. The study was published in a peer reviewed journal published in English between 1955 and 2005. Given the NCLB definition of scientifically-based research, we included only those studies that had been published and submitted for peer review, or which had been scrutinized through the thesis or dissertation process (n = 125).
2. Participants in the study were identified as students with a visual impairment of any degree (partial vision, low vision, partially sighted, blind) (n = 116; 9 studies investigated parents, families, or teachers).
3. Participants in the study were children and youth between 3 and 21 years of age (n = 110; 6 studies investigated individuals younger than 3 or older than 21 years of age).
4. The study reported some type of research (n = 42; 50 articles discussed a theory, belief, or practice, while 18 articles reported on a product review or evaluation).
5. The study described an educational intervention, defined as a systematic application of any program, product, practice, or policy with the intent of affecting an outcome (n = 16; 26 articles did not report on an intervention).
6. The study utilized a quantitative research design (n = 15; 1 study utilized a qualitative design).

7. The study included a control or comparison group of some type (n = 10; 5 studies did not have a comparison group, or utilized an inappropriate comparison group (see Warren, 1994).

Three team members had to agree that these criteria were met; where there were differences of opinion, the team members met to establish consensus. This process yielded 10 research studies that met the criterion for inclusion in the meta-analysis.

Citations to the 125 articles identified by this search procedure and their resulting classification for this analysis are found in Appendix B.

Data Analysis Strategy

Throughout this project, we applied the criteria developed by the What Works Clearinghouse (www.whatworks.ed.gov). While the evidence standards applied by the What Works Clearinghouse (WWC) are often viewed as too strict or inappropriate for some types of research questions (see, for example, the winter 2005 issue of *Exceptional Children*), application of these standards is a first step in determining how much confidence to place in the research and which studies yield best practice. We thus utilized the Study Design and Implementation Assessment Device (DIAD) (Valentine & Cooper, 2004) as a model for the development of our own study team DIAD (see appendix C). Because WWC has not yet developed DIAD elements for single subject designs, we added assessment options for Composite Questions 3 (clarity of causal inference) and 8 (precision of outcome).

After the DIAD was completed, each study was coded for its intervention and outcome measure. In addition, the effect sizes for each dependent variable were calculated. The effect size is a quantitative expression of the magnitude of difference between the scores of the experimental and control groups. Specifically, it is the difference between two means (e.g., treatment minus control) divided by the pooled standard deviation of the two conditions (Thalheimer & Cook, 2002). While statistical tests of significance tell us the probability of the null hypothesis, effect-size measurements tell us the size of the experimental effect and allow us to compare the magnitude of experimental treatments from one experiment to another (Thalheimer & Cook, 2002). Effect sizes have the same meaning across studies, even though studies use different measures and the scores have different score distributions (Glass, 1977). Effect size is used to review a set of quantitative research studies on a particular problem or it can be used as an aid to interpreting the results of a single study (Wilkinson, 1999).

Generally speaking, the effect size statistic is helpful in judging the practical significance of a research study. An effect size of 1.0 indicates that the treatment group mean was one standard deviation higher than the control group mean. Thus, the average participant in the experimental group performed at a level that was higher than approximately 84% of all participants in the control group. An effect size of 0 indicates that the treatment and control group means were identical, revealing the training had no effect. An effect size of 0.2 is considered small; an effect size of 0.5 is moderate; and an effect size of 0.8 or above is large (Cohen, 1992).

We were able to compute the effect size for 9 studies, using the statistics presented in each article. One study, however, did not provide sufficient data with which to calculate an effect size, and it therefore did not meet the WWC evidence standards. The formula used to calculate an effect size for these 9 studies was $Cohen's\ d = \frac{\bar{X}_t - \bar{X}_c}{S_{pooled}}$,

where the mean of the control group is subtracted from the mean of the treatment group, and the result is divided by the standard deviation of the two conditions (Thalheimer & Cook, 2002). In calculating effect size estimates for this study, the average scores were weighted by sample size according to procedures recommended by Hedges and Olkin (1985). Weighting was conducted because of the general tendency for treatment effects to be inversely related to sample size. We corrected for small sample sizes utilizing the following formula: $d' = d\left(1 - \left[\frac{3}{4N-9}\right]\right)$, where *d* is Cohen's *d*, above, and *N* is the number of study participants. Formulae for *Cohen's d* were also available if the study only reported an *F*- or *t*-statistic (Thalheimer & Cook).

One (1) of the qualifying studies utilized a single subject research design; for this study (Maddux, Cates, & Sowell, 1984), we used the method recommended by Scruggs and Mastropieri (2001; see also Scruggs, Mastropieri & Casto, 1987) for calculating effect sizes, which divides the number of data points that exceed the extreme value in the baseline condition by the total number of intervention data points.

Results

The 10 studies that met the criteria for inclusion in this analysis are identified in Table 1 by author and year of publication. Participants in these studies ranged from 3 to 79 students, who attended either regular public schools or specialized schools for students with visual impairments. Grades attended by participants ranged from primary through secondary. There was great variability in ages and grade levels of the students who participated in mathematics studies. Several studies failed to report sufficient detail about the participants that would allow generalization to the larger population of children with visual and/or multiple impairments. The blank cells in the table indicate that the information was not provided in the published article.

Table 2 presents information regarding the interventions and outcomes of the 10 studies that met selection criteria. Ten different interventions are documented here. Belcastro (1993) examined mathematics computation following instruction with the Belcastro rods in a randomized controlled study, although as seen from Table 1, only 5 students participated. Champion (1977) looked at performance on the Stanford Achievement Test for both computation and concepts, after instruction in the use of the talking calculator. Coffey (1963) examined computational performance after

Table 1. Description of Study Participants

Author(s)	Year Published	Number of Subjects	Visual Acuity	Cognitive Abilities	Additional Disability	Average Age	Percent Female	Educational Setting
Belcastro	1993	5	“blind”	“matched”		“matched”		1st gr., several schools for the blind
Champion	1977	9	“blind,” braille readers	“normal”				Grades 3-8, regular classes
Coffey	1963	32		“middle IQ range”				7-8th grade; 11-12th grade
Hatlen	1975	24	10/200 and LP to none	2d grade level SAT math		6 to10 yrs.		regular classes
Kapperman	1974	16	“braille students”	Mean = 100.6		15.7 yrs.		Grades 5-12, residential school
Maddux, Cates, & Sowell	1984	3	“braille reader”	“average or higher”		9-4 to 13-0 years	33%	summer school program at residential school
Manconi-Melendez	1989	6	20/200-20/420-NLP	"poor to good math level"		10 to13 yrs.	33%	Grades 4-6
Nolan & Bruce	1962	79	“braille and large type readers”					9 1st and 2nd grade classes at 3 residential schools
Nolan & Morris	1964	41	“braille readers”	82 – 135		12-0 to 16-7 yrs.	45%	Grades 7B-9B at Perkins

Author(s)	Year Published	Number of Subjects	Visual Acuity	Cognitive Abilities	Additional Disability	Average Age	Percent Female	Educational Setting
Sharpton	1977	16	6 braille, 10 large print	"average to above average WISC"		13.5 to 18.5 yrs.		12 regular schools, grades 9-12

Table 2. Description of Intervention Studies

Author(s)	Year of Study	Intervention Category	Outcome Measure Category	Effect Size	Adjusted Effect Size	Length of Intervention	Design	Effect Size Description	Comments
Belcastro	1993	Instruction with Belcastro rods	Oral pre- and posttest, addition and subtraction problems	3.46	2.52	One semester	Exp Cont, pre-post	Large effect for use of Belcastro rods over traditional methods	Random assignment, but small n; all participants scored 0 on pretest
Champion	1977	Instruction in use of Talking Calculator	SAT, Math Computation, braille version	1.20	1.59	3 wks.	Single Group pre-post	Talking Calculator use greatly impacted math computation	No control group; possible practice effect
			SAT, Math Concepts, braille version	0.67	0.89			Talking Calculator use had large impact on math concepts	
Coffey	1963	Braille vs. oral/aural presentation of mathematics curriculum	Researcher-developed pre- and posttest	Insufficient data reported to calculate effect size		2-3 mos.	Multiple Group pre/posttest	Insufficient data reported; effect size could not be computer	Random assignment to balanced conditions

Author(s)	Year of Study	Intervention Category	Outcome Measure Category	Effect Size	Adjusted Effect Size	Length of Intervention	Design	Effect Size Description	Comments
Hatlen	1975	Instruction in use of concrete augmentation board	General mathematics at 2nd grade level	1.50	1.45	46 days x 25 minutes in 10-week period	Pretest-posttest equivalent control-group design	Concrete augmentation board had large effect on student performance after treatment	Repeated measures procedure or examination of posttest gains would strengthen study
Kapperman	1974	Instruction in abacus	Accuracy of computation via braille, mental calculation, and abacus	.28	.27		Hierarchical or sequential regression	Small effect; braille more accurate than abacus for computation	
			Efficiency of computation via braille, mental calculation and abacus	.38	.37			Small effect; mental calculation more efficient than abacus for computation	
Maddux, Cates, & Sowell	1984	Instruction in fingermath	Number of addition and subtraction problems solved correctly during daily timed test	0.65	.00	45 mins./day for 36 days	Intrasubject ABAB design	Moderate effect for fingermath on mathematics skills	Small number of participants reduces effect size

Author(s)	Year of Study	Intervention Category	Outcome Measure Category	Effect Size	Adjusted Effect Size	Length of Intervention	Design	Effect Size Description	Comments
Manconi-Melendez	1989	Computer mathematics instruction program (3)	Arithmetic oral pre and posttest	-0.08	-0.08	1 hour	Pretest-posttest single group design	Computer programs had little impact on math skills	
Nolan & Bruce	1962	Math curriculum based on Schott	Median grade equivalent scores by grade level and modality (braille & large print)	.11	.10	1 school year (?)	Single Group Posttest design	Curriculum moderately effective for grade 1 regardless of modality, but negative effect for grade 2; not effective overall	Estimated weighted effect size
Nolan & Morris	1964	Abacus training program	SAT and Madden-Peak	0.55	0.54	8 mos.	Single Group, pre-post, no gain scores	Moderate to large effect for use of abacus to improve math skills	Possible practice effect
			SAT and Madden-Peak	0.91	0.90				
Sharpton	1977	English Language Grammar Method	Scores on study-specific pretest and posttest	0.89	0.86	25 daily sessions over 5 weeks	Single Group, pre-post, no gain scores	Large improvement in mathematics scores after curriculum implemented	Data not paired; possible practice effect

implementing an oral/aural algebra curriculum. Hatlen (1975) developed a concrete augmentation board that had a large positive effect on student performance following its use in instruction. Kapperman (1974) compared the accuracy and efficiency of computation when using either braille, mental calculation, or the abacus. Maddux, Cates, and Sowell (1984), utilizing a single subject design, found that instruction in fingermath improved mathematics skills. Manconi-Melendez (1989) determined that three different computer mathematics instruction programs had little impact on mathematics skills. Nolan and Bruce (1962) examined Schott's mathematics curriculum and use of the Numberaid, but found the curriculum had a greater impact on students in grade 1 than in grade 2. Nolan and Morris (1964) examined achievement scores following an abacus training program. Sharpton (1977) demonstrated that the English Language Grammar method of mathematics instruction resulted in improved test scores. The two studies that utilized the abacus as an intervention tool (Kapperman, 1974, and Nolan & Morris, 1964) utilized different procedures and different outcomes; for purposes of this analysis, they were treated as discrete interventions.

Other details about these studies are also included in Table 2. Adjusted effect sizes for the 9 studies ranged from a negligible -0.08 (Manconi-Melendez) to a huge 2.52 (Belcastro, 1993). Effect sizes could not be computed for one study (Coffey, 1963), because not enough data were reported in the publication. The intervention time for the studies ranged from three weeks to a school year, and multiple research designs were utilized. Comments of the authors are included in a separate column.

Because no two interventions were alike, we were unable to establish distinct categories or apply meta-analytic techniques with any group of studies. Accordingly, our initial syntheses of the research in mathematics for students with visual impairments yields promising, but not best practices. Without replication, even promising practices are preliminary and perhaps misleading in the absence of further research.

Table 3 summarizes how the studies met What Works Clearinghouse Evidence Standards (WWC, 2006). Four studies (marked with) were judged to meet WWC standards, with reservations. These studies were well designed and implemented, but they have never been replicated. Generalization to the larger body of students with visual impairment is not possible.

Conclusions

The test of any intervention or procedure is *evidence* – not "whatever works," but "*what works*." It seems absurd that there is more information about the effectiveness of various consumer products than there is about the methods we use to teach children with visual impairments.

Educational research on students with visual impairments is difficult to conduct. The population is geographically dispersed, making it difficult to identify an adequate group of study participants without considerable expense. Participants who are identified are often extremely heterogeneous and exhibit a range of visual disorders,

Table 3. Summary of Evidence for Mathematics Interventions, by Effect Size

Intervention	Strength of Studies[3]		Number, Size of Studies	Estimated Effects
Belcastro rods (Belcastro, 1993)	✓	RCT, no replication, small n	1 RCT, n = 5	*d* = 2.52 (huge)
Concrete augmentation board (Hatlen, 1975)	✓	RCT, no replication	1 RCT, n = 24	*d* = 1.45 (huge)
Abacus (Nolan & Morris, 1964)	✓	SGPP; no replication	1 SGPP, n = 42	*d* = .54, .90 (moderate, large)
Talking Calculator (Champion, 1977)	✗	SGPP	1 SGPP, n = 9	*d* = 1.59 computation (huge) *d* =.89 concepts (large)
English Language Grammar Method (Sharpton, 1977)	✗	SGPP	1 SGPP, n = 16	*d* = .86 (large)
Type of calculation (braille, mental, abacus) Kapperman (1974)	✓	RCT, no replication	1 RCT, n = 16	*d* = .27, .37 (moderate)
Special curriculum (Nolan & Bruce, 1962)	✗	SGPT	1 SGPT, n = 79	*d* =.10 (trivial)

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[3] The WWC Evidence Standards (What Works Clearinghouse, 2006) identify studies that provide the strongest evidence of effects: primarily well conducted randomized controlled trials and regression discontinuity studies, and secondarily quasi-experimental studies of especially strong design.

✓✓ "Meets Evidence Standards"--randomized controlled trials (RCTs) that do not have problems with randomization, attrition, or disruption, and regression discontinuity designs that do not have problems with attrition or disruption.

✓ "Meets Evidence Standards with Reservations"--strong quasi-experimental studies that have comparison groups and meet other WWC Evidence Standards, as well as randomized trials with randomization, attrition, or disruption problems and regression discontinuity designs with attrition or disruption problems.

✗ "Does Not Meet Evidence Screens"--studies that provide insufficient evidence of causal validity, are not relevant to the topic being reviewed, do not adequately report statistical tests, or did not provide sufficient data to determine effect size. In addition, the standards rate other important characteristics of study design, such as intervention fidelity, outcome measures, and generalizability.

Intervention	Strength of Studies[3]		Number, Size of Studies	Estimated Effects
Computer mathematics programmed instruction (Manconi-Melendez, 1989)		SGPP	1 SGPP, n = 6	*d* = -0.08 (trivial)
Fingermath (Maddux, Cates, & Sowell, 1984)		SS	1 SS, n = 3	*d* = .00 (none)
Oral/aural instruction (Coffey, 1963)		QED	1 QED, n = 32	Insufficient data reported

QED = Quasi-experimental designs
RCT = Randomized controlled trial
SGPP = Single Group Pre/Posttest design
SGPT = Single Group posttest design
SS = Single Subject Design

visual functioning levels, additional disabilities, and cognitive abilities. Specialized schools, once the greatest source of research samples, no longer offer the homogeneous population and curriculum they once did, as the largest proportion of students with visual impairments (86.55%) now attend general education classes in public schools (U.S. Department of Education, 2005, p. 169). Manipulation of variables in a controlled study often interferes with meeting the standards of the No Child Left Behind Act, and school districts are reluctant to consent to research because it takes away from other instruction.

Four studies over 50 years that meet at least some evidence standards suggest that the field of visual impairment has a weak foundation for its practice in mathematics education. The American Speech-Language-Hearing Association (ASHA) has identified four levels of evidence for examining research: (a) Meta-analysis including well-designed randomized controlled studies; (b) controlled studies without randomization and quasi-experimental designs; (c) well-designed non-experimental studies (i.e., correlational and case studies); and (d) expert committee report, consensus conference, and experience of respected professionals (ASHA, 2004). Applying these levels to the research in visual impairment, most studies have been conducted at levels (c) and (d). The field of visual impairment has an active literature, but the largest proportion of articles seems to be reports, program evaluations, or descriptive studies.

There are several observations about the literature that seem pertinent:

- While 18 articles reported on a program or product, the authors apparently never pursued a scientific trial that would yield definitive information on its effectiveness.

- Several studies utilized a sighted comparison group. These studies did not pass our evidence screening, since we could not respond affirmatively to the fair comparison question (“Were the participants in the group receiving the intervention comparable to the participants in the comparison group?”). We have been profoundly influenced by Warren’s (1994) individual differences approach and do not believe that comparison to a sighted standard is either fair or appropriate.

- Many studies, even ones that qualified for our analysis, failed to include pertinent information about the participants in the study. While omitting gender and additional disability status might be attributable to historical social conventions and the changing population of students with visual impairments, articles were also missing information about the ages of participants, their levels of visual function, their IQs, and their visual disorders. This information is critical to determine generalizability and to understand the results.

- The dearth of evidence for successful strategies in teaching mathematics has grave implications for the preparation of teachers and the continuation of practices that have not yet been established as effective. As C. Craig (personal communication, July 17, 2006) stated:

> In our field, the central question must always be . . . if this strategy or product for performing mathematical calculations is not taught, and the student does not learn to use it, will someone else have to do it for him or her for the rest of [his or her] life?

The lack of knowledge about how to teach mathematics means that successive generations of teachers have been teaching with strategies that do not yield the hoped-for results. The poor performance of students with visual impairments on statewide mathematics assessments (National Center on Low-Incidence Disabilities, 2006) should serve as a call to action for teacher preparation programs and researchers as well.

Promising Practices?

The ten studies suggest that there is at least some evidence for the following statements. These conclusions are extremely tentative, however, given the technical inadequacies of some of the studies, the small size of the sample studied, and the failure to replicate the studies in multiple environments with multiple subjects. All of these generalizations mandate further research and testing.

<u>Concrete mathematics aids can increase computation accuracy</u> (Belcastro, 1993; Champion, 1977; Hatlen, 1977). Concrete materials have been recommended when teaching students with visual impairments for at least 30 years, as Lowenfeld (1972) and Koenig and Holbrook (2000) recommend, and in this analysis, aids and devices do seem to assist with the acquisition of mathematics skills. Hatlen's concrete augmentation board, in spite of the success documented in his dissertation, has never been commercially produced. The Belcastro rods no longer seem to be commercially available, although similar manipulatives are incorporated into instructional programs. The talking calculator is not generally considered a concrete material, and in fact Kapperman, Heinze, and Sticken (2000) recommend against its use until mathematics skills are mastered:

> During initial instruction in arithmetic operations, manipulatives, paper and pencil or the braillewriter, and the abacus are the major tools used in calculations. The talking calculator should be used only as a reinforcer for skills learned using one of these approaches until a student masters the fundamental concepts involved in computation. (p. 386)

The accurateness of braille computation (Kapperman, 1974) was also promising and addresses the importance of developing braille reading and writing skills at an early age.

Comprehension of mathematics concepts can be increased with use of the Talking Calculator (Champion, 1977). While the greatest effect for Champion's study was for computation, the talking calculator was shown to impact math concepts as well. However, the Champion study employed only 9 participants and has never been replicated. Further investigation is warranted, particularly in light of Kapperman et al.'s (2000) recommendation above.

Instruction in fingermath may increase computation accuracy (Maddux, Cates, & Sowell, 1984). Maddux et al. studied only 3 students utilizing a single subject design. While the uncorrected effect size was promising, adjusting the effect size for the small number of subjects reduced the effect size to zero. Once again, the study deserves to be replicated with a larger number of students.

There is conflicting evidence for the effectiveness of the abacus (Kapperman, 1974, Nolan & Morris, 1964). While Nolan and Morris demonstrated higher test scores after 8 months of training in the use of the abacus, Kapperman found greater results for braille computation and mental calculation. Yet it continues to be used in classrooms today, without the rigorous research that would document its effectiveness. It is not known whether the time spent in teaching the mechanics of the abacus actually result in improved computation, or whether another intervention with another device might be more effective.

Next Steps

The difficulty in suggesting next steps is that there are so many steps to take. At the very least, the qualifying studies should be replicated with a greater variety and number of children. Studies that did not meet evidence standards should be designed and implemented to produce greater confidence in the results. New studies should be designed and conducted within the principles of scientifically-based research.

The list of studies that are needed is long, but the stakes are high. In an environment where the education of students with visual impairment is continually questioned about efficacy and outcomes, the manner in which we meet this challenge may determine the future of specialized services as much as it determines the futures of children and youth who are visually impaired.

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Appendix A

Citations Found in the ERIC Database
(not included in the meta-analysis)

Bluhm, D. L. (1968). *Teaching the retarded visually handicapped: Indeed they are children*. (ERIC Document Reproduction Service No. ED026773)

Callahan, L. G., & Glennon, V. J. (1975). *Elementary school mathematics: A guide to current research* (4th ed.). Washington, DC: Association for Supervision and Curriculum Development. (ERIC Document Reproduction Service No. ED 116966)

Geffen, L. F., & Palmore, S. J. (1969). *Selected bibliography on mathematics for the blind.* (ERIC Document Reproduction Service No.ED036018)

Glennon, V. J. (Ed.) (1981). *The mathematical education of exceptional children and youth: An interdisciplinary approach*. (ERIC Document Reproduction Service No. ED200425)

Kerr, J. J. (1974). *British and American arithmetic devices for the blind -- An analytical description.* Temple University. (ERIC Document Reproduction Service No: ED108920)

McCallister, C. J., & Kennedy, R. L. (2001). *Teaching basic statistics to a student who Is blind*. Paper presented at the Annual Meeting of the Mid-South Educational Research Association. Little Rock, AR, November 14-16, 2001. (ERIC Document Reproduction Service No: ED463607)

Riordan, M. (1973). *Teaching objectives for the itinerant resource teacher of visually limited students*. Phoenix, AZ: Creighton School District 14. (ERIC Document Reproduction Service No. ED077157)

Sica, M. G. (1982). *Blind persons report critical incidents of science and mathematics instruction*. (Report No. NSF/SED-82010; SED-79-20597). Washington, D.C.: National Science Foundation. (ERIC Document Reproduction Service No: ED220280)

Sticken, J., & Kapperman, G. (1998). *Collaborative and inclusive strategies for teaching mathematics to blind children.* (ERIC Document Reproduction Service No. ED421821)

Suppes, P. (1972). *A survey of cognition in handicapped children*. (Technical Report No. 197). Stanford, CA: Stanford University, Institute for Mathematical Studies in Social Science. (ERIC Document Reproduction Service No. ED072599)

Warger, C. (2002). *Helping students with disabilities participate in standards-based mathematics curriculum*. (Report No. EDO-EC-06). Arlington, VA: ERIC/OSEP Special Project. (ERIC Document Reproduction Service No: ED468579)

Appendix B. Literature Identified by the Analysis

Classification	Citation
No intervention	Adi, H., & Pulos, S. (1977/1978). Conservation of number and the developmental lag among the blind. *Education of the Visually Handicapped, 9*(4), 102-106.
Qualitative study; no intervention	Ahlberg, A., & Csocsan, E. (1999). How children who are blind experience numbers. *Journal of Visual Impairment & Blindness, 93(*9), 549-560.
Practitioner	Albrecht, M. (1957). A curriculum for a class of blind children. *International Journal for the Education of the Blind, 7*(2), 33-42.
Practitioner	Auerbach, H. (1959). Teaching arithmetic to partially seeing children. *International Journal for the Education of the Blind, 9*(2), 44-46.
Practitioner	Awad, M. M., & Wise, J. L. (1984). Mainstreaming visually handicapped students in mathematics classes. *Mathematics Teacher, 77*(6), 438-441.
Practitioner	Becker, C., & Kalina, K. (1975). The Cranmer abacus and its use in residential schools for the blind and in day school programs. *New Outlook for the Blind, 69*(9), 412-415, 417.
Practitioner	Belcastro, F. (1989). Use of Belcastro rods to teach mathematical concepts to blind students. *RE:view, 21*(3), 71-79.
Meets evidence standards with reservations	Belcastro, F. P. (1993). Teaching addition and subtraction of whole numbers to blind students: A comparison of two methods. *Focus on Learning Problems in Mathematics, 15*(1), 14-22.
No intervention	Bennett, R. E., Rock, D. A., & Novatkoski, I. (1989). Differential item functioning on the SAT-M braille edition. *Journal of Educational Measurement, 26*(1), 67-79.
No intervention	Bikson, T. H., Bikson, T. K., & Genensky, S. M. (1982). Television-mediated education for the visually impaired: A longitudinal investigation. *International Journal of Rehabilitation Research, 5*(2), 244-245.

Classification	Citation
Practitioner	Bohman, R. V., Bryan, W. H., & Tapp, K. L. (1972). An auditory quiz board: An orientation and mobility game for visually handicapped elementary school children. *New Outlook for the Blind, 66*(10), 371-373.
No intervention	Brothers, R. J. (1972). Arithmetic computation by the blind. *Education of the Visually Handicapped, 4*(1), 1-8.
No intervention	Brothers, R. J. (1973). Arithmetic computation: Achievement of visually handicapped students in public schools. *Exceptional Children, 39*(7), 575-576.
Practitioner	Bruce, R. E. (1975). Let's go metric: A manual for teachers. *Education of the Visually Handicapped, 7*(4), 119-123.
No intervention	Cahill, H., & Lindhan, C. (1996). Blind and partially sighted students' access to mathematics and computer technology in Ireland and Belgium. *Journal of Visual Impairment & Blindness, 90(*2), 105-114.
Participants studied are < 3 years or > 21 years of age	Campbell, J. S. (1997). A code for reducing figure-ground ambiguities in tactile graphics. *Journal of Visual Impairment & Blindness, 91*(2), 175-181.
Does not meet evidence screens; Threats to internal validity	Champion, R. R. (1976). The talking calculator used with blind youth. *Education of the Visually Handicapped, 8*(4), 102-106.
No intervention	Chavez, M. (1980). A comparative study of the arithmetic achievement of sensory mathematics students. *Unpublished master's thesis,* Chicago State University, Chicago, Ill.
Does not meet evidence screens; insufficient data reported	Coffey, J. L. (1963). Programmed instruction for the blind. *International Journal for the Education of the Blind, 13*(2), 38-44.
Participants studied are < 3 years or > 21 years of age	Crandall, J. M, Hammill, D. D., Witowski, C., & Barkovich, F. (1968). Measuring form discrimination in blind individuals. *International Journal for the Education of the Blind, 18*, 65-68.
Practitioner	Czerwinski, M. H. (1979/1980). Curriculum development for an iterant program for the visually impaired. *Education of the Visually Handicapped, 11*(4), 125-128.

Classification	Citation
No intervention	Czerwinski, M. H. (1982). An examination of blind children's braille symbol knowledge in the areas of reading and mathematics. *Dissertation Abstracts International, 43*(10), 3285A. (UMI. No. 8306160)
Inappropriate comparison group	Daugherty, K. M. (1977). Monterey learning systems: Improving academic achievement of visually impaired learners. *Journal of Visual Impairment and Blindness, 71*(7), 298-301.
No intervention	del Regato, J. C. (1976). The utilization of echoic codes by visually handicapped in mathematical learning: An exploratory investigation. *Dissertation Abstracts International, 37*(06), 3548A. (UMI No. 7627639)
Participants were parents, families, or teachers	DeMario, N. C., & Lian, M.-G. J. (2000). Teachers' perceptions of need for and competency in transcribing braille materials in the Nemeth code. *Journal of Visual Impairment & Blindness, 94(*1), 7-14.
Participants were parents, families, or teachers	DeMario, N. C., Lang, S., & Lian, M. G. J. (1998). Teachers' self-assessed competence and attitudes toward literary braille and the Nemeth code. *Journal of Visual Impairment & Blindness, 92*(5), 354.
Practitioner	Dick, T., & Kubiak, E. (1997). Issues and aids for teaching mathematics to the blind. *Mathematics Teacher, 90*(5), 344-349.
Program or product description	Dick, W. E. (1992). Sidestepping optical character recognizers: Speculation on a graphical method to produce large print. *Journal of Visual Impairment & Blindness, 86(*1), 84.
Practitioner	Dodd, C. A. (1975). Multiply successes when introducing basic multiplication ideas to visually handicapped children. *Education of the Visually Handicapped, 7*(2), 53-56.
No intervention	Ducker, L. (1993). Visually impaired students drawing graphs. *Mathematics Teaching, 86*(144), 23-26.
No intervention	Duran, P., & Tufenkjian, S. (1981). Tactile-kinesthetic methods for measuring length used by congenitally blind children. *Perceptual and Motor Skills, 38*, 395-400.

Classification	Citation
Program or product description	Durre, I. K., & Durre, I. (1999). Instant print-braille compatibility with COBRA. *Journal of Visual Impairment & Blindness, 93(*3), 140-151.
No intervention	Easton, R. D., Kenedy, C., & Bentzen, B. L. (1980). Tactile perception of angles. *Journal of Visual Impairment & Blindness, 74(*7), 258-261.
Practitioner	Eichenberger, R. J. (1974). Teaching science to the blind student. *Science Teacher, 41*(9), 53-54.
Program or product description	Evans, R., & Simpkins, K. (1972). Computer assisted instruction for the blind. *Education of the Visually Handicapped, 4*(3), 83-85.
Practitioner	Fawson, P. C., Fielding, L., Howell, G.G., Gerritsen, B. R., Peterson, M., & Wilson, B. P. (1982). Basic functional competency: An analysis of curriculum objectives. *Education of the Visually Handicapped, 14*(1), 15-20.
Practitioner	Fleharty, J. (1985). Software for English, mathematics, and elementary classes. *American Annals of the Deaf, 130*(5), 362.
No comparison group; evaluation study	Franks, F. L., & Huff, R. (1977). Educational materials development in primary science: Linear measurement unit for young blind students. *Education of the Visually Handicapped, 9*(1), 23-28.
Inappropriate comparison group	Friedman, J. & Pasnak, R. (1973). Attainment of classification and seriation concepts by blind and sighted children. *Education of the Visually Handicapped, 3(6)*, 55-62.
Practitioner	Gissoni, F. L. (1965). The abacus explosion. *New Outlook Blind, 59*(2), 75-76.
Participants studied are < 3 years or > 21 years of age	Goodrich, G. L., Bennett, R. R., Wiley, J. K. (1977). Electronic calculators for visually impaired users: An evaluation. *Journal of Visual Impairment and Blindness, 71*(4), 154-157.
Practitioner	Griffin, H. C., & Gerber, P. J. (1982). Tactual development and its implications for the education of blind children. *Education of the Visually Handicapped, 13*(4), 116-123.

Classification	Citation
Meets evidence standards with reservations	Hatlen, P. H. (1975). The effect of direct concrete augmentation in mathematics for blind children. *Dissertation Abstracts International.* (UMI No. not available)
Practitioner	Hattendorf, J. K. (1971). An abacus update. *New Outlook for the Blind, 65*(4), 112-116.
Practitioner	Hoffmeyer, D. B. (1980). Computer-aided instruction at the Florida school for the deaf and the blind. *American Annals of the Deaf, 125*(6), 834-840.
Practitioner	Holladay, D. (1982). Computer applications to Braille. *Journal of Visual Impairment and Blindness, 76*(8), 324-325.
Practitioner	Hooper, M.S. (1957). The Nemeth code: How and why. *International Journal for the Education of the Blind, 7*(2), 56-60.
No comparison group; evaluation study	Huff, R., & Franks, F. (1973). Educational materials development in primary mathematics: Fractional parts of wholes. *Education of the Visually Handicapped, 5*(2), 46.
Practitioner	Hussey, S. R., & Legge, L. (1956). The “Halifax method” of arithmetical calculations. *International Journal for the Education of the Blind, 6*(2), 36-40.
No intervention	Jackson, L. M. (2003). The effects of testing adaptations on students' standardized test scores for students with visual impairments in Arizona. *Dissertation Abstracts International, 64*(10), 3644A. (UMI No. 3108915)
Practitioner	Jones, P. S. (1978). Notes on numeration: Arithmetic on a checkerboard numerals for the blind. *School Science and Mathematics, 78(*6), 481-488.
Practitioner	Kang, Y. W., & Masoodi, B. A. (1978). Abacus instruction for moderately retarded blind children. *Education of the Visually Handicapped, 10*(3), 79-84.
Meets evidence standards with reservations	Kapperman, G. G. (1974). A comparison of three methods of arithmetic computation by the blind. *Dissertation Abstracts International,* DAI-A 35/05, p. 2810, Nov 1974.
Program or product description	Kapperman, G., & Sticken, J. (1998). The braillewriter as a calculation tool. *RE:view, 30*(2), 65-83.

Classification	Citation
Program or product description	Kapperman, G., & Sticken, J. (2002). A software tutorial for learning the Nemeth code of braille mathematics. *Journal of Visual Impairment & Blindness, 96*(12), 855-857.
Program or product description	Kapperman, G., & Sticken, J. (2003). A case for increased training in the Nemeth code of braille mathematics for teachers of students who are visually impaired. *Journal of Visual Impairment & Blindness, 97(*2), 110-112.
Program or product description	Kapperman, G., & Sticken, J. (2003). Using the Braille Lite to produce mathematical expressions in print. *Journal of Visual Impairment & Blindness, 97*(11), 710-713.
Program or product description	Karshmer, A. I., Gupta, G., Geiger, S., & Weaver, S. (1999). Reading and writing mathematics: The MAVIS project. *Behaviour & Information Technology, 18*(1), 2-10.
Practitioner	Krebs, C. S. (2001). Learning to solve word problems in a middle school vision class. *Journal of Visual Impairment & Blindness, 95*(12), 757-760.
No intervention	Kumagai, J. (1995). Inventions born of necessity offer new tools for the blind to study and do science. *Physics Today, 48*(3).
Program or product description	Lamon, W. E., & Threadgill, J. (1975). The Papy-Lamon minicomputer for blind children: An aid in learning mathematics. *New Outlook for the Blind, 69*(7), 289.
No intervention	Landau, B., Gleitman, H., & Spelke, E. (1981). Spatial knowledge and geometric representation in a child blind from birth. *Science, 213*(4513), 1275-1278.
Some participants studied are < 3 years or > 21 years of age	Landau, S., Russell, M., Gourgey, K., Erin, J. N., & Cowan, J. (2003). Use of the talking tactile tablet in mathematics testing. *Journal of Visual Impairment & Blindness, 97(*2), 85-96.
Practitioner	Lennon, E. M., Feirer, J. L., & Purdy, W. K. (1976). Metrics for visually impaired persons. *New Outlook for the Blind, 70*(1), 1-4.
Practitioner	Lewis, M. (1970). Must visually handicapped students be low achievers in math? *Education of the Visually Handicapped, 2*(2), 60.

Classification	Citation
Practitioner	Lewis, M. (1970). Teaching arithmetic computation skills. (1970). *Education of the Visually Handicapped, 2*(3), 66-72.
Practitioner	Lewis, M., & Coker, G. (1971). The use of abacus contests to increase interest in mathematics. *New Outlook for the Blind, 65*(2), 41-48.
Practitioner	Liedtke, W. W., & Stainton, L. B. (1994). Fostering the development of number sense--selected ideas for the blind (braille users). *Journal of Special Education, 18*(1), 24-32.
No intervention	Lister, C., Leach, C., & Simpson, L. (1994). An exploration of understanding of quantity in children who are blind. *Early Child Development & Care, 103*, 43.
No intervention	Loeding, B. L., & Greenan, J. P. (1998). Reliability and validity of generalizable skills instruments for students who are deaf, blind, or visually impaired. *American Annals of the Deaf, 143*(5), 392-403.
Program or product description	Lueck, A. H. (1999). Setting curriculum priorities for students with visual impairments. *RE:view, 31*(2), 54-66.
Program or product evaluation	Luxton, K., & Spungin, S. J. (1976). Effectiveness of calculator instructional materials: A pilot study. *New Outlook for the Blind, 70*(9), 380-384.
Meets evidence standards with reservations	Maddux, C. D., Cates, D., & Sowell, V. (1984). Fingermath for the visually impaired: An intrasubject design. *Journal of Visual Impairment and Blindness, 78*(1), 7-10.
Practitioner	Maddux, C. D., Cates, D. L., & Sowell, V. M. (1983). Abacus or fingermath: How do we decide? *Journal of Visual Impairment & Blindness, 77*(5), 210.
Does not meet evidence screens; threats to internal validity	Manconi-Menendez, L. (1989). The educational effectiveness of mathematics computer software for the blind and partially sighted. *Dissertation Abstracts International, 40*(07). (UMI No. 51371)
Practitioner	Mandola, J. (1968). A theoretical approach to graphic aids for the blind. *International Journal for the Education of the Blind, 18*(1), 20-24.

Classification	Citation
Program or product description	Mangold, S. S. (2003). Speech-assisted learning provides unique braille instruction. *Journal of Visual Impairment & Blindness, 97*(10), 1-14.
Participants were parents, families, or teachers	Mao, L-W. (1976). Efficacy and generalizability of mental abacus techniques in the preparation of teachers of the visually handicapped. *Dissertation Abstracts International, 37*(04), 2113A. (UMI No. 7621634)
Practitioner	McCollum, K. (February 12, 1999). Science material for the blind placed on-line. *Chronicle of Higher Education, 45*(23), A26-30.
No intervention	McCrimmon, S. (1974). Programmed instruction as a means of teaching blind children addition and subtraction on the abacus. *Education of the Visually Handicapped, 6*(3), 72-79.
Participants studied were < 3 years or > 21 years of age	Meehan, A. M., Hoffert, D., & Hoffert, L. C. (1993). Strategies and resources for teaching statistics to visually impaired students. *Teaching of Psychology, 20*(4), 242.
Program or product description	Melrose, S., & Goodrich, G. L. (1984). Evaluation of voice-output calculators for visually handicapped users. *Journal of Visual Impairment and Blindness, 78*(1), 17-19.
No intervention	Moore, M. (1973). Development of number concept in blind children. *Education of the Visually Handicapped, 5(*3), 65-71.
Does not meet evidence standards; insufficient data reported	Morgali, R. R., & Lamon, W. E. (1976). Using the Papy-Lamon minicomputer to teach basic addition facts and related concepts to visually handicapped children: A pilot study report. *Education of the Visually Handicapped, 8*(2), 33-43.
Program or product description	Morris, J. E. (1972). The 1973 Stanford Achievement Test Series as adapted for use by the visually impaired. *Education of the Visually Handicapped, 6*(2), 33-48.
Practitioner	Nadash, A. (1977). Metric for the blind. *American Metric Journal, 5*(1), 21-22.
Practitioner	Nemeth, A. (1959). Teaching meaningful mathematics to blind and partially sighted children. *New Outlook Blind, 53*(9), 318-321.

Classification	Citation
Practitioner	Neumann, F. T. (1970). A tactile-developmental technique for abacus instruction and operation. *New Outlook Blind, 64*(6), 161-166.
Practitioner	Newland, T. E. (1964). Prediction and evaluation of academic learning by blind children: 1 – problems and procedures in prediction. *International Journal for the Education of the Blind, 14*(1), 1-7.
Practitioner	Newland, T. E. (1964). Prediction and evaluation of academic learning by blind children: 1 – problems and procedures in prediction. *International Journal for the Education of the Blind, 14*(2), 42-51.
Practitioner	Nezol, A. J. (1978). A quick guide to the Nemeth code. *Education of the Visually Handicapped, 10(*1), 10-13.
Practitioner	No Author. (1993). New braille code for advanced mathematics. *Journal of Visual Impairment and blindness, 87*(10), 44.
Practitioner	No Author. (2003). Virtual pencil for math. *Journal of Visual Impairment and Blindness, 97*(7), 44.
No intervention	Nolan, C. Y. & Ashcroft, S. C. (1959). The Stanford achievement arithmetic computation tests: A study of an experimental adaptation for braille administration. *International Journal for the Education of the Blind, 8*, 89-92.
Does not meet evidence screens; insufficient data reported	Nolan, C. Y. & Bruce, R. E. (1962). An experimental program in elementary mathematics for the blind. *International Journal for the Education of the Blind, 11*, 71-74.
Does not meet evidence screens; threats to internal validity	Nolan, C. Y. & Morris, J.E. (1964). The Japanese abacus as a computational aid for blind children. *Exceptional Children, 31*, 15-17.
No intervention	Nolan, C. Y. (1959). Achievement in arithmetic computation: Analysis of school differences and identification of low achievement. *International Journal for the Education of the Blind, 8*(4), 125-128.
Practitioner	Nolan, C. Y. (1964). Research in teaching mathematics to blind children. *International Journal for the Education of the Blind, 13*, 97-100.

Classification	Citation
No intervention	O'Donohue, N. E. (1992). Blind and sighted children's reasoning in transformational geometry: Modality specific and non-specific influences. *Dissertation Abstracts International, 52*(09), 4997B. (UMI No. 9207107)
Practitioner	Ohtake, N., & Kanahori, T. (2003). A conversion tool for mathematical expressions in web xml files. *Journal of Visual Impairment & Blindness, 97*(11), 1-13.
Practitioner	Osterhaus, S., Weaver, C., & Siller, M. A. (2001). More accessibility for math students: AFB solutions forum stakeholders and their pursuit of braille conversion software. *Journal of Visual Impairment & Blindness, 95(*3), 184-185.
Participants were parents, families, or teachers	Rapp, D. W., & Rapp, A. J. (1992). A survey of the current status of visually impaired students in secondary mathematics. *Journal of Visual Impairment and Blindness, 86(*2), 115-117.
Program or product description	Robicheaux, R. T. (1993). Mathematical connections: Making it happen in your classroom. *Arithmetic Teacher, 40*(8), 479-481.
No intervention	Rosenblatt, B. (1994). Helping partially sighted, students learn academic skills through orientation and mobility. *RE:view, 26*(2).
Participants were parents, families, or teachers	Rosenblum, L. P., & Amato, S. (2004). Preparation in and use of the Nemeth braille code for mathematics by teachers of students with visual impairments. *Journal of Visual Impairment and Blindness, 98(*8), 484-496.
No intervention	Sakamoto, S. I. (1999). The Cranmer abacus: Its use in teaching mathematics to students with visual impairments. *Dissertation Abstracts International, 60*(09), 3298A. (UMI No. 9946797)
Practitioner	Schott, A. F. (1957). New tools, methods for their use, and new curriculum in arithmetic. *The Arithmetic Teacher, 4*, 204-209.

Classification	Citation
Does not meet evidence screens; threats to internal validity	Sharpton, R. E. (1977). An experimental study to measure the effects of the English language grammar method of teaching mathematics on the mathematics performance of the visually impaired. *Dissertation Abstracts International, 8*(03), 1206A. (UMI No. 7718545)
Practitioner	Sicilian, S. P. (1988). Development of counting strategies in congenitally blind children. *Journal of Visual Impairment & Blindness, 82*(8), 331-335.
Participants were parents, families, or teachers	Sinclair, F. L., & Sanderson, J. (1978). Talking calculator survey. *Journal of Visual Impairment and Blindness, 72*(4), 151-152.
No intervention	Stebbins, W. C., Emmel, A., Heriot, J. T., & Rockowitz, R. J. (1975). Congenital ophthalmoplegia and school achievement: A case study. *Developmental Medicine & Child Neurology, 17*(2), 237.
Participants were parents, families, or teachers	Steinbrenner, A. H. (1980). A survey on the use of the abacus in residential schools. *Journal of Visual Impairment and Blindness, 74(*5), 186-188.
Participants were parents, families, or teachers	Steinbrenner, A., & Becker, C. (1982). Current status of abacus training in teacher education institutions. *Journal of Visual Impairment and Blindness, 76*(3), 107-108.
Practitioner	Stevens, R. D., Edwards, A. D. N., & Harling, P. A. (1997). Access to mathematics for visually disabled students through multimodal interaction. *Human-Computer Interaction, 12(*1), 47.
No intervention	Stewart-Brown, S., Haslum, M. N., & Butler, N. (1985). Educational attainment of 10-year-old children with treated and untreated visual defects. *Developmental Medicine & Child Neurology, 27*(4), 504.
Program or product description	Struve, N. L., Cheney, K. M., & Rudd, C. (1979). Chisanbop for blind math students. *Education of the Visually Handicapped, 11(*4), 108-112.
No comparison group	Tinsley, T. (1972). The use of origami in the mathematics education of visually impaired students. *Education of the Visually Handicapped, 4*(1), 8-11.

Classification	Citation
Program or product description	Townsend, A. H. (1977). ELINFA portable Braille cassette recorder. *Journal of Visual Impairment and Blindness, 71*(7), 324-325.
Practitioner	Utz, W. R. (1979). The blind student in the mathematics classroom. *American Mathematical Monthly, 86(*6), 491-494.
Practitioner	Walter, M. (1974). Use of geoboards to teach mathematics. *Education of the Visually Handicapped, 6(*2), 59-62.
Practitioner	Weiss, J. B. (1977). Teaching abacus to deaf-blind persons. *Journal of Visual Impairment and Blindness, 71*(10), 459.
Participants studied were < 3 years or > 21 years of age	Weiss, J. B., & Weiss, J. (1981). Use of the talking calculator to improve mathematical skills. *Journal of Visual Impairment and Blindness, 75*(2), 61-63.
Practitioner	Williams, F. N. (1955). Enriched mathematics for the blind. *International Journal for the Education of the Blind, 4*(3), 50-52.
Participants were parents, families, or teachers	Wolffe, K. E., Sacks, S. Z., Corn, A.L, Erin, J. N., Huebner, K. M., & Lewis, S. (2002). Teachers of students with visual impairments: What are they teaching? *Journal of Visual Impairment & Blindness, 96(*5), 293-304.
Practitioner	Zimin, B. (1968). The education and employment of blind mathematicians in computer centers in the Soviet Union. *New Outlook for the Blind, 62*(10), 307-308.

The What Works Clearinghouse Evidence Standards

The WWC Evidence Standards identify studies that provide the strongest evidence of effects: primarily well conducted randomized controlled trials and regression discontinuity studies, and secondarily quasi-experimental studies of especially strong design.

"Meets Evidence Standards"—randomized controlled trials (RCTs) that do not have problems with randomization, attrition, or disruption, and regression discontinuity designs that do not have problems with attrition or disruption.

"Meets Evidence Standards with Reservations"—strong quasi-experimental studies that have comparison groups and meet other WWC Evidence Standards, as well as randomized trials with randomization, attrition, or disruption problems and regression discontinuity designs with attrition or disruption problems.

"Does Not Meet Evidence Screens"—studies that provide insufficient evidence of causal validity, are not relevant to the topic being reviewed, do not adequately report statistical tests, or did not provide sufficient data to determine effect size.

APPENDIX C

National Center on Low-Incidence Disabilities
Study Design and Implementation Device (Short Form)

Reviewer (circle one):

Buettel Ferrell Pearson

Other: ______________________________ Date: _______________

Citation: ____

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<u>**Composite Question 1**</u>**. Intervention's Relevance to the Review:** Was the intervention properly defined?

a. Yes, the intervention was adequately described, and it fully reflected ideas about what the intervention should be.	Yes ☐
b. Maybe Yes, the intervention was adequately described, and it at least largely reflected ideas about what the intervention should be.	Maybe Yes ☐
c. Maybe No, there were important details missing from the description of the intervention and/or possible problems with its implementation.	Maybe No ☐
d. No, the intervention did not reflect ideas about what it should be and/or there were known problems with its implementation.	No ☐

<u>**Composite Question 2**</u>**. Outcome Measure's Relevance to the Review:** Was the outcome measure properly defined and aligned to the intervention?

a. Yes, the report presented evidence that the outcome measure was properly defined and aligned to the intervention.	Yes ☐
b. [There is no "<u>Maybe Yes</u>" answer for this question.]	
c. Maybe no, there was evidence that the measure had face validity and was properly aligned to the intervention. However, evidence suggested the measure might not be reliable.	Maybe No ☐
d. No, it is unclear what the outcome was.	No ☐

<u>Composite Question 3a</u>. Clarity of Causal Inference: Fair Comparison (for Randomized Designs): Were the participants (e.g. students, schools) in the group receiving the intervention comparable to the participants in the comparison group?

a. Yes, participants were randomly assigned to conditions and few participants dropped out during the study.	Yes ☐
b. Maybe Yes, random assignment was used but there was severe dropping out by participants.	Maybe Yes ☐
c. Maybe No, random assignment was used but there was differential dropping out of participants across conditions.	Maybe No ☐
d. No, although random assignment was used, participants dropping out during the study probably led to the groups not being comparable.	No ☐

<u>Composite Question 3b</u>. Clarity of Causal Inference: Fair Comparison (for Quasi-Experimental Designs): Were the participants (e.g. students, schools) in the group receiving the intervention comparable to the participants in the comparison group?

a. [There is no “Yes” answer for these types of designs.]	
b. Maybe Yes, reasonable steps were taken to make the groups comparable.	Maybe Yes ☐
c. Maybe No, although steps were taken to make the groups comparable, the steps may not have been adequate.	Maybe No ☐
d. No, it is unlikely that the participants in the groups were comparable.	No ☐

<u>Composite Question 3c</u>. Clarity of Causal Inference: Fair Comparison (for Regression Discontinuity Designs): Were the participants (e.g. students, schools) in the group receiving the intervention comparable to the participants in the comparison group?

a. Yes, an assignment variable with specified cutoffs was used to place participants into groups and there was no attrition problem.	Yes ☐
b. Maybe Yes, an assignment variable with specified cutoffs was used to place participants into groups but severe attrition may have affected study results.	Maybe Yes ☐
c. Maybe No, an assignment variable with specified cutoffs was used to place participants into groups, but differential attrition may have affected study results.	Maybe No ☐
d. No, an assignment variable with specified cutoffs was not used to place participants into groups.	No ☐

<u>Composite Question 3d</u>. Clarity of Causal Inference: Fair Comparison (for Single-Factor Within-Subject Designs where two or more interventions are administered to a single sample of participants): Were the participants assigned to treatments in such a way that the effects of the intervention could be interpreted unambiguously?

a. Yes, participants were randomly assigned to one the possible counterbalanced orders of treatment combinations to control *practice effects*; there was no potential for *differential carry-over effects*; and few participants dropped out during the study. — Yes ☐
b. Maybe yes, practice effects and differential carry-over effects were controlled, but there was severe attrition during the study. — Maybe Yes ☐
c. Maybe no, practice effects were controlled, but there was potential for differential carry-over effects. — Maybe No ☐
d. No, neither practice effects of differential carry-over effects were controlled. — No ☐

<u>Composite Question 3e</u>. Clarity of Causal Inference: Fair Comparison (for Single Subject Designs, with baselines and one or more interventions, administered to the same sample of participants): Did the participants receive treatments in such a way that the effects of the intervention could be interpreted unambiguously?

a. Yes. A rigorous design was used, all participants experienced all baseline/treatment combinations; there were sufficient data points for all conditions to draw conclusions. — Yes ☐
b. Maybe yes. A rigorous design was used and all participants experienced all essential baseline/treatment combinations. However, one or more of the following was present: some additional (or different) interventions were carried out with some but not all of the subjects; some of the data sets for certain conditions were small (less than 5) — Maybe Yes ☐
c. Maybe no. Although an acceptable design was used, one or more of the following was present: the design poorly controlled for multiple intervention interference; not all participants experienced all essential baseline/treatment combinations; some of the data sets for certain conditions appeared insufficient (less than two) — Maybe No ☐
d. No. There were serious flaws in either the design or the execution of the study, which resulted in the presence of multiple competing hypotheses, either acknowledged or suspected. — No ☐

<u>Composite Question 4.</u> Clarity of Causal Inference: Was the study free of events that happened at the same time as the intervention that confused its effect?

a. Yes, other events that might be alternative explanations to the intervention's effect have been ruled out. — Yes ☐
b. Maybe Yes, there were no other identified events that could be alternative explanations, but some alternative explanations remain plausible. — Maybe Yes ☐
c. [There is no "Maybe No" answer for this question.]
d. No, other events happening at the same time as the intervention may have caused the effect. — No ☐

<u>Composite Question 5.</u> Generality of Findings: Inclusive Sampling: Were targeted participants, settings, outcomes, and occasions included in the study?

a. Yes, the targets are represented in the sample. — Yes ☐
b. Maybe Yes, most important characteristics of the targets are represented in the sample. — Maybe Yes ☐
c. Maybe No, although some important characteristics of targets are represented in the sample, many important targets are not. — Maybe No ☐
d. No, the sampled participants were not part of the target populations. — No ☐

<u>Composite Question 6.</u> Generality of Findings: Effects Tested Within Sub-Groups: Was the intervention tested for its effectiveness within important subgroups of target participants, settings, outcomes, occasions, and intervention variations?

a. Yes, the intervention was tested for its effectiveness on targeted variations. — Yes ☐
b. Maybe Yes, the intervention was tested for its effectiveness within most important subgroups of the participants and settings. — Maybe Yes ☐
c. Maybe No, although the intervention was tested for its effectiveness within some important subgroups of the participants and settings, many were left out. — Maybe No ☐
d. No, at best the intervention was only tested for its effectiveness within limited important subgroups of the participants, settings, outcomes, occasions, and intervention variations. — No ☐

<u>Composite Question 7.</u> Precision of Outcome: Effect Size Estimation: Were the effect sizes accurately estimated?

a.	Yes, the effect sizes appear to be accurately estimated.	Yes ☐
b.	Maybe Yes, there was some evidence of statistical issues that may have caused the effect size to be inaccurately estimated, but the likely impact on inferences was minimal.	Maybe Yes ☐
c.	Maybe No, there was evidence that statistical issues may have caused the effect sizes to be inaccurately estimated.	Maybe No ☐
d.	No, the assumption of statistical independence was not met, and dependence was not accounted for in the effect sizes.	No ☐

<u>Composite Question 8a.</u> Precision of Outcome: Statistical Reporting: Were the statistical tests adequately reported?

a.	Yes, the statistical tests were adequately reported.	Yes ☐
b.	Maybe Yes, sufficient statistical information was reported to allow, at a minimum, imprecise effect sizes to be calculated for most measured outcomes.	Maybe Yes ☐
c.	Maybe No, effect sizes could not be calculated for most outcome measures.	Maybe No ☐
d.	No, sample sizes were not reported, OR neither the magnitude nor the direction of the effects could be discerned for most outcome measures.	No ☐

<u>Composite Question 8b.</u> Precision of Outcome: Statistical Description and Graphic Representation for Single Subject Designs: Were descriptions of the quantitative results and/or graphic representations adequately reported?

a.	Yes, clear quantitative information was presented either graphically and/or through descriptive statistics to support all major conclusions.	Yes ☐
b.	Maybe Yes, sufficient quantitative information was reported to allow, at a minimum, imprecise effect sizes to be calculated for most measured outcomes.	Maybe Yes ☐
c.	Maybe No, effect sizes could not be calculated for most outcome measures.	Maybe No ☐
d.	No, neither the magnitude nor the direction of the effects could be discerned for most outcome measures.	No ☐

The American Printing House for the Blind (APH) is an American non-for-profit corporation in Louisville, Kentucky promoting independent living for people who are blind and visually impaired. For over 150 years APH has created unique products and services to support all aspects of daily life without sight. The first United States schools for blind children opened in the 1830s. There were very few books and educational materials for the students. Teachers made their own tactile teaching aids and... State education agencies (SEAs) and programs serving persons who are blind may order materials free of charge up to the amount of funds allo- cated to each state for educational materials. The APH also conducts research related to developing and improving products and provides advisory services to professional and consumer organizations on the availability and use of materials produced by APH. Types of Projects Materials produced by APH include textbooks in Braille and large type, education tools such as Braille typewriters and computer software and hardware, teaching aides such as tests and performance measures, and other special supplies. The APH... The Departmen of Education lacks a formal schedule and mechanism to monitor the federally funded program at the American Printing House for the Blind. It does not conduct site visits on a regular basis, document the actual use of funds in activity categories, assess program data quality, or assess the program's compliance with the Act to Promote the Education of the Blind. The Department of Education has not developed efficiency measures for this program to ensure that it is operating effectively and meeting the needs of its service population. Improvement Plan. About Improvement Plans. We are taking the following actions to improve the performance of the program