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Using American Sign Language with a Direct Instruction Mathematics Program to Affect the Mathematics Achievement of Deaf Students

Annette J. Bass
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USING AMERICAN SIGN LANGUAGE WITH A DIRECT INSTRUCTION MATHEMATICS PROGRAM TO AFFECT THE MATHEMATICS ACHIEVEMENT OF DEAF STUDENTS

by

Annette J. Bass

A Project Report
Submitted to the
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USING AMERICAN SIGN LANGUAGE WITH A DIRECT INSTRUCTION MATHEMATICS PROGRAM TO AFFECT THE MATHEMATICS ACHIEVEMENT OF DEAF STUDENTS

Annette J. Bass, Ed.S.
Western Michigan University, 1993

The effectiveness of supplemental instruction using a scripted direct instruction program, *Connecting Math Concepts* (Englemann & Carnine, 1992), with four lower elementary deaf students was compared to the effectiveness of supplemental instruction in their traditional math curriculum, *Mathematics Today* (Abbott, 1985). A two-phase multiple baseline design across students was used. During the first phase, the students' achievement on curricula-based math probes was assessed while using the *Mathematics Today* as a supplement. During the second phase, the students' achievement was assessed while using *Connecting Math Concepts* as a supplement. The teacher presentation scripts in this program were translated into American Sign Language. The results were mixed; some students scored higher with instruction in *Mathematics Today* and others scored higher with instruction in *Connecting Math Concepts*. The mixed results indicate a need for an in-depth analysis of the *Connecting Math Concepts* scripts and translation to American Sign Language before they can be optimally effective for deaf students.
ACKNOWLEDGMENTS

I would like to thank the students and teacher who gave me all their cooperation in time, attention and effort to help me complete this study. I would also like to thank my advisor, Howard Farris, for his advice and assistance in planning my experimental design and in writing my project. I also extend thanks to Michael Bahr for his advice and references on curriculum-based assessment, and to Galen Alessi and Al Poling for their advice and suggestions.

Annette J. Bass
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Using American Sign Language with a direct instruction mathematics program to affect the mathematics achievement of deaf students

Bass, Annette J., Ed.S.
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INTRODUCTION

Historically, mathematics education for the deaf has been relatively ignored, and is in dire need of attention. This fact becomes quite clear in a review of the literature, revealing the effects of this traditional negligence. Gentile (1972) and Allen (1986) both reported that the mathematics scores of deaf students on the Stanford Achievement Test are substantially lower than those of same age hearing students (Johnson, 1989). Furthermore, Allen's study demonstrated that the average deaf high school graduate has math computation scores which fall well below the seventh grade level (Johnson, 1989). Additional information regarding low achievement in mathematics of the deaf comes from the Gallaudet University School of Preparatory Studies. The School is designed to help deaf high school graduates achieve a skill level adequate enough to begin their freshman year at the University. Hillegeist and Epstein (1989) reported that every year, over half of the incoming class of students are "not prepared for fundamental algebra," "are deficient in basic computational skills and have a very weak understanding of fundamental mathematical concepts" (p. 704).

These figures are distressing, yet not unexplainable. There are many reasons for deaf students' lack of success in math, and in fact, many of them could be cited for the lack of success also found among hearing students. First, teaching mathematics is the area in which teachers feel they have the least ability and one which they least enjoy (Crown, 1990; Fridriksson & Stewart, 1988). A number of
authors contend that students cannot be expected to learn a subject well if the teachers themselves are not competent or comfortable with the subject matter. In addition, teachers are generally unfamiliar with strategies for teaching mathematics, making them overly dependent on textbooks to dictate the computational methods they teach (Hernandez, 1979; Fridriksson & Stewart, 1988). Teachers in the United States tend to be highly dependent on repetitive drill and practice in teaching mathematics, a procedure many students may find boring and non-productive.

Fridriksson and Stewart (1988) suggest several additional reasons why deaf students have a hard time succeeding in math. They assert that math is viewed as not being a critical component in deaf students' overall education when compared to the emphasis placed on the development of their language and speech. They also point out that competency in math is viewed only as a secondary goal and not sufficient by itself if a good language base is not acquired. However, in a world of computers and advancing technology, reasoning such as this places deaf students at a decided competitive disadvantage.

A final but significant consideration in the inadequacy of deaf students' math education focuses on the issue of language. Several researchers have studied the relationship of mathematics and language involving deaf students (Hargis, 1969; Hillegeist & Epstein, 1989) and hearing students who are bilingual. A review of these studies reveals that language ability is closely associated with achievement in mathematics. Hillegeist and Epstein, in their review of bilingual literature, concluded that students require a certain amount of knowledge about how mathematical
"concepts are...embedded in a language structured to express that knowledge." They report that problems native English speakers have in math are made even worse for students not familiar with the English language. This type of research is pertinent to deaf students, because most of them use English as a second language. A unique problem in teaching math to deaf students is the lack of common signs for math terminology. Teachers and interpreters are often left to invent signs for many common math terms, signs which may or may not be used by the next teacher or interpreter. In addition, many mathematical terms, such as rational, irrational and column have other, more common meanings. When new words such as these are introduced with the assumption that students will understand the distinction between meanings, confusion results. In fact, some sign language systems even use the sign for the everyday or common word to represent the sign for the mathematical term. Given the importance of the role of language in the instruction of mathematics, these concerns should be taken seriously.

Although many of the reasons for the failure of math education are well documented, there is little research focusing on the best way to teach mathematics to deaf students. The literature that is available consists mostly of anecdotal reports about single classroom trials or addresses only one particular math skill, such as borrowing (Christianson & Silvia, 1978), understanding of word problems (Hernandez, 1979), knowledge of basic addition and subtraction facts (LaSasso & Mackall, 1983) and counting, regrouping, and conversion of money (Silvia, 1983). Other reports are survey studies, designed to determine the most common methods of teaching math.
Most instruction involves computational practice and drill on the blackboard or worksheets, instead of focusing on mathematical concepts (Johnson, 1977; Fridriksson & Stewart, 1988; Dietz, 1991). Johnson (1977) has looked at the role of computers as another method teachers have tried, but again, the emphasis is on computation skills rather than the teaching of mathematical concepts.

Even fewer studies have been done to determine which mathematics curriculum is best suited for deaf students. In a survey of mathematics curricula used with the deaf across the country, Johnson (1977) reported a wide array of curricula being used. Johnson suggested the reason for this variability is that there is no single textbook series available to meet the needs of deaf children. A major problem with most textbooks is the lack of adequate examples for deaf students. Some schools have attempted to accommodate the needs of deaf students by supplementing the program used for hearing students (Cowan, 1990). Some use of programmed texts with the deaf was also attempted (Bornstein, 1964). Overall, no curricula used with deaf students has been shown to be exceptionally effective.

It can be seen from the above discussion that there is an unequivocal need to improve existing mathematical instruction for deaf children. However, many questions remain, especially with respect to the inherent problem of language. One extremely effective curriculum taking into account the problem of language is that of Direct Instruction. Although curricula utilizing the direct instruction methods have had empirically documented success with hearing students in areas of reading, writing,
spelling, social studies, and mathematics, no attempts have been made to demonstrate its applicability with the deaf.

Research in this area has considerable promise because Direct Instruction programs are based on instructional characteristics known to utilize effective teaching practices, such as careful teaching of new words and concepts, using specific strategies for problem solving, appropriate instructional pacing, optimal sequencing of lessons, constant monitoring of student progress, students' and teacher's active participation (Kluwin & Moores, 1989) and built-in motivational systems. Perhaps a major reason that these programs have not been tried with the deaf is that they are based primarily on oral presentations of scripted lessons with accompanying student material. This makes much of the Direct Instruction material virtually inaccessible to deaf students as it now exists.

The goal of this study will be to explore the use of a Direct Instruction program in mathematics with the standardized script converted from English to American Sign Language.

The rationale for selecting a Direct Instruction program is based on its documented success with hearing students and on the program's ability to address many of the deficits that exist in traditional mathematics instruction for the deaf. Previously mentioned were problems involving lack of sufficient examples to adequately teach a concept. Providing positive and negative examples is a strong characteristic of Direct Instruction (DI). Another strength of DI as an instructional tool is the strong behavioral base for its teaching methods which are largely neglected.
in other programs for teaching deaf students. According to Jones (1984), in a comprehensive review of the literature there were only 36 studies that reported using behavioral procedures with hearing impaired students, and "all...were effective; that is, the target behaviors were either developed or reduced in accordance with the study's aims."

The proposed study will attempt to establish the effectiveness of converting a DI mathematics program to American Sign Language and using it as a supplement to regular math instruction for deaf students. The students' math achievement will be evaluated using mathematical skills probes.
METHOD

Subjects

The subjects participating in this study were four deaf elementary school students who use American Sign Language (ASL). All came from hearing families who had learned ASL to communicate with their children.

Subject 1 was a nine-year-old girl with profound sensorineural (problem confined to the inner ear) hearing loss bilaterally, although while using hearing aids, she has only a severe loss. She began school at the age of two in the school's hearing-impaired preschool program. At the time of the research, she was mainstreamed with an interpreter for half of the day into a second grade classroom for math, science, and social studies.

Subject 2 was a ten-year-old boy with profound sensorineural hearing loss, bilaterally, although while using hearing aids, he has only a moderate to severe loss. He began school at the age of four and at the age of five was transferred to the school's hearing-impaired preschool program. At the time of the research, he was mainstreamed with an interpreter for part of the day into a third grade classroom for computers, art, handwriting, and a show & tell/social time. This subject had also been diagnosed with Attention Deficit Disorder and was on medication (Ritalin).
Subject 3 was an eight-year-old girl with profound sensorineural hearing loss, bilaterally, although while using hearing aids, she has only a moderate to severe loss. She began school at the age of two at the schools' hearing-impaired preschool program. At the time of the research, she was mainstreamed for part of the day into a first grade classroom for gym, art, and computer/library time.

Subject 4 was a seven-year-old boy with profound sensorineural hearing loss bilaterally, although while using hearing aids, he has only a severe loss. He began school at the age of two at the school's hearing-impaired preschool program. At the time of the research, he was mainstreamed for part of the day into a first grade classroom for gym and computer/library time.

The above demographics for each subject is included because of the results of studies which have suggested that these factors play a role in the achievement of deaf students in academics (Kluwin & Moores, 1989).

Setting

The setting was an elementary hearing-impaired Total Communication classroom in which American Sign Language was used as the predominant language. The teacher and teacher's aide in the classroom had worked with these same students for several years. Some subjects were taught to all the students as a group, while other subjects were taught to students individually, due to their different ages and academic levels. For this project, each student received supplementary instruction in
mathematics on a one-to-one basis separate from the ongoing classroom activities, at a table in the corner of the room.

Materials

During the first part of the project, the materials from the mathematics curriculum presently employed in the subjects' classrooms were used. The curriculum in use was *Mathematics Today* (Abbott, 1985), published by Harcourt Brace Jovanovich, Inc. Included in the program are student workbooks, student textbooks, practice workbooks, teacher's editions, and teacher's resource books.

The Direct Instruction mathematics program used during the last part of the project was Science Research Associates' *Connecting Math Concepts* (Englemann & Carnine, 1992). The program consists of the student workbook, presentation book and teacher's guide. The program has three levels: A, B, and C, and students are placed into the appropriate level through the use of a placement test. The English script used in the teacher's presentation book was converted to American Sign Language for presentation to the deaf students. Only the language was changed; all other aspects of the presentation remained intact.

Dependent Variables

The dependent variable in this study was the students' acquisition of math skills as indicated by two different assessment procedures. The first assessment was repeated administrations of 2-minute mathematics skills probes. The second measure
was pre- and post-intervention administrations of the mathematics areas of the Stanford Achievement Test–8th edition (SAT).

The mathematics skills probes are curriculum-based measures developed after careful inspection of both curricula to ensure that the probes contain representative questions of all skills from each unit taught throughout the study. Alternate forms of the probes were developed so that they could be administered frequently without producing practice effects. A thorough explanation of the procedures used to develop, administer and score the probes and sample copies of the probes are included in the Appendix. The probes were administered at the beginning of each lesson during baseline and intervention, two to three times a week. In addition, for comparison purposes, the final form of the probe administered to each deaf student was also administered to a classroom of each of their hearing peers at the conclusion of the study.

The three mathematics subtests of the SAT were administered according to procedures recommended by the Center for Assessment and Demographic Studies at Gallaudet Research Institute for administration to hearing impaired students. It was administered to students as a pre-test just before they entered Phase I, and again as a post-test after they completed Phase II. The only exception to this arrangement occurred with Subject 1. During Phase II it was realized that she had not been given the SAT just prior to Phase I. It was administered upon this realization, during Phase II.
Independent Variable and Experimental Design

The research framework for the study was a multiple baseline across students. The intervention consisted of two phases: (1) supplementary instruction in the students' current mathematics program, and (2) supplementary instruction in the DI program. All students began in the baseline condition, their regular math instruction. Following the baseline condition, the first subject entered Phase I. Afterward, each remaining subject entered Phase I in a staggered fashion, so that for each week only one subject entered Phase I at a time. All subjects entered Phase II in the same manner. Entry into the phases was staggered as such to ensure that the intervention itself was affecting the changes in scores, and not some other confounding variable in the classroom, such as any changes in the subjects' regular mathematics instruction.

Using two phases in the design serves a dual purpose. First, because the researcher conducted both supplementary instruction phases, it eliminates any effects that may occur during intervention simply because of a difference in teaching or sign language style between the researcher and classroom teacher. Additionally, any effects resulting simply because of extra one-on-one instruction is eliminated.
RESULTS

Mathematics Skills Probes

In examining the results from the mathematics skills probes, there are three factors to consider. The first is the rate at which the subjects mastered skills they were taught, which is indicated by the slopes of their graphs. The second is how well the subjects mastered skills they were taught, which is indicated by the means of their scores. The third is how much improvement the subjects showed. This is indicated by examining the last three data points of each phase. These three factors are plotted on the subjects' individual graphs in Figures 1–4, and are discussed in detail below.

Rate of Mastery

The rate of mastery of the skills taught to the students is indicated by the slope of their graphs. The steeper their slope, the more quickly they are mastering the skills. A general positive slope is expected even with no intervention, as students inevitably learn concepts and skills over time.

Overall Data

All students experienced an improvement in their rate of mastery during supplemental instruction. Subjects 1 and 2 experienced their biggest increase in rate of mastery during Phase I (supplemental instruction in their traditional
Scores

Baseline
Mean: 14.7
Slope: -0.10

Phase I
Mean: 19.2
Slope: 1.19

Phase II
Mean: 24.8
Slope: 1.16

Figure 1. Mathematics Skills Probes Scores Subject 1.
Scores

Baseline
Mean: 28.7
Slope: 0.41

Phase I
Mean: 34.1
Slope: 0.42

Phase II
Mean: 34.3
Slope: 0.11

Days

Figure 2. Mathematics Skills Probes Scores Subject 2.
Scores

Baseline
Mean: 6.3
Slope: 0.32

Phase I
Mean: 9.3
Slope: 0.59

Phase II
Mean: 12.3
Slope: 0.75

Figure 3. Mathematics Skills Probes Scores Subject 3.
Scores

Baseline
Mean: 7.3
Slope: 0.36

Phase I
Mean: 7.9
Slope: -0.79

Phase II
Mean: 10.2
Slope: 3.38

Days

Figure 4. Mathematics Skills Probes Scores Subject 4.
program). However, Subjects 3 and 4 experienced their biggest increase in rate of mastery during Phase II (supplemental instruction in the DI program).

**Individual Data**

The slope of Subject 1 increased by 1.29 during Phase I, but decreased by 0.03 during Phase II. The slope of Subject 2 increased by 0.01 during Phase I, but decreased by 0.31 during Phase II. The slope of Subject 3 increased by 0.27 during Phase I, and increased again by 0.16 during Phase II. The slope of Subject 4 decreased by 0.57 during Phase I but increased dramatically by 3.59 during Phase II. These data are summarized in Table 1.

<table>
<thead>
<tr>
<th>Subject</th>
<th>Phase I</th>
<th>Phase II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject 1</td>
<td>+1.29</td>
<td>-0.03</td>
</tr>
<tr>
<td>Subject 2</td>
<td>+0.01</td>
<td>-0.31</td>
</tr>
<tr>
<td>Subject 3</td>
<td>+0.27</td>
<td>+0.16</td>
</tr>
<tr>
<td>Subject 4</td>
<td>-0.57</td>
<td>+3.59</td>
</tr>
</tbody>
</table>

Note: Rate of mastery is indicated by the slope of each subject's graph.

**Level of Mastery**

For each phase of the study, the level of mastery of the skills taught to the students is indicated by their mean score on the mathematics skills probes. A general
increase in mean is expected even with no intervention, as students increase their level of understanding of more skills over time.

**Overall Data**

All students experienced an increase in their level of mastery during each phase. Subjects 1 and 4 increased their level of mastery the most during Phase II (supplemental instruction in the DI program). Subject 2 increased level of mastery the most during Phase I (supplemental instruction in the traditional program). Subject 3 increased level of mastery by the same amount during Phase I and Phase II.

**Individual Data**

The mean score of Subject 1 increased by 4.5 during Phase I and increased again by 5.6 during Phase II. The mean score of Subject 2 increased by 5.5 during Phase I, but increased by only 0.2 during Phase II. The mean score of Subject 3 increased by 3.0 during Phase I and again by 3.0 during Phase II. The mean score of Subject 4 increased by only 0.6 during Phase I, but increased by 2.3 during Phase II. These data are summarized in Table 2.

**Improvement in Scores**

When examining the last three data points of each phase on each subject's graph, it can be seen that each subject improved upon the scores obtained in each previous phase. This indicates that supplementary instruction was beneficial to all
Table 2

Summary of the Increase of Each Subject's Level of Mastery During Each Phase of the Study

<table>
<thead>
<tr>
<th></th>
<th>Phase I</th>
<th>Phase II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject 1</td>
<td>+4.5</td>
<td>+5.6</td>
</tr>
<tr>
<td>Subject 2</td>
<td>+5.5</td>
<td>+0.2</td>
</tr>
<tr>
<td>Subject 3</td>
<td>+3.0</td>
<td>+3.0</td>
</tr>
<tr>
<td>Subject 4</td>
<td>+0.6</td>
<td>+2.3</td>
</tr>
</tbody>
</table>

Note: Level of mastery is indicated by the subjects' mean score on the mathematics skills probes.

students but that supplementary instruction in the Direct Instruction program was the most effective for all students. Although students would be expected to show general improvement over time as a result of ongoing learning in the classroom, the multiple baseline design across students helps eliminate the confound of a general learning improvement. The fact that the scores for each phase were an improvement over the last three data points for each phase indicates that Direct Instruction can be used with success.

Mathematics Skills Probes—Comparison With Hearing Peers

When each deaf subject's means were compared with the mean of a classroom of same-aged hearing peers, the results were uniform across all subjects. The means obtained by all hearing classes at the conclusion of the study were within two points of their deaf cohorts' means during baseline. By the end of Phase II, the deaf
subjects' scores were at least 2.5 points higher than their hearing peers' scores and up to 10.6 points higher. Table 3 displays the means obtained by the deaf subjects in all phases and the means obtained by their hearing peers.

Table 3

<table>
<thead>
<tr>
<th></th>
<th>Baseline Mean</th>
<th>Phase I Mean</th>
<th>Phase II Mean</th>
<th>Mean of Hearing Peers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject 1</td>
<td>14.7</td>
<td>19.2</td>
<td>24.8</td>
<td>14.2</td>
</tr>
<tr>
<td>Subject 2</td>
<td>28.7</td>
<td>34.1</td>
<td>34.3</td>
<td>28.3</td>
</tr>
<tr>
<td>Subject 3</td>
<td>6.3</td>
<td>9.3</td>
<td>12.3</td>
<td>7.7</td>
</tr>
<tr>
<td>Subject 4</td>
<td>7.3</td>
<td>7.9</td>
<td>10.2</td>
<td>7.7</td>
</tr>
</tbody>
</table>

Stanford Achievement Test

With only two exceptions, all subjects obtained scores that fell within the normal range for their age groups on both the pre- and post-test administrations of the SAT. These scores, converted to percentile ranks, fell between the mean and one standard deviation below the mean.

The only exceptions were in the case of Subject 3 and 4. On the pre-test administration of Mathematics Computation subtest, Subject 3 obtained a percentile rank of 22, which is in the normal range of above one standard deviation below the mean. However, on the post-test administration, he obtained a percentile rank of 6,
which falls below one standard deviation from the mean. The other exception was Subject 4. On the Mathematics Computation subtest she obtained a percentile rank of 4, almost two full standard deviations below the mean. Yet, the percentile rank she obtained on the post–test administration was a 14, which is consistent with her first score, falling below one standard deviation below the mean.

The pre– and post–test percentile ranks obtained by each subject on each subtest are displayed in Table 4.

Table 4
Pre– and Post–Test Percentile Ranks Obtained by Each Subject on the SAT Mathematics Subtests

<table>
<thead>
<tr>
<th>Concepts of Number</th>
<th>Mathematics Computations</th>
<th>Mathematics Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
</tr>
<tr>
<td>Subject 1</td>
<td>34</td>
<td>18</td>
</tr>
<tr>
<td>Subject 2</td>
<td>39</td>
<td>40</td>
</tr>
<tr>
<td>Subject 3</td>
<td>21</td>
<td>34</td>
</tr>
<tr>
<td>Subject 4</td>
<td>38</td>
<td>43</td>
</tr>
</tbody>
</table>

Note: Percentiles given are based on hearing–impaired norms for students with severe to profound learning loss.
DISCUSSION

Results of the Mathematics Skills Probes

Overall, the results were mixed. Some students showed an increase in rate of mastery during supplemental DI instruction and some did not. Similarly, some students showed an increase in level of mastery during supplemental DI instruction and some did not. However, all showed an improvement in scores after each phase of the study. There are a number of possible reasons for these mixed effects.

First, comparing the effects of two programs such as Connecting Math Concepts (Englemann & Carnine, 1992), the DI program, and Mathematics Today (Abbott, 1985), the traditional program used in the subjects' classroom, turned out to be like comparing apples to oranges. The programs differ greatly in their scope and sequence of instruction and teach competing strategies to solve problems. This difference between them, coupled with time constraints during the study, contributed greatly to the mixed results.

If it had been possible to extend the instructional sessions with the subjects to daily lessons lasting the full school year, comparison of the two programs may have been easier, and effects may have been more striking. Connecting Math Concepts presents units in "strands" that are taught in small parts throughout the year, whereas Mathematics Today, presents units all at once and does not return to those topics again. This difference in presentation made it difficult to compare them over just a
limited time, because at a specific point in the school year, *Connecting Math Concepts* had not fully presented some topics that *Mathematics Today* had presented in entirety, although by the end of the year the topics were covered completely by each program.

Teaching daily lessons for a full school year also would have allowed the time necessary to get more answers regarding one of the basic questions of this project—the ability of each curriculum to teach concepts as opposed to the simple drilling of facts. The subjects' understanding of math concepts could have been more precisely evaluated after a full school year of instruction in the programs.

Daily lessons during a full school year would also have allowed subjects more exposure to the effects of the DI program. After the necessary staggering of the baselines due to the multiple baseline design, some subjects did not get much exposure to instruction in the DI curriculum.

Another possible reason for the mixed effects is the independent variable, the math skills probes. The subjects' problem solving behaviors were different when working on the math skills probes than when working on lessons. In other words, strategies they learned in lessons did not transfer to the test taking situation. Subjects continued to refer back to previously learned, ineffective strategies. This could have been remedied by administering the skills probes at the end of each lesson instead of at the beginning. In this way, the subjects may have made a connection between what they were just taught and the problems on the skills probes.
In addition, effects of each phase of the study may have been easier to detect if the math skills probes had been developed for each subject according to his or her individual instructional level. Instead, math skills probes were developed to encompass the instructional levels of all 4 subjects in order to facilitate comparison among them.

Results of Mathematics Skills Probes—Comparison With Hearing Peers

The math skills probes distributed to the hearing children in the subjects' grades was also administered as a possible source of extra information. The results support the use of supplemental instruction, but not of any specific program. Since it was only administered once, any comparisons to the hearing-impaired subjects are inconclusive. If the hearing children had an equal amount of practice on the probes but no supplemental instruction, it would be interesting to see the value of their scores. In any future studies similar to this one, a measure similar to this should be included, but should occur continually throughout the study to facilitate a more direct comparison.

Results of the Stanford Achievement Test

The SAT was administered as a possible source of extra information. However, the subjects' results on the SAT suffer from the problems that are commonly associated with standardized tests: the SAT was not representative of
either curricula, and was thus was not sensitive to learning that occurred. Another problem with this instrument is that, although normed on a hearing-impaired population, it is still a very English language-based test and the language, again, was difficult for the deaf subjects. In addition, as with their performance on the math skills probes, their knowledge of how to solve problems did not generalize to the testing situation.

Language of the Scripts

The goal of this project was to begin to "unlock the curriculum" (Johnson, 1989), and make the Direct Instruction mathematics curriculum accessible to deaf students. It became apparent, however, that to fully unlock the curriculum, it would be necessary to conduct an in-depth analysis of the wording used in the DI scripts and perform a major conversion of the English language used in them to American Sign Language. The proper translation represents a separate project in itself. It would also be necessary to empirically validate the translated ASL scripts to determine its effectiveness, just as it is done with the English scripts. Due to the constraints placed on this project, an in-depth translation was not possible during the current study. The scripts were converted to sign language, making them partially accessible, but did not fully incorporate all the linguistic components of ASL.

Certain modifications necessary in an ASL translation were noted. For example, explanations and directions need to be even more direct and less wordy due to the nature of ASL. The subjects in this study were adept at correctly repeating a
simple procedure after they had gone through it one time. Repeating the instructions for such simple procedures often, as the DI scripts do to ensure understanding, may only serve to slow down the instruction in ASL. Although not substantiated, it appears that many other hearing-impaired students also have this imitative skill.

Another modification that may be needed is breaking up the lessons into shorter increments. The subjects of this study were not accustomed to attending to so much language, for such a long time and became fatigued. However, if students became accustomed to this type of instruction as part of their daily lesson, they would likely be less fatigued. This aspect of scripted lessons would have to be examined during any future empirical validation of the translated DI programs.

In some instances, specific language used in the program needed to be changed. For example, the scripts in Level C often used the phrase "count by 5, 3 times." The translation of this from English to ASL was confusing to subjects. It should either be explained differently or be replaced with another phrase easier to translate.

Although time and translation limitations affected this study, the beginning of the task of unlocking the DI curriculum for deaf and hearing-impaired students has begun. This project has been the first step. It is clear what needs to be done to make Connecting Math Concepts accessible to deaf students. The few problems noted above clearly demonstrate the inadequacies of a simple conversion from English to sign language. An in-depth analysis of the language must first occur. The resulting translation must then be field validated with deaf students. These components are
missing from the present study and undoubtedly contributed to the mixed results. This author believes that the DI program, *Connecting Math Concepts*, can be used with deaf students, but first the language of math must be adequately analyzed and translated. This is a critical and needed next step.
Appendix A

Procedures Used to Develop Mathematics Skills Probes
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Procedures Used to Develop Mathematics Skills Probes

The procedures used to develop the curriculum-based mathematics skills probes are those created by Tilly and Carlson (1990b) for mixed math. The procedures as followed for this project are outlined below, step by step:

1. **Decide which skills will be included on the mixed probes.**

   After reviewing all curricula to be used with the students, it was determined that the skills to be taught during the study were single- and multiple-digit addition with and without carrying and single- and multiple-digit subtraction with and without regrouping.

2. **Decide what percentage of total problems in the sampling pool will be of each skill type.**

   The percentage of each skill type on the probes is equivalent to the percentage of each skill type found in each curricula used in the study. Each curriculum is approximately equally represented (*Mathematics Today*=53%, *Connecting Math Concepts*=47%). There is an equal percentage of addition and subtraction problems on the probes. To more accurately represent the percentages of types of problems found in the curricula, the addition and subtraction problems were further separated by several other factors: number of digits in the problem, place value of the digit to be carried, place value of
the digit requiring regrouping, and number of times carrying or regrouping was required.

3. **Decide how many probes will be created.**

It was determined that the maximum number of instructional sessions with each student would be 42. Instead of creating 42 individual probes, the number was divided in half, and 21 probes were created. After the first 21 probes were administered, they were administered again in the same order. Since 2 months lapsed between the students' experience with the first probe and its duplicate, it is reasonable to expect no practice effects from the first probe.

4. **Calculate the total number of problems that will need to be created.**

Tilly & Carlson suggest using approximately 50 problems on each probe. Therefore, 21 different probes with 50 problems on each one resulted in the need for 1,050 different math problems.

5. **Randomly select mixed math problems.**

Tilly & Carlson provide two ways to select problems to be used on the probes. The method chosen for this study was the "fish bowl" method. Using this method, a pool of mixed problems was created by writing problems on small slips of paper. These problems were taken directly from materials in each curriculum: workbook pages, practice pages, reteaching pages, and chapter tests, pretests and posttests. Each type of problem (e.g., double-digit addition involving carrying) was placed in its own "fish bowl", and the specific
percentage of each type was selected, resulting in 50 problems chosen for the probe.

6. **Construct Math Probes.**

There are two methods for constructing the math probes. The method chosen for this study was the retype method. After selecting each problem from the "fishbowl" for the first probe, the problems were typed on a computer six across the page in the order in which they were selected. The same method was followed for each subsequent probe except that the order of the problems was kept the same for each probe because Tilly & Carlson report "recent research suggests that keeping the problem order the same for each probe may increase reliability of measurement".

7. **Create Scoring Templates.**

After all student probes were created, a second copy of each one was made. On these duplicate copies, each problem on the probes was solved in the longest way possible and all work was shown. To the right of each problem, the total number of correct digits possible for that problem was written. At the far right of each row of problems, the cumulative number of correct digits for that row was written.

Since the students' scores on the probes were determined by the number of correct digits they wrote, care was taken during the creation of the probes to ensure that the number of correct digits possible was consistent for each type of problem on every probe.
Administration Procedures

The following administration procedures follow the guidelines established by Tilly & Carlson (1990a) for administering mixed math probes. Students were given their math probe and a pencil. For the first few administrations, these directions were given:

"The sheets on your desk are math facts. There are several types of problems on the sheets. Some are addition and some are subtraction. Look at each problem carefully before you answer it."

"When I say 'begin', start answering the problems. Begin with the first problem and work across the page. Then go to the next row. If you cannot answer the problem mark an 'X' through it and go to the next one. If you finish a page, turn the page and continue working."

The students then had 2 minutes to do as many problems as possible. Students were monitored to ensure that they worked across the page and did not skip around and answer only specific problems.

Scoring Procedures

Each correct digit a student wrote for a problem was scored as one point, regardless of whether the whole answer was right. Points for the problems in each row were totalled at the end of the row, then totalled for the entire probe. The total amount possible for each probe was 98 points. Following is a list of guidelines established by Tilly & Carlson (1990a) as well as some guidelines developed especially for this project.

1. Score each correct digit within a student response
2. If the problem has not been completed, credit is earned for the correct digit(s) written.

3. Parts of the answers above the line ("carries" or "borrows") are not counted as correct digits.

4. Reversed digits are counted as correct.

5. Rotated digits, with the exception of 6 and 9, are counted as correct.

6. If the problem has been crossed out, credit is earned for the correct digits written.

7. If the answer is correct, the digits do not have to be aligned correctly for full credit to be scored.

8. If the answer is incorrect, the digits must be aligned correctly for credit to be scored.

Additional guidelines:

9. If the student writes a double digit number in one place value position instead of carrying the first digit, it is considered to hold one place value position, thus being scored as only 1 incorrect digit.

10. If the student writes a double-digit answer for a problem containing an answer with only one place value, it is not scored as correct even if the digit in the ones place is correct.
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