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One hundred and thirty-three mathematics teachers of deaf students from grades 6–12 responded to a survey on mathematics word problem-solving practices. Half the respondents were teachers from center schools and the other half from mainstream programs. The latter group represented both integrated and self-contained classes. The findings clearly show that regardless of instructional setting, deaf students are not being sufficiently engaged in cognitively challenging word problem situations. Overall, teachers were found to focus more on practice exercises than on true problem-solving situations. They also emphasize problem features, possibly related to concerns about language and reading skills of their students, rather than analytical and thinking strategies. Consistent with these emphases, teachers gave more instructional attention to concrete visualizing strategies than to analytical strategies. Based on the results of this study, it appears that in two of the three types of educational settings, the majority of instructors teaching mathematics and word problem solving to deaf students lack adequate preparation and certification in mathematics to teach these skills. The responses of the certified mathematics teachers support the notion that preparation and certification in mathematics makes a difference in the kinds of word problem-solving challenges provided to deaf students.

Recent calls for reform in mathematics education for deaf students have targeted mathematics word problem solving and general reasoning skills as critical areas of emphasis (Daniele, 1993; Dietz, 1994; Pagliaro, 1998b). Educators have encouraged programs serving deaf students to adopt the recommendations included in the standards advocated by the National Council of Teachers of Mathematics (NCTM). In particular, these standards emphasize that problem solving is more than applying specific strategies when solving different classes of word problems. In the view of the NCTM, problem solving is “not only a goal of learning mathematics, but also a major means of doing so” (NCTM, 2000, p. 52).

Unfortunately, studies show that deaf students do not perform well in problem-solving tasks, achieving well below hearing students (Traxler, 2000). The poor performance of deaf students in this area has been attributed to a combination of linguistic, cognitive, and experiential factors.

Linguistic content of the problems or the English-language abilities of the students have been considered the primary contributing factors to deaf students’ difficulties with mathematics in general, as well as with word problems in particular (Barham & Bishop, 1991; Pagliaro & Ansell, 2000). Barham and Bishop noted that teachers of deaf students, “when asked about the problems their pupils are having with mathematics, seem to have an intuitive feeling that language is at the heart of their difficulties” (p. 180). Pagliaro and Ansell asked primary-level teachers about the difficulty of word problems presented to their deaf students. Concerns included language-related issues primarily within problem content and problem representation, and to a lesser degree within student proficiency and teacher abilities. Others have also discussed the potential language-related factors, noting that deaf students generally have...
great difficulties with English, graduating well below grade level in reading (Traxler, 2000). Rudner (1978) identified English-language structures used in both written and verbal instructions for mathematics that cause special difficulty for deaf students. These language structures include conditionals (if, when), comparatives (greater than, the most), negatives (not, without), inferentials (should, could, because, since), low-information pronouns (it, something), and lengthy passages (p. 33). More recently, Kidd and Lamb (1993) and Kidd, Madsen, and Lamb (1993) identified additional English-language difficulties that deaf students experience in learning mathematics. Their findings included words that have different meanings within mathematics than they do outside mathematics, multiple ways of expressing a single concept, and varied forms, abbreviations, and symbols.

In examining the linguistic aspect further, Kelly and Mousley (2001) studied reading comprehension. They reported that deaf college students’ problem-solving performance decreased on word problems as the computational information increased. Whereas reading ability level was associated with the deaf students’ lower scores when solving the word problems, the analyses showed that other factors also contributed to the decline of their scores: computation errors (rather than procedural errors), leaving word problems blank, and a negative, disengaged approach to the word problem-solving tasks. These results demonstrated that successful word problem solving involves more than reading comprehension.

In examining generic thinking skills, important to successful problem solving, of hearing students, Wooditch (1991) suggested that selective attention, sustained analysis, analogizing, suspension of closure, and autocensorship are characteristic of “good problem solvers” who give conscious, focused, and undivided attention to a problem. They persist in considering all relevant information and use analogies to known information to better understand the new problem situation. Furthermore, they assess all available problem information before making a conclusion and they test or evaluate their potential solution covertly, before affirmation.

Such characteristics have not been consistently associated with deaf students. Glennon (1981) cites evidence showing that deaf students exhibit unreflective behavior and demonstrate a lack of persistence in working through difficult problems. These students have difficulty in transferring learning from one context to another and in remembering what has been learned. Deaf students generally perform as well as hearing students when the tasks involve only one dimension, but their performance drops significantly when two or more dimensions are involved in the problem (Ottem, 1980). Reasons suggested by Marschark, Lang, and Albertini (2002) are that concepts appear to be less interconnected for deaf students than for hearing students and that there may be a difference in the persistence of deaf students in solving problems. These authors also write, however, that research conducted in the past has rarely involved real-world situations, which are extremely complex, and that most research has focused on tasks that have clearly defined problem spaces and answers.

Mousley and Kelly (1998) examined the potential of strategy instruction to improve the problem-solving performance of deaf students. Teacher modeling with regard to analyzing all information available and explaining answers while solving algebra problems led to improved performance of the experimental group. The control group that did not receive strategy instruction showed no such improvement in performance. In a study on the use of a cognitive intervention model (instrumental enrichment) with deaf participants, Martin (1995) also found a “measurable” improvement in several areas including problem solving and “abstract thinking” when participants were involved with a teaching–learning model using instructional enrichment.

Though general skills, such as reading, following instructions, and making simple mathematical inferences, are useful techniques for solving many problems, they simply are not sufficient to solve most “real” problems, according to Glover, Ronning, and Bruning (1990). These authors state that formal instruction should provide learners with organizational focus and ways to relate their knowledge to problem solving and should give students practice in problem representation. Teachers should emphasize the strategy of using analogies to understand problem situations and relate the problem situation via analogy to knowledge and information that the students already have. Students should be given considerable practice with problem representation and re-representation and with ill-defined problems because most real-world problems are not well defined. The ex-
tent to which these emphases exist in the mathematics classrooms for deaf students has not been investigated.

Another important distinction expressed in the literature on problem solving is that between practice exercises and true problems (Lochhead & Collura, 1981; Smith, 1991). Practice exercises are defined as “tasks for which the student knows appropriate solution procedures, but has yet to become adept at applying these procedures” (Smith, p. 6). Smith comments that a practice exercise is a relatively easy, straightforward, well-defined charge that can be solved algorithmically by recognition, recall, and reproduction. In contrast, true problems are more difficult, complex tasks that require analysis and reasoning toward a goal (or solution) based on an understanding of the domain from which the task is drawn (Smith, 1991). Smith states that true problems require more than just simple recognition or recall from memory. These problems cannot be solved algorithmically with little or no understanding of what has been done or why it was correct. In making this distinction, he emphasizes that solving true problems requires analysis and reason that must be based on understanding of the content involved. Smith also suggests that much classroom problem solving (for hearing students) involves tasks that would be considered practice exercises.

The extent to which deaf students have been educated with an emphasis on drill and practice in mathematics word problem-solving lessons, as compared to an emphasis on critical thinking skills, has not been investigated to this point. Applications in real problem-solving situations are essential for preparing deaf students to benefit from a college education or to compete successfully on the job. Marschark et al. (2002) contend that “all too often deaf students are allowed to get by with less than would be required of hearing students, thus depriving them a valuable educational experience” (p. 83). These authors state that “cognitive narrowing” may result from the willingness of teachers to accept superficial, one-dimensional answers from deaf students rather than encouraging deeper extended discussions. A factor in these decisions may be deaf education teachers’ lack of preparation in mathematics and mathematics education and insufficient knowledge about the value of word problems (Pagliaro, 1998a).

Based on an analysis of 141 questionnaires filled out by educators in center schools, Pagliaro (1998a) found that teachers more familiar with mathematics reform, as summarized in the NCTM standards, increased the amount of problem-solving activities in their instruction. Likewise, Pagliaro and Ansell (2002) found that primary-level deaf education teachers who had completed at least one mathematics methods course during their preparation programs incorporated word problems more frequently into their instruction than those who had taken none. However, both studies were conducted with teachers primarily in center schools. It is not known whether there is a comparable pattern of professional development preparation among teachers with deaf students in mainstream programs. Likewise, the extent to which teachers’ pedagogical and content knowledge may influence the learning outcomes of deaf students has not been studied.

In summary, there is a need to examine the emphases teachers give to mathematics word problem solving for deaf students in center schools and mainstream environments, particularly with regard to the use of practice exercises versus true problems. Knowing more about how deaf students throughout the grade levels are taught to solve word problems may lead to implications for instruction, teacher education, and research. This need led to this survey of how teachers in grades 6–12 provide mathematics instruction to deaf students. These were the research questions:

1. For teachers providing mathematics instruction to deaf students, do their educational backgrounds and certification differ based on type of school program?
2. Do teachers’ instructional emphases differ for teaching mathematics word problem solving to deaf students based on type of school program? Specifically for teaching and providing
   a. general problem-solving strategies?
   b. concrete visualizing and analytical strategies?
   c. practice opportunities for word problem solving?
3. Do educational backgrounds and certification of teachers make a difference in the instructional emphasis and experiences they provide to deaf students for practice exercises versus true problems?
4. Do teachers’ perceptions of their deaf students’ abilities to solve word problems differ based on type of school program?
Method

Respondents

The mailing list for the survey used in this study was generated from a list of high schools compiled from the entry data of students to the National Technical Institute for the Deaf. This national mailing list of 253 programs consisted of 185 mainstreamed schools and 68 public and private center schools for deaf students. Multiple copies of the survey were sent to these programs serving deaf students with a cover letter requesting that they be given to mathematics teachers who instruct deaf and hard-of-hearing students in grade levels 6–12. The respondents were asked to answer survey questions specific to one mathematics course that they are currently teaching. A follow-up reminder was mailed to all schools that did not initially respond.

A total of 133 mathematics teachers responded to the survey from 68 center schools and 64 mainstreamed programs (one respondent did not indicate school type). Thus, the teachers responding were about equally divided, with 51.5% from center schools and 48.5% from mainstreamed educational environments. We achieved a 100% response from all center schools on the mailing list, but a lower response rate of 35% for the mainstreamed programs, which we considered an acceptable return rate representative of the mainstreamed programs surveyed. Further delineation of teachers working in the mainstreamed programs show that 45% (29 out of 64) were teaching mathematics to deaf students in integrated classrooms, while 55% (35 out of 64) were teaching mathematics to deaf students in self-contained classrooms serving deaf students only. These 133 responses were from educational programs located in 35 different states and Washington, D.C.

Of the 133 respondents, 101 teachers indicated their total school enrollments for deaf students. The percentages of teachers in center schools and mainstreamed programs relative to total school enrollment are provided in Table 1. Most of the teachers responding from mainstreamed programs (25 out of 42 = 60%) teach in educational programs that have 25 or fewer deaf students enrolled. In contrast, only 5% (3 out of 59) of the teachers from center schools teach where there are 25 or fewer deaf students enrolled.

The teachers were also asked to indicate the total number of deaf students enrolled in the mathematics course they selected as the basis for their survey responses. Of 133 respondents, 123 indicated the number of deaf students in their mathematics course. Table 2 summarizes the number of deaf students per class for teachers in both center schools and mainstream programs.

With respect to educational background, Table 3 provides the percentages of 131 respondents from center schools and mainstreamed environments with baccalaureate and master’s degrees. As shown, 40% of the teachers from center schools indicated undergraduate and graduate educational backgrounds in mathematics and mathematics education compared to 67% of the teachers in integrated classes and 15% of the teachers in self-contained classrooms.

For teacher certification, approximately 41% of

<table>
<thead>
<tr>
<th>Table 1  Percentage of responding teachers relative to school enrollments of deaf students (based on the responses of 101 teachers out of 133 surveyed)</th>
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</thead>
<tbody>
<tr>
<td>Total enrollments of deaf students</td>
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<tr>
<td></td>
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<tr>
<td>10 or fewer</td>
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<td>11–25</td>
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<tr>
<td>26–30</td>
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<tr>
<td>51–100</td>
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<tr>
<td>101–150</td>
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<tr>
<td>151–200</td>
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<tr>
<td>201–250</td>
</tr>
<tr>
<td>251–300</td>
</tr>
<tr>
<td>301 or more</td>
</tr>
<tr>
<td>Total</td>
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</tbody>
</table>
teachers from center schools and 39% from mainstream programs indicated that they had certification in mathematics or mathematics education. However, pattern differences in certification are revealed when the teachers from mainstream programs are examined relative to teaching in integrated classes or self-contained classes, $\chi^2 = 29.95, df = 2, p = .0001$. Seventy-six percent of the teachers in the integrated mainstream classes are certified in mathematics or mathematics education, compared to only 9% of teachers in self-contained classes and 41% of teachers in center schools.

Regarding the respondents’ teaching experience, the teachers from center schools had on average 13.8 years of experience in that environment, with minimal mainstream experience. Conversely, for the mainstream teachers responding to this item, their primary experience teaching deaf students was in mainstreamed environments (integrated teachers’ average = 7.5 years and self-contained teachers’ average = 12.2 years), with minimal experience in center schools. Only the mainstream teachers in integrated classes had any significant experience teaching hearing students (average 6.8 years experience).

### Survey Design

In addition to the teachers’ background and school-related information, the survey instrument was designed to collect information about the instructional approaches used in teaching mathematics word problems to deaf students.

A question was included to identify the title of the course on which teachers were basing their responses to this survey and whether they were using “at grade level” text materials. They were asked to indicate whether problem solving was a written or implied expectation for the mathematics curriculum at their respective schools. Additionally, they were asked to indicate the amount of time they allocated weekly to all problem-solving activities, specifically, on word problem solving, and the percentage of homework assignments involving word problem solving.

The subsequent survey questions were specific to the instructional process for teaching word problem solving only. It was divided into sections that focused on problem-solving strategies and teaching behaviors.

The first section of eight questions was on general

### Table 1

<table>
<thead>
<tr>
<th>Number of students</th>
<th>Center teachers ($n = 65$)</th>
<th>Mainstream teachers</th>
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<tbody>
<tr>
<td></td>
<td>$n = 65$</td>
<td>Integrated classes ($n = 24$)</td>
</tr>
<tr>
<td>1–5</td>
<td>32%</td>
<td>96%</td>
</tr>
<tr>
<td>6–10</td>
<td>46%</td>
<td>4%</td>
</tr>
<tr>
<td>11–15</td>
<td>13%</td>
<td>0</td>
</tr>
<tr>
<td>16 or more</td>
<td>9%</td>
<td>0</td>
</tr>
</tbody>
</table>

### Table 3

Educational preparation indicated by 131 respondents

<table>
<thead>
<tr>
<th></th>
<th>Center schools ($n = 69$)</th>
<th>Mainstream teachers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Integrated classes ($n = 27$)</td>
<td>Self-contained classes ($n = 33$)</td>
</tr>
<tr>
<td>In mathematics/mathematics education</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bachelor’s only</td>
<td>3%</td>
<td>19%</td>
</tr>
<tr>
<td>Both bachelor’s and master’s</td>
<td>4%</td>
<td>22%</td>
</tr>
<tr>
<td>Bachelor’s with master’s in other field</td>
<td>32%</td>
<td>15%</td>
</tr>
<tr>
<td>Master’s with bachelor’s in other field</td>
<td>1%</td>
<td>11%</td>
</tr>
<tr>
<td>In deaf education or other field</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bachelor’s only</td>
<td>9%</td>
<td>11%</td>
</tr>
<tr>
<td>Bachelor’s and master’s</td>
<td>51%</td>
<td>22%</td>
</tr>
</tbody>
</table>
problem-solving strategies. In response to the question “I teach the following general problem-solving strategies and review these strategies with my students,” the teachers indicated their frequency of instruction on a 6-point equal-interval Likert scale from 1 = never to 6 = very often for eight strategies worded exactly as follows:

- identifying the target goal (what is to be solved),
- making a plan,
- identifying the key information,
- evaluating one’s plan and solution,
- hypothesis generating and testing,
- estimating,
- testing trial and error approach, and
- dividing a problem into subproblems (two or more procedural operations).

The second section contained 20 statements pertaining to skills and practices in teaching word problem solving. The same 6-point equal-interval scale for responses was used. The 20 statements were randomly ordered and covered the following topics:

- problems for specific content domain areas (one item),
- problem representation (three items),
- teacher modeling of problem-solving process (one item),
- having students talk “out loud” or sign their thoughts as they solve (one item),
- using analogies to solve word problems (two items)
- posing new problems from given facts and situations (one item)
- problems that require active engagement through diagram representation or manipulative hands-on materials (one item)
- providing instructional and learning experiences with practice exercises that students should know and to which they can apply learned skills and formulae (exact wording of five items listed below, not in order asked on survey)
  1. I only give students problem situations that I know they have been taught the procedures for solving them.
  2. I give my students practice in representing problems that are clearly defined and easy to understand.
  3. I give my students practice with problem situations that are simple, familiar, and straightforward.
  4. I give my students practice with well-defined problem situations that have clear procedural solutions.
  5. I give my students practice with problem situations for which they should know the procedures for solving them.

The final survey section consisted of five statements asking teachers’ perceptions of their deaf students’ capabilities for solving word problems:

1. My deaf students are capable of reading a word problem and representing it in their thoughts before solving it.
2. My deaf students are capable of reading a word problem and representing it on paper using illustrations, diagrams, relational charts, etc.
3. My deaf students are capable of reading a word problem and representing it on paper in writing by identifying the target goal and organizing the relevant information for analysis.
4. My deaf students’ English skills are the primary barrier to their being able to successfully solve word problem situations.
5. My deaf students are capable of posing new problems from a given set of facts or situation.

For these five statements, the teachers were asked to respond on a 6-point equal-interval scale ranging from 1 = never to 6 = very often.
1 = strongly disagree to 6 = strongly agree. Respondents had the opportunity to add clarifying comments.

**Results**

While the original intent of this study was to examine similarities and differences primarily among two groups of teachers—from center schools and mainstream programs—the analyses for educational background and certification suggested that there were really three groups of teachers who responded to the survey. This finding gave support to analyzing the data at a more detailed level. Within the mainstream environment, there were two distinct groups rather than one: those teaching in integrated classes and those teaching in self-contained classes. Thus, the research questions will be analyzed relative to the 132 teachers responding from center schools (n = 68), mainstream integrated classes (n = 29), and mainstream self-contained classes (n = 35), who are providing mathematics instruction to deaf students.

The effect of preparation in mathematics and related certification will also be examined. For all statistical tests, we used an alpha level of .05 to reject the null hypotheses. The actual values of the statistics computed are reported for each of the tests.

**Grade Level of Texts**

There was a statistically significant difference in the teachers’ responses, \( \chi^2 = 12.05, df = 2, p = .0024 \). Ninety-two percent of the teachers in integrated classes indicated using “at grade level” mathematics texts, compared to 63% of the center teachers and 50% of the teachers from self-contained classes.

**Expectations to Teach Problem Solving**

Seventy-four percent of the 129 respondents to this question indicated that the expectations for teaching problem solving in the mathematics curriculum of their respective schools were in writing, 23% indicated that they worked under implied expectations, and 3% said there were no expectations. There were no differences in responses from the teachers in center schools or the mainstream integrated and self-contained classes, \( \chi^2 = 5.04, df = 8, p = .75 \).

**Time Spent on Problem Solving**

With respect to the total classroom time allocated per week to all problem-solving activities, there were no significant differences between teachers from center schools, integrated classes, or self-contained classes, \( F(2, 120) = 1.94, p = .15 \). Overall, 84% of the teachers responded that they allocated 6 hours or fewer per week, for an average of 3.7 hours per week. Of this, approximately 42% (~1.57 hours/week on average) was allocated to teaching word problem solving. For homework assignments, on average only 25% were allocated to word problems.

**General Problem-Solving Strategies**

Table 4 provides the means and standard deviations of the teachers’ responses to the eight categories of general problem-solving strategies described previously. The Likert responses were designed as a 6-point equal-interval scale and are treated as interval data for analysis purposes. Under these conditions, “an experimenter may choose to use a parametric test in order to take advantage of the additional information that is available” (Kirk, 1968, p. 492). Likert scores are generally treated as interval data; thus, parametric tests such as analysis of variance (ANOVA) are appropriate.

A 3 (center schools vs. integrated vs. self-contained) \( \times \) 8 (categories of general problem solving) repeated measures ANOVA was used to examine any potential differences between teachers in center schools and mainstreamed environments for the eight general problem-solving strategies. The ANOVA test for repeated measures showed that there were no differences between teachers in the three environments for teaching the eight general problem-solving strategies, \( F(2, 119) = 1.27, p = .28 \), and no group by strategy interaction, \( F(14, 833) = 1.09, p = .36 \). Similarly, there were no differences in teaching these general problem-solving strategies for teachers with certification in mathematics/mathematics education compared to teachers with certification in deaf education and other areas combined, \( F(1, 121) = .44, p = .51 \), and no group by strategy interaction, \( F(7, 847) = 1.83, p = .08 \). The estimate of reliability was \( r = .79 \) for teachers responding to these eight general problem-solving strategies. The reliability estimate was calculated.
with the procedures described by Kerlinger (1973, p. 448) using the individual and residual error variances generated by ANOVA.

The highest rated general problem-solving strategy for all teachers regardless of educational environment was “identifying the target goal (what is to be solved),” and the second highest was “identifying the key information for solving the problem.” These were followed by “making a plan,” “dividing a problem into subproblems,” “evaluating one’s plan and solution,” “estimating,” “testing trial and error,” and, last, “hypothesis generating and testing.” Pair-wise t tests comparisons for correlated means between the first two strategies in Table 4 and all other strategies were significant at the .0001 level.

### Instructional Emphases for Teaching Word Problem Solving

A summary of the mean scores of teachers from center schools and mainstream programs pertinent to the items measuring their perceived instructional emphases for teaching problem solving is provided in Table 5. Teacher responses from center schools, integrated classes, and self-contained classes all showed a similar instructional focus with respect to these items based on a repeated measures ANOVA. The analysis showed no statistically significant differences between educational environments, $F(2, 120) = 2.72, p = .07$, and no group by instructional emphases interaction, $F(18, 1080) = 1.25, p = .063$. The estimate of reliability was $r = .76$ for teachers responding to the 10 items of instructional emphases for teaching problem solving. Overall, teachers in both center schools and mainstream environments appear to give more instructional attention to concrete visualizing strategies for problem representation through diagrams, illustrations, and signing, teacher modeling, signing their thoughts, and hands-on activities. In contrast, they tend to give much less instructional attention to teaching problems for specific content, having students represent problems in writing, problem posing, and analogical reasoning. For all the respondents, the difference in teaching concrete visualizing strategies (combined $M = 4.7$) versus the other more analytically oriented problem-solving strategies (combined $M = 3.7$) was statistically significant, correlated $t = 14.21$, $df = 654$, $p = .0001$.

Teachers with certification in mathematics and mathematics education, however, did show a significant difference with respect to the more analytically oriented problem-solving strategies than those teachers with no mathematics related certification. This difference was based on an ANOVA test for repeated measures, $F(1, 125) = 5.54, p = .0202$, with a significant group by strategy interaction showing that they had a different response pattern for the five analytical strategies, $F(4, 500) = 3.72, p = .0054$. A subsequent analysis was conducted to examine for what specific analytical strategies they differed. The post hoc analysis showed that teachers with mathematics-related certification indicated a greater emphasis in three of the five analytical strategies:

1. Teaching problems for specific content domain areas ($M = 4.0$ vs. $3.4$), Scheffé’s critical difference = $0.518, p = .016$;
2. Teaching the use of analogies to understand word
problems \( (M = 4.1 \text{ vs. } 3.4) \), Scheffé’s critical difference = .468, \( p = .005 \); and

3. Using analogies to relate problem situations to current knowledge \( (M = 4.4 \text{ vs. } 3.8) \), Scheffé’s critical difference = .486, \( p = .047 \).

With respect to teaching concrete visualizing strategies, there were no significant differences between teachers with certification in mathematics and mathematics education compared to teachers without mathematics-related certification.

### Practice Exercises Versus True Problems

In addition to the instructional emphases summarized in Table 5, there were 10 items related to providing students instructional practice with practice exercises as compared to true problems (the exact wording of these 10 items is provided in the Method section under *Survey Design*). A repeated measures ANOVA revealed no significant differences between the \( M \) responses (see Table 6) of teachers from center schools, integrated classes, and self-contained classes for giving practice exercises, \( F(2, 128) = .67, p = .51 \), versus true problems, \( F(2, 126) = .93, p = .40 \). Importantly, there were no group by type of practice interaction effects, \( F(8, 512) = 1.26, p = .26 \), and \( F(8, 504) = 1.82, p = .07 \), respectively. Thus, the responses of teachers from center schools, integrated classes, and self-contained classes showed similar instructional patterns for giving deaf students practice exercises and true problems. The overall estimate of reliability was \( r = .84 \) for teachers responding to these items.

Because there were no significant differences between teachers with respect to types of educational environment, we conducted a subsequent analysis across all teachers to examine any possible differences between giving practice exercises compared to true problems. A correlated \( t \) test for paired comparisons showed that the teachers gave their practice exercises significantly more often than true problems, \( t = 19.622, df = 659, p = .0001 \). Table 6 provides the mean responses \( (M \text{ and } SD) \) of the teachers for giving their students practice exercises compared to true problems.

Mathematics certification, however, does appear to have an effect relative to teaching true problems.

### Table 5  Instructional emphases on problem-solving dimensions \((M \text{ and } SD)\)

<table>
<thead>
<tr>
<th>Statements</th>
<th>Center teachers ((n = 66))</th>
<th>Integrated classes ((n = 29))</th>
<th>Self-contained classes ((n = 34))</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Concrete visualizing strategies</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Having students represent problem situations visually on paper using</td>
<td>4.9 (1.2)</td>
<td>5.3 (0.8)</td>
<td>4.7 (1.4)</td>
</tr>
<tr>
<td>diagrams, illustrations, charts, etc.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Having students represent problem situations using signs or by speaking</td>
<td>4.7 (1.3)</td>
<td>4.3 (1.3)</td>
<td>4.8 (1.0)</td>
</tr>
<tr>
<td>Teacher modeling of problem solving procedures</td>
<td>4.9 (1.2)</td>
<td>5.3 (1.1)</td>
<td>4.9 (1.1)</td>
</tr>
<tr>
<td>Having students think “out loud” by talking or signing their thoughts as</td>
<td>4.4 (1.4)</td>
<td>4.4 (1.5)</td>
<td>4.7 (1.1)</td>
</tr>
<tr>
<td>they solve problems</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Giving practice with problems requiring active engagement in</td>
<td>4.3 (1.4)</td>
<td>4.7 (1.3)</td>
<td>4.3 (1.1)</td>
</tr>
<tr>
<td>representing through diagrams or hands-on</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Analytical strategies</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teaching problems for specific content domain areas</td>
<td>3.4 (1.6)</td>
<td>4.1 (1.5)</td>
<td>3.6 (1.4)</td>
</tr>
<tr>
<td>Having students represent problem situations in writing</td>
<td>3.8 (1.3)</td>
<td>3.8 (1.3)</td>
<td>3.9 (1.3)</td>
</tr>
<tr>
<td>Having students pose new problems from given facts and information</td>
<td>3.5 (1.3)</td>
<td>3.8 (1.4)</td>
<td>3.5 (1.1)</td>
</tr>
<tr>
<td>Teaching the use of analogies to understand word problem situations</td>
<td>3.5 (1.4)</td>
<td>4.2 (1.1)</td>
<td>3.7 (1.5)</td>
</tr>
<tr>
<td>Using analogies to relate problem situations to knowledge and information</td>
<td>3.8 (1.4)</td>
<td>4.7 (1.0)</td>
<td>3.8 (1.5)</td>
</tr>
</tbody>
</table>

*Center teachers = 64, integrated classes teachers = 29, self-contained classes teachers = 33.*
ers certified in mathematics showed a statistically significant difference for giving deaf students practice with true problems when compared to teachers without mathematics certification, $F(1, 659) = 7.36, p = .0068$. The mean responses and standard deviation for mathematics certified teachers was $M = 3.2 (SD = 1.3)$ compared to those without mathematics certification, $M = 2.8 (SD = 1.4)$. No group differences occurred for giving practice exercises, $F(1, 661) = 1.06, p = .303$. However, both teachers with and without mathematics certification still gave relatively more attention to practice exercises ($M = 4.4$ and $4.3$, respectively) than true problems, similar to the pattern shown in Table 6.

Teacher Perceptions of Students’ Abilities to Solve Word Problems

The final survey section consisted of five statements asking teachers for their perceptions of deaf students’ capabilities for solving word problems. Table 7 presents the mean results and standard deviations for the teachers’ perceptions. A 3 (center schools vs. integrated vs. self-contained) × 5 (perceptual statements) ANOVA for repeated measures was conducted to see if there were any differences as to how the teachers from the three educational environments responded to the five perceptual statements. Whereas the analysis showed a statistically significant difference for how the three groups of teachers responded, there was a significant group interaction by perceptual statements, $F(8, 488) = 6.27, p = .0001$. This interaction indicates a differential pattern of perceptions for at least one group of teachers. Table 7 provides the $M$ responses for the teachers from the three different types of educational programs, and Figure 1 provides a graphic representation of their patterns of responses. The post hoc analyses showed that the teachers from integrated mainstream settings had higher perceptions of their students’ problem-solving capabilities for the following three areas:

1. Capable of representing word problems in their thoughts, compared to teachers in self-contained classes: Scheffé’s critical difference = .694, $p = .019$;
2. Capable of representing word problems graphi-
cally, compared to teachers in both center schools and self-contained classes: Scheffé’s critical differences = .639 and .716, respectively, \( p = .026 \) and \( .001 \), respectively; and

3. Capable of representing word problems in written form, compared to teachers in both center schools and self-contained classes: Scheffé’s critical differences = .680 and .765, respectively, \( p = .013 \) and \( .004 \), respectively.

Conversely, the mathematics teachers in integrated mainstream settings had significantly lower perceptions compared to center teachers (\( p = .001 \)) and self-contained teachers (\( p = .023 \)) that English skills are the primary barrier for deaf students success in solving word problems, Scheffé’s critical difference = .784 and .881, respectively. All teachers from the three types of programs had similar perceptions regarding deaf students’ capabilities for posing new problems from a given set of facts or situation, with no significant differences shown using Scheffé’s test. The overall estimate of reliability was \( r = .65 \) for teachers responding to these perceptual items.

An examination of the responses of teachers with certification in mathematics and mathematics education compared to those without mathematics-related certification also showed a significant difference in perceptions, \( F(1, 645) = 15.79, p = .0001 \). The mathematics-certified teachers’ perceptions of their deaf students’ capabilities to solve word problems was similar to the responses of teachers from integrated classes shown in Table 7 and Figure 1 (76% of whom were mathematics certified).

**Discussion**

The primary purpose of this study was to examine how teachers provide instruction in mathematics word problem solving to deaf students in grades 6–12. In addition to discussing the results, recommendations are also pro-
vided for teacher preparation programs and further research.

Educational Preparation and Certification

As expected (based on previous research and knowledge of the field), the majority of teachers from mainstream integrated classrooms held mathematics-related degrees or certifications, while less than half of the teachers from center schools and just five from mainstream self-contained classrooms had such backgrounds. Conversely, the majority of teachers from center schools and mainstream self-contained classrooms held deaf education degrees. Upon reflection, these distributions are predictable for several reasons. Public schools look for certification in mathematics as their first priority for teachers of mathematics, and any deaf students taught by these teachers are integrated into their assigned courses. Center schools also look for certified mathematics teachers but have the additional need for experience or certification in education of deaf students, making it more difficult to find teachers qualified in both areas. For self-contained classes, however, the public schools appear to be primarily looking for teachers prepared in the education of deaf students to teach in a resource room or the like. These teachers tend to teach all subjects; therefore, a mathematics background or certification may not be these schools’ top priority. Regardless of the reasons, it is clear that in two of the three school settings deaf students are receiving mathematics instruction from teachers who are not qualified by education or certification to teach mathematics and related problem-solving skills. In the remaining setting, students are being taught by teachers who have not been educated in the specific needs of deaf learners. Additional research is needed to compare the relative advantages of teachers’ educational and experiential preparation and the quality of problem-solving instruction.

Using “At Grade Level” Mathematics Text Materials

Results from this study show that the reported use of “at grade level” texts is also predictable. The survey design, however, did not include a question about whether texts were below or above grade level. It can be assumed, based on what is known of deaf students’ mathematical performance and achievement, that they are primarily using “below grade level” texts. Students in self-contained classes in mainstream programs are generally assigned to this setting because they need assistance in one or more subjects to “catch up.” If they were “at grade level,” they would likely be moved to an integrated classroom fully mainstreamed for mathematics. The fact that the vast majority of the teachers in integrated classes are using “at grade level” mathematics text materials suggests they are teaching deaf students who are functioning in mathematics at the same level as their hearing peers. This may (at least partially) explain their differential perceptions of deaf students’ abilities to solve mathematical word problem solving.

Time Spent on Problem Solving

Similar patterns occurred across all groups for the amount of weekly time responding teachers spent on teaching word problems and assigning word problems for homework. While the time spent on these tasks may seem reasonable, whether it is sufficient depends on the quality of this instructional time. Based on their responses to other items in this survey, teachers, unfortunately, use this time to focus on application of procedures to practice exercises rather than true problems (Table 6) and give more emphasis to visualizing strategies rather than analytical strategies (Table 5). Teachers’ responses suggest that they focus more on surface cues, language comprehension, and exercise drills rather than on analytical strategies and cognitively challenging problems. Subsequent analyses regarding teachers’ perceptions (especially those from center schools and self-contained classes) of deaf students’ capabilities to solve word problems and teachers’ preparation in mathematics may contribute to the limited problem-solving experiences they give deaf students.

General Problem-Solving Strategies

The analyses for teaching the eight general problem-solving strategies indicated that regardless of instructional environment or mathematics certification, teachers showed similar response patterns. Results suggest that teachers of deaf students give considerable attention and time to the comprehension of word problems
and pre-problem-solving set-up and much less to the in-depth aspects of solving problems and analysis of the problem’s solution strategies. While focusing on understanding the meaning of the printed text in the word problems is important, comprehension of problem variables alone is insufficient for a successful problem solver. At the minimum, one must then take the problem variables and make a realistic plan to account for them, divide a problem into subproblems depending on the complexity, and evaluate and reevaluate one’s plan and solution. Further strategies may also be necessary for some problem problems, including estimation, trial and error, and generation and testing of a hypothesis. The overemphasis by teachers on understanding the problem may logically be attributed to meeting the deaf students’ generally lower English-language (or reading) abilities reinforced by most of their perceptions that English is the primary barrier to deaf students’ ability to successfully solve word problems.

Instructional Emphases for Teaching Word Problem Solving

The teachers’ responses presented in Table 5 and the related data analyses parallel the pattern for general problem-solving strategies. While concrete visualization is clearly an excellent strategy for understanding variables in a word problem, it is insufficient by itself for advanced problem solving. Students’ experiences with recognizing and solving problems related to specific content domains, representing problems in written English, posing new problems from given information, and using analogies to relate problem situations to knowledge already known is critical for success. Unfortunately, the teachers’ responses indicate that they give relatively less instructional attention to these aspects of problem solving. Further, there is evidence suggesting that teachers of deaf students tend to avoid the more cognitively challenging aspects of word problem solving. Though a partial explanation for this once again may be a response to deaf students’ difficulties with English, it may also relate to poor curriculum and texts that focus on problem solving as an application of a learned algorithm and not as the basis for constructing knowledge. In addition, teachers’ insufficient preparation in mathematics may be a factor in their inability to adequately teach this topic, as evidenced by results showing those with mathematics certification giving greater emphasis to three of the five analytical strategies. Teachers without certification and background in mathematics may not be as generally aware of the importance of these more analytical problem-solving strategies and, certainly, would not be professionally prepared to teach them.

Practice Exercises Versus True Problems

Results from the survey also showed that teachers across settings give deaf students problem exercises more than true problems. Since true problems are generally more complex in terms of language, information, and variables to consider, a plausible explanation may be that teachers perceive true problems as too difficult for deaf students’ language abilities and cognitive functioning. It may also be related to curriculum and texts that focus instruction in this manner. Clarifying qualitative statements written on the survey by a number of teachers support the notion that they often provide students simple (one-step), straightforward, familiar problems and avoid complex (multistep), unfamiliar problems.

Regardless of the reasons, the teachers’ overemphasis on problem exercises has implications for deaf students’ preparation for postsecondary study and for their abilities to solve problems on the job or in real-world situations. These data also confirm earlier findings regarding teacher practices showing that teachers maintain (at least somewhat) a traditional perspective in their mathematics instruction and use of word problems (Pagliaro, 1998a; Pagliaro & Ansell, 2002). This study shows that teachers of deaf students continue to place relatively less emphasis on the development of critical thinking, reasoning, synthesis of information, and other essential skills needed for effective problem solving. In educating deaf students, the traditional curriculum’s emphasis on drill and practice-type problem-solving instruction appears to remain in vogue.

Teachers’ Perceptions of Deaf Students’ Word Problem-Solving Capabilities

The data clearly show a difference between teachers from different settings and educational backgrounds regarding student ability perceptions (Table 7 and Figure
That teachers from mainstream integrated classes have a higher perception of deaf students’ problem-solving abilities may stem from the fact that deaf students in this setting are more likely to be at grade level in the curriculum. Teachers, therefore, may have developed similar perceptions and expectations for all students, deaf and hearing alike. In addition, these teachers may have limited experiences with deaf students and are basing their perceptions on the few deaf students in their classes (as indicated in Table 2).

The perception held by teachers in center schools and self-contained classrooms that deaf students are less able to solve word problems was attributed primarily to students’ abilities and skills with English. There may be several reasons for this. First, teachers from these settings, who primarily have backgrounds in the education of deaf students, may be more attuned to the language issues of deaf students. Therefore, they may either be able to recognize the link between difficulties with English and mathematics or erroneously come to believe that English-language skills are the basis for most learning problems associated with students who are deaf and thus focus their instruction solely in this area. A second contributing factor may be the influence and effect of teaching experience with hearing students. The teachers from both center schools and self-contained classrooms had minimal to no teaching experience with hearing students. Primarily prepared to be educators of deaf students with no comparative experiences teaching hearing students, they may have developed perceptions and expectations of deaf students without the context of a broader perspective. Many hearing students have similar difficulties with word problems. Deaf students’ problem-solving capabilities need to be evaluated against those of the general population.

Regardless of the reasons for teachers’ perceptions and expectations of students, they have been shown to influence student behavior and performance (Rosenthal & Jacobson, 1968). Therefore, teachers’ low expectations of their deaf students’ abilities may actually factor into the students’ performance with mathematics word problems. Those teachers across settings with a mathematics background had higher expectations of the deaf students. This finding, coupled with those that showed these teachers also provided more analytical problem-solving instruction and true problems, supports the view that more positive perceptions and expectancies held by these teachers, in combination with their educational preparation in mathematics, influence the rich learning activities they provide to all students, including those who are deaf.

In summary, the responses to this survey study by teachers who provide mathematics and problem-solving instruction to deaf students lead to a number of conclusions relative to classroom instruction and professional preparation of teachers.

Recommendations for Classroom Instruction

Results of this study strongly suggest that teachers of deaf students typically do not challenge their students cognitively in solving mathematics word problems. The lack of challenge appears to be related to a number of contributing factors: (1) insufficient teacher preparation in mathematics leading to unsuitable decisions on word problem-solving instruction, (2) low teacher perceptions and expectations of deaf students’ capabilities limiting student opportunities to learn from true problem-solving situations, and (3) the perception that English skills are the primary barrier to learning, causing teachers to emphasize comprehension strategies and cues and to neglect the complete process of problem solving.

Teachers cannot expect deaf students to perform well at problem-solving tasks if they do not give them opportunities to be engaged in cognitively challenging word-problem situations. The time spent on problem-solving tasks and word problems must consist of high quality and meaningful teaching–learning activities that build knowledge and do not simply focus on the application of algorithms.

Professional Preparation of Teachers

Preparation and certification in mathematics make a difference in the kinds of mathematics word problem-solving instruction provided to deaf students, especially for the more analytical and cognitively challenging aspects. Though this study does not examine the effect of teacher preparation on student achievement, past research in mathematics has indicated the benefits of such (Bodenhausen, 1988; Cooney, 1994). Teachers on all
levels of the curriculum need to be prepared with strategies to strengthen problem solving, critical thinking, and metacognitive skills. They must provide students with the opportunities to think—to synthesize information, research, discover, and build knowledge and understanding through authentic and meaningful tasks. As Marschark et al. (2002) explain, teachers with poor preparation in content often resort to didactics because lecturing offers more control over the instruction and the type of questions asked. The NCTM standards strongly encourage a departure from such teacher-centered approaches, advocating student-centered instruction and discovery learning. Better understanding of the standards and reform-like constructivist learning may also help teachers perceive the goals of promoting cognitive development. On all levels, training in content and best practices may influence teaching and learning. Pagliaro and Ansell (2002), for example, summarized how primary-level teachers at center schools who took at least one methods course in mathematics incorporated story problems with a significantly higher frequency than did those with no coursework.

A comprehensive professional development approach is needed for teachers of mathematics to infuse true problem-solving practices into the curriculum on a continual basis. This includes pedagogy, content, and assessment. Teachers need to be informed as to the benefits of instructing students to solve word problems effectively. We call on teacher preparation programs to address this issue in their preservice curriculum and in their professional support to in-service teachers. We also urge schools and programs for deaf students to hire teachers with adequate preparation in mathematics.

In conclusion, we strongly recommend additional research to examine the efficacy of mathematics preparation and knowing problem-solving content, to determine the origin and impact of teacher perceptions, and to identify best practices for those teachers providing mathematics and problem-solving instruction to deaf students.

Notes

1. The term deaf refers to both deaf and hard-of-hearing students.

References


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