Using Technology to Meet the Developmental Needs of Deaf Students to Improve Their Mathematical Word Problem Solving Skills

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Abstract

“Project Solve” addresses, in an innovative and practical way, a critical problem facing most deaf college students and other learners with special needs—inequitable preparation and practice in problem solving and analytical thinking. Supported by a grant from the Fund for the Improvement of Postsecondary Education (FIPSE), U.S. Department of Education, Project Solve will provide web-based problem-solving instruction and guided practice for mathematical word problems. While deaf college students are the primary audience, this project has clear implications for other college students for whom reading and comprehension of mathematical word problem solving is difficult, especially Learning Disabled (LD) students. This project also has instructional implications for high school students who are college bound, and who face similar difficulties with reading comprehension, problem-solving logic, and organization.

Introduction

According to a recent national study of deaf readers, the median reading level for deaf 18-year-olds was a 3.9 grade equivalent* compared to hearing readers (Gallaudet Research Institute, 1996). Nevertheless,

* Deaf students at 18 years of age on average read at about the same level as typical normally hearing students in the 4th grade. Only approximately 3% of 18-year-old deaf people in the United States read at the same level as an average hearing reader of the same age (Center for Assessment and Demographic Studies, 1991).
approximately 24,000 deaf college students are now enrolled in over 2,500 post-secondary institutions across the country (Rodriguez, 2000; The National Center for Educational Statistics, 1994, 1999). Of these students, more than 12,000 deaf and hard-of-hearing students are enrolled in 2-year post-secondary education programs and almost 11,000 in 4-year institutions. Furthermore, it is estimated that only 8% of the deaf students enrolled in post-secondary programs read at the 8th grade level or higher (Allen, 1994). The functional reading ability of deaf students will certainly affect their learning performance in all of their college courses, including mathematics and word problem solving. However, research has shown that deaf college students can improve their problem-solving performance with strategy instruction (Mousley & Kelly, 1998).

Educators in mathematics education for deaf students have long targeted mathematics word problem solving and general reasoning skills as critical areas of emphasis (Daniele, 1993; Dietz, 1994; Pagliaro, 1998). The research documents that deaf students do not perform well in problem solving tasks, achieving well below hearing students (Traxler, 2000).

Linguistic content of the problems combined with the English language abilities of deaf students have been considered the primary contributing factors to their difficulties with mathematics in general, as well as with word problems in particular (Barham & Bishop, 1991; Pagliaro & Ansell, 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. 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 as compared to outside mathematics; multiple ways of expressing a single concept; and varied forms, abbreviations, and symbols. These language difficulties of deaf students continue into their college years.

Kelly and Mousley (2001) studied reading comprehension of deaf college students for mathematical word problems. The findings showed that deaf students' problem solving performance decreased on mathematical word problems as the computational information increased. While reading ability level was associated with the deaf students' lower scores when solving the mathematical word problems, the analyses showed that other factors also contributed to the decline of their scores. These other factors included computation errors (rather than procedural errors), leaving word
problems blank, and a negative, disengaged approach to the mathematical word problem solving tasks. These results show that successful mathematical word problem solving by deaf students involves more than reading comprehension.

In another study Kelly, Lang, Mousley, and Davis (2003) examined deaf college students’ ability for solving compare word problems where the relational statements were either consistent or inconsistent with the arithmetic operation required for the solutions. The results showed that the deaf students were more likely to miscomprehend a relational statement and commit a reversal error when the required arithmetic operation was inconsistent with the statement’s relational term (e.g., having to add when the relational term was less than). Also, the reversal error effect with inconsistent word problems was magnified when the relational statement was a marked term (e.g., a negative adjective such as less than) rather than an unmarked term (e.g., a positive adjective such as more than). Reading ability levels of deaf students influenced their performance in a number of ways. As predicted, there was a decrease in goal monitoring errors, multiple errors, and the number of problems left blank as the reading levels of the deaf college students increased. Contrary to expectations, higher reading skills did not affect the frequency of their reversal errors.

Unfortunately, the situation of deaf students entering college poorly prepared for mathematics and mathematical word problem solving will continue for some time. A recent survey by Kelly, Lang, and Pagliaro (2003) of teachers who provide mathematics instruction to deaf students (in grades 6-12) shows that the majority of instructors teaching mathematics and word problem solving to deaf students lack adequate preparation and certification in mathematics to teach these skills. Furthermore, 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 as compared to true problem solving situations. Both practice exercises and true problems are written, and thus, verbal in nature. 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, 1994, p. 6). 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). 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, Smith emphasizes that in solving true problems the task requires analysis and reason that must be based on understanding the content involved.

Teachers of deaf students also place more emphasis on problem features (e.g., identifying both the target goal to be solved and the key information), possibly related to concerns about language and reading skills of their students, and much less emphasis on analytical and thinking strategies. Consistent with these emphases, teachers gave more instructional attention to concrete visualizing strategies as compared to analytical strategies. Thus, cognitive and experiential factors combine with deaf students' linguistic deficits to hinder the development of good mathematical word problem solving skills.

Project Solve

Project Solve offers college and high school teachers a platform to provide deaf and LD students independent assignments for practicing and improving their analytical thinking and problem solving skills without restructuring their courses. Their web site provides a range and variety of word problems presented in language typically found in first-year college mathematics courses. An optional help menu provides clear concise written and graphic information to guide students with a range of reading abilities (8th-12th grade) through each mathematical word problem. Thus, while deaf and LD students are challenged with solving high school and college level mathematical word problems, they have readable guidance help options available at their ability levels. This web program is available daily on a 24-hour basis, giving students independent, unrestricted access to problem-solving instruction and guided practice. The primary goals for Project Solve are:

1) To develop an asynchronous web site providing guided practice and instruction for mathematical word problem solving to deaf college and high school students.

2) To evaluate the overall effectiveness of the web site as a practical on-line problem solving resource in the education of deaf students.

3) To widely disseminate the problem solving web site resources, including information to enhance pre-service and in-service teacher education for grades 9-12 programs.

4) To evaluate the effectiveness of the problem solving web site with LD students having learning disabilities for reading and mathematics, and to appropriately modify the web site.
The Project Solve web site (http://problemsolve.rit.edu/) is designed to provide a large bank of mathematics word problems to solve with guided help. The “Help” provided is based as much as possible on what is known from educational research about the linguistic and experiential factors that explain why deaf and hard-of-hearing students struggle with a variety of mathematical word problems. For each word problem in the Project Solve item pool, customized Help guidance is provided for that specific problem. Listed below is a brief description of the optional Help buttons available to guide students through each word problem:

The Question button: What is the problem asking for?

Given button: What information is given in the word problem?

Find button: What other information does the student need to know or calculate?

Definition button: Definitions are provided for key vocabulary or explanations of important terms used in the problems in order to help students increase their understanding of the word problems.

Graphic button: Animated illustrations or other graphic representations are provided to help students visualize the word problem.

After the students understand the problem, they try to solve it and then type their answer in the window labeled "Your Response" followed by clicking on the Submit Response button. Once they submit, the correct answer then appears along with a Show Me How button. The Show Me How button gives one clear example of a step-by-step procedure for solving that specific problem. Students are cautioned that there are often several ways to solve a mathematical word problem, and they are only being shown one procedural approach.

The Project Solve item pool includes a variety of mathematical word problems for students to practice in the following categories:

<table>
<thead>
<tr>
<th>A. Arithmetic</th>
<th>B. Algebra – one variable and two variable problems</th>
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<tbody>
<tr>
<td>- Fractions</td>
<td>- Communicating with symbols/literal expressions</td>
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<tr>
<td>- Variation</td>
<td>- Coin problems</td>
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<tr>
<td>- Percents (fractional and decimal)</td>
<td>- Consecutive integer problems</td>
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<td>- Averages</td>
<td>- Age problems</td>
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<tr>
<td>- Conversions</td>
<td>- Investment problems</td>
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<td>- Mixture problems (percents)</td>
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<td>- Motion/distance problems</td>
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<td>- Work problems</td>
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<td>- Probability problems</td>
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<td></td>
<td>- Logarithms</td>
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The mathematical word problems in the item pool were selected for inclusion by reviewing the types of problems on several standardized tests as well as from high school textbooks.

Project Solve has just completed its initial year of a three-year FIPSE grant. During this initial year, 125 mathematical word problems with full guidance help were added to the item pool. The goal is to add 100 mathematical word problems per year during the second and third years of the grant for a total of 325 practice problems distributed among the arithmetic and algebra categories listed above. Initially, field test procedures will be conducted in selected high school and post-secondary settings in the northeast, primarily in the states of New York, Pennsylvania, and New Jersey. In subsequent years, field test procedures will be expanded to other states and Canada.

Summary

Project Solve will provide a practical operational instructional avenue by which the students can improve their mathematical word problem-solving skills through practice combined with guidance and feedback. Importantly, the guided practice environment is not dependent on the schedule of tutors and school instruction. Thus, students will have a readily accessible independent learning option. Project Solve will also collect data on the students’ problem-solving performance, thus offering the potential to develop a database in a wide range of problem-solving situations. And finally, the teacher information page will provide informational links and guidance for how teachers can utilize this web site to improve their students’ mathematical word problem solving skills. In addition, it will also give directions on how teachers can contribute to the item pool of the practice word problems. The goal of this approach is to assure a sufficient and increasingly wide selection of relevant and challenging mathematical word problems in the web site item pool. It is hoped that teachers who contribute to the item pool will be more likely to have their students use the web site to independently practice their problem solving skills.

Project Solve is funded in part by the U.S. Department of Education Fund for the Improvement of Postsecondary Education. For further information on this project, contact Ronald R. Kelly at rrknep@rit.edu.
References

Allen, T.E. (1994). Who are the deaf and hard-of-hearing students leaving high school and entering postsecondary education? Paper submitted to Pelavin Research Institute as part of the project, A Comprehensive Evaluation of the Postsecondary Educational Opportunities for Students who are Deaf or Hard of Hearing, funded by the U.S. Office of Special Education and Rehabilitative Services.


