http://doi.org/10.35847/LGinsburg.4.3.66

Research Digest

Mathematical Word Problems in Adult Education: What the Research Says

Lynda Ginsburg, Rutgers University (retired)

Mathematical word problems, sometimes called story problems, are generally defined as "verbal descriptions of problem situations, presented within a scholastic setting, wherein one or more questions are raised the answer to which can be obtained by the application of mathematical operations to numerical data available in the problem statement or on numerical data derived from them" (Verschaffel et al., 2020, para. 1). The problems are positioned as representing how math is applied in real life, although in real life there is usually less clarity about the specific questions that need to be answered as well as the available situational data. Students are urged to limit their focus to the facts or data which is provided within the word problem itself.

Students of all ages encounter mathematical word problems, and they are an ongoing challenge for many students and their teachers. Over the last 50 years, many researchers have looked at a variety of word problems, creating classification schemes based on the linguistic aspects of the problems as well as on their mathematical demands. Further, researchers have analyzed samples of student work and responses to these problems as well as the students' relevant affective factors as they attempt to solve the problems. This research has primarily been focused on young children and elementary school students younger than 13 or 14 years of age. A summary of some of this literature is available in review articles (see Daroczy et al., 2015; Verschaffel et al., 2020).

Here, I report on recent research (from 2015 to the present) that focuses on how and when adult learners, including those in adult education settings, community colleges, early college, or late high school, encounter word problems and the strategies they and their instructors might employ to increase success in solving them. This is important because word problems are commonly found in mathematics assessments, particularly for high stakes purposes such as high school equivalency tests (GED, HiSet) or for educational placement purposes. Adult education program funding is often dependent upon evidence of student progress as demonstrated by performance on standardized mathematics tests. Therefore, most published instructional materials provide some word problems. In addition, large-scale, cross-national assessments (i.e., PIAAC) measure numeracy levels by including word problems.

Do Word Problems Represent the Mathematics of Adult Learners' Real Worlds?

Word problems are often promoted as a means of demonstrating that classroom mathematics is relevant and useful in the outside world and can be applied in a variety of everyday situations.

Correspondence: ginsburg@scarletmail.rutgers.edu

For adult learners, this rationale is of particular significance because they are likely simultaneously managing their own and family members' everyday lives, holding jobs, managing money, and having responsibility for housing while participating in their own education. Adult learners recognize that they encounter and must use mathematics daily (Ginsburg & Waldron, 2021).

However, some have questioned whether the word problems appearing on assessments and in instructional materials actually do represent the lived experiences of most adult learners. Bright (2017) asked 58 graduate students to examine word problems in curricular materials and they found that many problems represented middle-class ideals and experiences. For example, problems focused on calculating area and/or perimeter by describing redecorating projects that would be most likely undertaken by home owners with disposable income rather than renters with more limited funds available. Bright notes that some might argue that middle-class contexts can be seen not as problematic for learners but rather as "aspirational," that is, included to provide less-privileged students with suggestions for things or goals they may aspire towards (p. 18).

Indeed, whether these real world examples are unfamiliar or aspirational, they do not provide meaningful contexts that represent the lived experiences of most economically struggling adult learners. Thus, the learners are unlikely to be able to draw upon their own experiences to find meaning in the stories or to be able to employ their own informal mathematical strategies to help solve the problems.

While Bright (2017) discusses issues of privilege and inequity, it might also be argued that the issue of the contexts of word problems differs somewhat for immigrants who are learning about the culture of a new country so as to be able to function well within it. Maphosa and Oughton (2021) interviewed adult learners in England who had immigrated from Zimbabwe and found they struggled with and became anxious about problems with "real-life contexts" because the contexts were unfamiliar to them. For example, some learners were unfamiliar with cooking turkey for Christmas holiday so problems about time measurements for cooking turkeys of different weights were meaningless to them. One of their instructors explained that while she could and does use example recipes from other cultures during instruction, such examples will not show up on the assessments because the assessments are culturally British based.

Yet, using word problems that represent aspects of the real-world contexts of the adult learners helps them see the relevance of their math study, going from the classroom to their real-world lives. In addition, since the learners are adults and really do currently manage their activities in the real-world (managing money, shopping, working, participating in social groups, etc.), they likely have developed (independently or through informal means) strategies that are useful and meaningful to them. These personal strategies can be shared, examined, and considered for accuracy, usefulness, and transferability to other contexts, thus going from real-world lives to the classroom.

What Are the Steps to Solving a Word Problem?

Another aspect of word problems that often challenges learners is how to actually solve them. When word problems are presented, students are expected to go through a sequence of steps to complete the problem. These steps are:

1. read/decipher the problem;

2. create a mathematical model of the situation (often called mathematizing);
3. solve the problem using mathematics; and,
4. reflect on the solution for its reasonableness.

The first two steps are discussed here.

Reading the Problem

Reading word problems effectively is a meaning making process that involves decoding and comprehension about the situation presented. (See Walkington et al., 2018, for a discussion of readability factors such as problem length, word difficulty and pronouns.) For adult learners, including English language learners, however, understanding what the words actually mean may be an issue. For example, a problem might include polysemous words, meaning words with a specific mathematical meaning that are commonly used in daily life with other meaning(s). Examples include yard, table, base, similar, mean, odd, even, face, proper and product. Further, researchers refer to the challenge of the mathematics register, meaning the styles of communication used by the mathematics disciplinary community (Herbel-Eisenmann et al., 2015). Word problems are often presented using elements of the mathematics register with which learners may not be familiar and thus have difficulty understanding the implied meaning of the problem.

In addition, Orrantia et al. (2015) found that low-skilled adults' performance in correctly solving word problems was impacted by the format in which numbers were presented. When numbers were presented as Arabic digits rather than as the number words (i.e., 70 vs. seventy), problem solving speed and accuracy improved, particularly when larger numbers were involved. Therefore, the authors suggest that "the format in which numbers are present affects the calculation mechanisms and not just the encoding processes." (p. 277).

Creating a Mathematical Model of the Situation Described in the Word Problem

A mathematical model is created during the problem-solving process when the solver transfers the information provided in the problem to a symbolic mathematical format through visualizing the problem situation, identifying relevant mathematical concepts, discarding irrelevant information, and making sense of the relationships described. (Jupri & Drijvers (2016). Unfortunately, as most adult educators would agree, some students do not create mathematical models of word problems, but rather grab all the numbers in the problem and use them in some way, even if the answer makes no sense. Their rationale seems to be that if a number is there, it must need to be used.

However, Di Lonardo Burr et al. (2021) found that *irrelevant* numbers within word problems did not contribute to college students' errors when solving problems. The problems used in their research were provided in two forms, as in the following example (the italics represent the manipulated information):

> Amy, a museum tour guide, was busy preparing for the next big tour. *She picked up 15/some maps. She put down 15/some maps* and collected payment from the tour group attendees. She collects $56 in total. If each person in the group paid $7, how many people are in her tour group? (p. 263)

The college students were able to ignore the irrelevant numbers; their errors were due to using an incorrect operation (i.e., multiplication instead of division) or arithmetic errors. However, there is no research to indicate whether the results would be the same with adult basic education learners.

In a somewhat related study, Givven et al. (2019) investigated whether changing word problems by removing opportunities to calculate solutions

allowed community college, developmental education students to focus more directly on the relationships in the problem. They operationalized this by providing students with three problems in either "calculable" and "non-calculable" conditions. An example of a "non-calculable" problem is "Andrew was planning a big party for his friends. He found a bakery that had amazing cupcakes and wanted to make sure each person could have seconds. The bakery only sells the cupcakes in boxes of six. How many boxes does he need to buy?" (p. 11). Note that since the number of people attending the party is not included, a simple numerical solution is not possible. Instead, subjects were asked to "write an explanation of each problem that they thought would help another student understand the problem" (p.3). A follow-up study asked that the explanations also include a diagram. All subjects were then asked to solve four transfer test questions, including one far transfer item. The researchers found that across both studies, the number of students from the non-calculable group answering the far transfer items correctly was three times as great as the number from the calculable group, suggesting that the non-calculable students may have become more inclined to apply sense-making strategies than those who jumped to calculate quickly. The study was relatively small in scale, but it does suggest that focusing on the relationships within word problems rather than merely focusing on the procedures needed for a solution can be beneficial.

Instructional Strategies that Support Word Problem Solving

Adult educators want to help their students be successful in solving mathematics word problems and want to provide them with a simple strategy with which to attack problems. Frequently, they encourage students to read the problem and then underline or otherwise note the "key words" that may denote mathematical procedures. Then, it is suggested that the students use those words to guide the process of solving the problems. However, researchers have found this strategy to be ineffective and not used by successful word problem solvers. Verschaffel, et al (2020) states:

> Indeed, roaming around the research field of word problem solving, one encounters numerous examples of well-documented persistent errors due to learners' failure to inhibit superficial erroneous response tendencies. This is, for instance, the case for learners' failure to inhibit the strong association between the keyword "more" and the operation "add" in problems such as "Pete has 8 apples. He has 5 more apples than Ann. How many apples does Ann have?" leading to the erroneous response 13 (instead of 3) (p. 9)

Such superficial problem-solving strategies might be fostered by the relative positioning of word problems during instruction. Indeed, many commonly used instructional materials provide extensive practice with procedures, and then include a few word problems at the bottom of the page. Often, learners do not even have to read or understand the word problem – if the mathematical procedure being practiced on the page was "adding fractions," they can pretty confidently assume that the same procedure will need to be used with the numbers in the word problem.

The research summarized in this section suggests that developing learners' word problem solving skills requires a change in typical instructional practices: word problems must be an important focus of mathematics instruction and should forefront instruction, not just be an add-on at the bottom of the page. Two instructional strategies are suggested.

Create Word Problems Representing the Students' Real Worlds

As noted above, word problems that are promoted as reflecting real-world applications may not actually reflect the real worlds of adult learners.

Word problems situated in meaningful contexts help learners see when, where, and how mathematics is, or can be, used in their lives as well as provide them with opportunities to reflect on and examine their own mathematical practices. Jorgensen (2015) provides a framework and suggestions for helping instructors design more authentic word problems for their classroom instruction and a rubric for gauging the extent to which word problems simulate real-world mathematical situations.

Encourage and Value Student-to-Student Conversations When Solving Problems

An important step in solving word problems is to create mathematical models of the problems. This involves reasoning about the problem situation to see how the story can be re-envisioned as a mathematical situation. Since this is not a straightforward translation task, but rather a reasoning and envisioning process that must be developed, sharing one's thinking and ideas can be useful in this process. Givvin et al (2019) cited research showing that the process of explaining problems to oneself or to another person leads to enhanced learning and effective problem solving, when "explaining" does not simply mean listing a series of computation steps.

Since all adult learners come with their own earlier learning trajectories, real-world experiences, and ways of managing everyday situations, they may have also developed their own personal problem-solving strategies and both formal and informal mathematical reasoning. Through the task of explaining their own thinking and hearing the explanations of others, they enhance their ability to reason about mathematical situations depicted in word problems (National Council of Teachers of Mathematics, 2013).

A variety of problem types can be used to trigger discussions, including meaningful problems that have multiple answers and problems that can be solved with multiple strategies. For numberless problems, students can be directed to answer questions such as "What do you know about the answer?," "Can there be more than one answer?," "How do you know?"

Finally, Stacey (2016) reports on an additional benefit of encouraging such discussions in an adult mathematics class. In a small study, she found that English language learners in the UK, who were voluntarily taking an ESOL math class in addition to their ESOL class, improved their English language skills more than did non-participating ESOL students, as measured on ESOL exams. This may be because the students worked in pairs on verbal problem solving and observers found that the students interacted in the discussions in English at higher levels than they did in their ESOL classes.

Conclusion

The recent research on mathematical word problems provides guidance on instructional practices that help adult learners become more successful in solving such problems when they are encountered on high stakes assessments, but also empowering them to develop the mathematical reasoning that can be used outside of the classroom as well. As technologies (such as handheld calculators, computers, telephone apps) are more frequently being used for arithmetic computation, and even increasingly allowed on assessments, adults have less need to practice and demonstrate procedural skills. Instead, adults need to be able to find mathematical meaning in situations, decide how to go about solving problems with mathematical components, determine what computational procedures can

be applied, and then evaluate if solutions are sensible and meaningful. To help build such mathematical reasoning skills, word problems should be in the forefront of math instruction rather than as add-ons.

It would be beneficial to the field to have additional research on how adult learners, particularly those at the high school equivalency level, come to develop the mathematical reasoning skills needed to solve word problems on assessments, in real-life situations and the transfer process between them. In addition, studies of how adult education instructors modify their practices to include more emphasis on word problem solving would inform professional development initiatives.

References

Bright, A. (2017). Education for whom? Word problems as carriers of cultural values. *Taboo: The Journal of Culture and Education*, 15(1), 6-22. https://doi.org/10.31390/taboo.15.1.04

Daroczy, G., Wolska, M., Meurers, W.D., & Nuerk, H.-C. (2015). Word problems: A review of linguistic and numerical factors contributing to their difficulty. *Frontiers in Psychology, 6*(Article 348). https://www.frontiersin.org/articles/10.3389/fpsyg.2015.00348/full

Di Lonardo Burr, S., Turner, J., Nietmann, J., & LeFevre, J.-A. (2021). When does the story matter? No evidence for the foregrounding hypothesis in math story problems. *Journal of Numerical Cognition*, *7*(3), 259-274. https://jnc.psychopen.eu/index.php/jnc/article/view/6053/6053.pdf

Ginsburg, L., & Waldron, S. (2021). *Adult learners' reported use of mathematics in their current and future lives. Report for SABES Mathematics and Adult Numeracy Curriculum & Instruction PD Center at TERC*. SABES. https://www.sabes.org/sites/default/files/resources/Adult_Learners_Reported_Use_of_Math_web_0.pdf

Givvin, K.B., Moroz, V., Loftus, W., & Stigler, G.W. (2019). Removing opportunities to calculate improves students' performance on subsequent word problems. *Cognitive Research: Principles and Implications, 4*(24). https://cognitiveresearchjournal.springeropen.com/track/pdf/10.1186/s41235-019-0175-2.pdf

Herbel-Eisenmann, B., Johnson, K.R., Otten, S., Cirillo, M., & Steele, M.D. (2015). Mapping talk about the mathematics register in a secondary mathematics teacher study group. *Journal of Mathematical Behavior*, *40*(Part A), 29-42. https://doi.org/10.1016/j.jmathb.2014.09.003

Jorgensen, M. (2015). Simulating outside-the-classroom maths with in-class word problems. In A. Hector-Mason, & S. Beeli-Zimmermann (Eds.), *Adult learning mathematics—Inside and outside the classroom*. Proceedings of the 21st International Conference of Adults Learning Mathematics – A Research Forum (ALM), June 29 to July 2, 2014 (pp. 135-140). University of Bern, Switzerland. https://www.alm-online.net/wp-content/uploads/2014/07/alm2015-proceedings-alm21-complete.pdf

Jupri, A., & Drijvers, P. (2016). Student difficulties in mathematizing word problems in algebra. *Eurasia Journal of Mathematics, Science & Technology Education, 12*(9), 2481-2502. https://doi.org/10.12973/eurasia.2016.1299a

Maphosa, N., & Oughton, H. (2021). "What am I doing here?" Perspectives of Zimbabwean adult learners on the relevance of adult numeracy to their needs and aspirations. *Adults Learning Mathematics: An International Journal*, *15*(1), 19-44. https://alm-online.net/wp-content/uploads/2021/11/almij151.pdf

National Council of Teachers of Mathematics. (2013). *What does research say the benefits of discussion in mathematics class are?* https://www.nctm.org/Research-and-Advocacy/Research-Brief-and-Clips/Benefits-of-Discussion/

Orrantia, J., Múñez, D., San Romualdo, S., & Verschaffel, L. (2015). Effects of numerical surface form in arithmetic word problems. *Psicologica*, *36*, 265-281. https://www.uv.es/psicologica/articulos2.15/4ORRANTIA.pdf

Stacey, J. (2016). Does adding mathematics to English language learners' timetables improve their acquisition of English? *Adults Learning Mathematics: An International Journal, 11*(2), 52-57. https://www.alm-online.net/wp-content/uploads/2016/12/almij_full_issue_vlast+1.pdf

Verschaffel, L., Schukajlow, S., Star, J., & Van Dooren, W. (2020). Word problems in mathematics education: A survey. *ZDM-Mathematics Education, 52*(1), 1-16. https://doi.org/10.1007/s11858-020-01130-4

Walkington, C., Clinton, V., & Shivraj, P. (2018). How readability factors are differentially associated with performance for students of different backgrounds when solving mathematics word problems. *American Educational Research Journal*, *55*(2), 362-414. https://doi.org/10.3102/0002831217737028