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Work in Progress: Role of Conceptual Modeling in the Students’ Ability to Solve Word Problems

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Work in Progress: Role of Conceptual Modeling in the Students' Ability to Solve Word Problems

Introduction:

Word problems are a common form of problem solving found in engineering education and one that many students struggle with. Word problems contain a quantitative problem embedded in a narrative or story. The first steps in the solution of word problems include: the development of a model to represent a problem, understanding the concepts and principles to apply for the solution of a problem, and devising an approach to solve the problem. Those first steps are essential for the proper solution of a word problem.

To extract information from the first steps of the engineering problem solving approach, the investigators propose the use of prompts that are incorporated into word problems and that students will answer while solving those problems. Those prompts were designed to allow the investigators to determine if the appropriate principles were identified, if an appropriate model was developed, and if the proposed approach was suitable for the solution of the problem.

To better understand those first steps and the suitability of the use of prompts in word problems, the following questions were addressed in this study: a) how can adding prompts to word problems help us better understand the first steps of the problem solving approach?, b) are those prompts sufficient to extract information from the first steps of the problem solving approach?, and c) does the use of prompts interfere with students ability to solve word problems?

This study will benefit engineering programs searching for ways to identify issues in students' problem solving skills and looking for ways to correct those deficiencies.

Background:

Word problems are the type of problems most frequently solved in engineering programs. Word problems are classified based on their complexity, content, and structuredness [1].

To provide a consistent metric to evaluate student work, rubrics are used in education to evaluate word problems. Rubrics are evaluation tools that help measure performance and learning based on a given set of criteria and objectives. Several rubrics have been developed and used to assess students' ability to solve word problems. Permatasari and colleagues [6] implemented a four indicator problem solving rubric based on: Identification of the Problem, Planning a Solution, Implementing a Solution, and Evaluation. The rubric, which implemented a 1-4 scoring scale, was tested in a Physics class with 55 senior high school students [5]. Another rubric implemented in Physics uses 44 sub-skills split in different categories: knowledge, beliefs, expectations and motivations, and processes [6]. That rubric was used to evaluate problem solving skills in students enrolled in courses from College Algebra to Introductory Calculus [6].

The first steps in solving a word problem involve a) being able to understand the problem and b) to identify principles and concepts required to solve it. A concern with rubrics developed to assess problem solving skills is that most are developed to assess the later stages of problem solving.

The work in this paper is based on Jonassen's research in problem solving. According to Jonassen’s Design Theory of Problem Solving, to solve story problems the learner needs to develop a conceptual model of the problem that integrates the math and engineering concepts reinforced in the problem and the story being described [1]. That model also integrates the operations necessary to solve the problem [1]. Most problem solving rubrics don’t evaluate those initial steps that Jonassen considered essential for problem solving.

Methodology:

Participants: Forty-one first semester engineering students participated in the study. Students were all enrolled in a first year engineering course. Students were enrolled in College Algebra at the time of the study. The group included 7 females (17%) and 34 males (83%), which is representative of the gender distribution in our First Year Engineering Program at West Virginia University. The study was reviewed and approved by the WVU Institutional Review Board (IRB).

Assessment: Students were given several problem solving assessments throughout the semester. Those problem solving assessments were included in quizzes and exams and were aimed at understanding students’ ability to solve word problems. Several prompts were added to the problems to understand students’ ability to construct an appropriate model of the problem, and the ability to identify key engineering and math concepts necessary to solve the problem. A third prompt was added to understand how the student planned to approach the solution of the problem.

Examples of prompts added to the problems to extract information during problem solving include:

> Prompt 1: In your own words, describe the major engineering and math principles and concepts needed to solve the problem.
>
> Prompt 2: Prepare a diagram/figure illustrating the problem.
>
> Prompt 3: What plans do you have for approaching and solving this problem?

Some examples of the problems analyzed include:

Problem 1: When concentrations of formaldehyde in the air exceed 33µg/ft3 (1µg = 1 microgram = 10^{-6} gram), a strong odor and irritation to the eyes often occurs. One square foot of hardwood plywood paneling can emit 3365 µg of formaldehyde per day. A 4-ft by 8-ft sheet of this paneling is attached to an 8-ft wall in a room having floor dimensions of 10-ft by 10-ft.

- If there is no ventilation in the room, write a linear equation that models the amount of formaldehyde (F) in the room after x days.
- Find the total number of micrograms of formaldehyde that are released into the air by the paneling each day.
- How long will it take before a person’s eyes become irritated in the room?

Problem 2: A chemical engineer is working with a company to market a new blend of coffee that sells for $3.90 per pound by mixing two coffees that sell for $2.75 and $5.00 per pound, respectively. What amounts of each coffee should be blended to obtain the desired mixture? Assume that the total weight of the desired blend is 100 pounds.

Data Analysis: Problems were graded based on correctness of the solution. A total score was assigned to each problem. In addition, each prompt presented was analyzed.

Analysis of the principles and concepts: Principles and concepts were analyzed based on whether the information presented was correct or wrong.

Analysis of the diagram: Diagrams were analyzed based on whether the representation was correct, vague/incomplete, or wrong.

Analysis of the plan to solve the problem: The appropriateness of the plan was analyzed based on whether the plan was correct, incomplete, or wrong.

Results:

This study represents the first time the investigators add prompts to word problems to gather information about students' thinking process and the first steps followed by students while solving word problems.

Students' ability to identify major engineering and math principles and concepts: The concepts and principles defined by students as necessary to solve those word problems were categorized based on whether those were correct or incorrect (which include vague information provided). For both problems presented in this paper, approximately 50% of the students defined the appropriate concepts and principles necessary to solve the problem. Examples of appropriate concepts include: mixture problems, systems of equations, and linear equations. Incorrect answers include critical thinking, known and unknowns, mathematics, problem solving skills, accuracy, precision, among others.

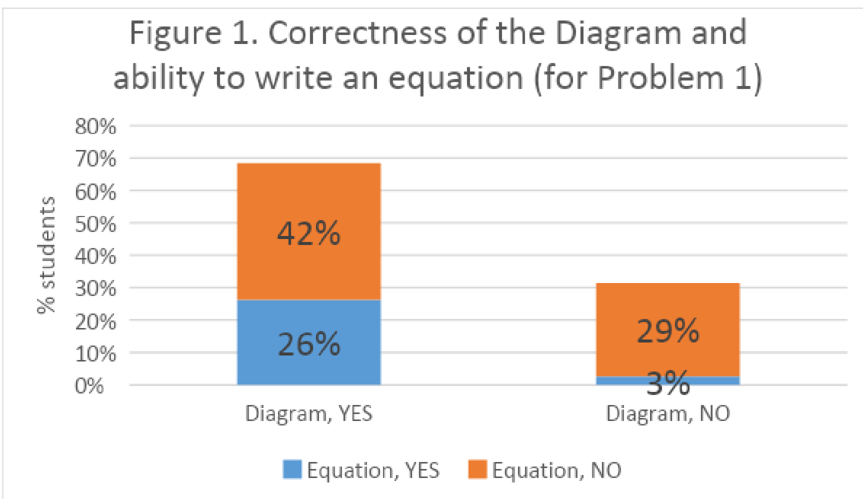

Figure 1. Correctness of the Diagram and ability to write an equation (for Problem 1)

Students' ability to represent a problem using a figure/diagram: Since students are normally not asked to prepare a representative diagram when solving problems, some of the students' representations of the problem were either incomplete or incorrect. Incomplete diagrams were missing information, whereas other diagrams prepared contained the wrong information. Both incomplete and incorrect diagrams received a grade of “No” in the analysis because they were insufficient to fully describe the problem.

In terms of the analysis of the diagram, it was found that students that had the diagram wrong were unlikely to create an algebraic representation of the problem (see Figure 1, result for Problem 1). According to Figure 1, for question 1, 32% of the students had the diagram wrong, and of those, 29% were unable to write the correct equation to solve the problem. Similar results were obtained for Problem 2 (data not shown).

<u>Students’ plan to approach and solve the problem</u>: Only 26% of the students had an appropriate plan to solve problem 1 and 31% had an appropriate plan to solve problem 2. Some of the plans were found to be superficial and not applicable to the problem.

Some of the plans written by students that were not applicable (graded as incorrect) are:

> “Think about what the questions ask in reference to what is given. Consider things from different angles.”
>
> “I would approach this problem by creating an exhaust system of a fan that takes the air out of the room and keeps it fresh. As the problem mathematically, I would start by making some equations to find how much formaldehyde is in the room at a certain time. “

It could be possible that some of the students did not understand the question, whereas others may not have an appropriate plan on how to approach the problem.

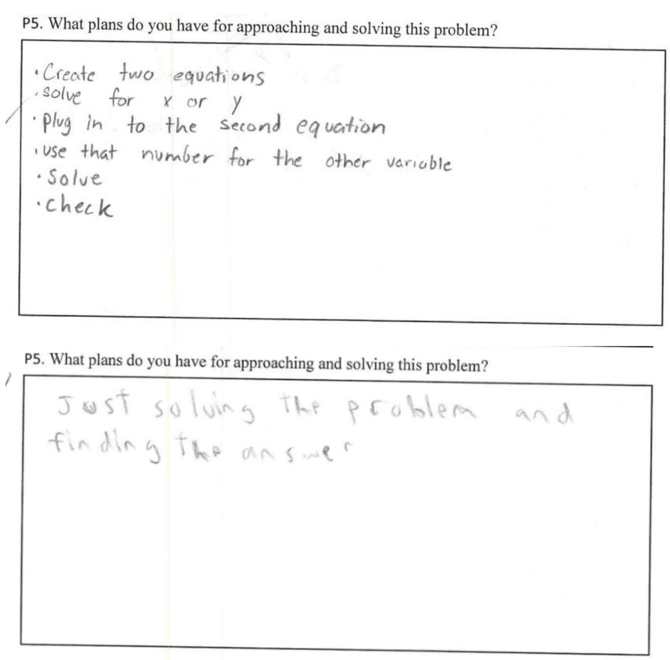

Figure 2. Examples of appropriate (figure above) and incomplete/unacceptable (figure below) plans

Student’s ability to find the correct solution to the problem: The majority of the students that had the equation or equations correct, had the final answer to the problem correct. They did not struggle in solving one or more equations. If the equation or equations were wrong, for the most part, the final solution to the problem was incorrect.

Discussion:

Adding prompts with questions to a word problem helped us better understand how students solve word problems. Those prompts allowed us to extract meaningful information from students’ answers.

For the purpose of this paper, we are only including the analysis of two word problems. We are currently analyzing additional problems to further understand students’ challenges solving word problems. We are especially interested in the role of the first steps of problem solving (creating an appropriate diagram, generating correct equations), in finding the appropriate solution to a word problem.

In terms of identifying concepts and principles needed to solve the problems, some students were unable to indicate the appropriate concepts and principles necessary to solve the problems. One reason for this could be that they may not understand the meaning of “principles and concepts”. The second reason could be that some students don’t prioritize identifying concepts/principles when they are solving word problems. Training students on what constitutes appropriate principles and concepts is needed to avoid general comments such as math, critical thinking, and accuracy in their answers.

In these word problems, students were asked to create a diagram that represents the problem. Some of the students did not include enough information or some of the information added was wrong. In addition, if the instructor doesn't ask students to create a diagram of a problem, the student will not do it. This was seen in our previous work on problem solving and was one reason we implemented the use of prompts in this study.

A major challenge for students was found to be in generating equations from a word problem. Students could visualize the problem, but struggle to understand how to translate the visualization of the problem into math language and equations. The inability to represent a word problem in terms of equations is hampering their ability to solve word problems. Once the appropriate equation (or equations) was found, the solution was reachable.

One key point observed from the solution presented by students was that many of them used “guess and check” to solve problems instead of using algebraic manipulation to solve equations. “Guess and check” appears to be considered by students as a valid mathematical method for solving problems. Further exploration of this observation is needed, especially, since this preferential approach could signal a deficiency in procedural knowledge.

The prompts used in this study did not allow us to specifically understand why many students are unable to create a mathematical model (equation) to represent a problem algebraically. For future work, we also recommend that students need to be trained on what we expect from them when answering those types of prompts.

When students are presented with metacognitive prompts during their solution of word problems, they are able to reflect on their understanding of the problem. The failure of students to adequately answer some of the prompts, as observed in this study, have also been documented by other investigators [15].

In terms of limitations of the work, we noticed that students took a longer time solving word problems when prompts were added to a problem. This limits the amount of problems we could use in an assessment. We also learned that students need to be trained on how to answer prompts and on how to create appropriate diagrams prior to the collection of data.

Since this research is work in progress, at this point we are still analyzing word problems and working in the development of a detailed grading rubric to better understand students' ability to define the first steps of solving word problems. We have been using the answers to word problems to decide what an acceptable and unacceptable answer is. The goal is, for each word problem, to have each of the prompts evaluated using 3 levels of performance, and evaluated by multiple reviewers. Then, we will address the validity, reliability, and consistent scoring of that final assessment method.

Conclusion:

The use of prompts allowed us to extract meaningful information from students' answers without influencing students' ability to solve problems. It was found that some students are unable to visualize the problem using a diagram, and also unable to generate appropriate equations to represent a problem. We also found that some students had the diagram correct, but still were unable to generate the equation (or equations) to solve the problem. The step of representing a word problem into an appropriate equation seems to be challenging for problem solving.

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