BOARD # 303: Teaching Students How to Solve Story Problems: Lessons Learned from a Metacognitive Study

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NSF IUSE - Teaching Engineering Students How to Solve Story Problems: Confidence of Judgement During Problem Solving

Introduction

Problem-solving is at the heart of engineering. Broadly speaking, problem-solving has been defined as “a goal-directed sequence of cognitive operations” that is essential for everyday situations [1-2]. In engineering programs, students are trained to become proficient problem-solvers.

Engineers tackle a variety of problems, and story problems, also known as word problems, are the most common type encountered in formal education. These problems present a quantitative challenge embedded in a narrative or story [1-2]. To enhance students' problem-solving skills, it is important that they can accurately assess the correctness of their solutions.

Confidence judgments play a central role in research in metacognition [3-6]. In typical problem-solving tasks, students first arrive at a solution and then rate their confidence in it. Confidence judgments tend to be more accurate when made immediately after solving the problem. However, a lack of experience in solving word problems often leads students to either overestimate or underestimate the accuracy of their solutions.

This study summarizes the approach used to evaluate confidence judgments after solving word problems. Additionally, we present results of confidence judgments from first-semester non-calculus ready students immediately after they begin their first semester in college.

As we train future engineers to design buildings, bridges, and provide solutions to real-world problems, it is vital to emphasize the importance of developing sound and accurate judgment. The safety and welfare of the public depends on these judgments.

Methodology

This study was conducted at a land-grant institution in the Mid-Atlantic region. At the time of the study, all participants were first-semester engineering students enrolled in College Algebra. Ninety-five (95) students completed a pre-assessment test designed to evaluate their ability to solve algebra-based word problems and to evaluate the accuracy of their confidence judgments. Sixteen (16) females and seventy-nine (79) males completed the assessment. The study was approved by the Institutional Review Board.

Problems were graded and analyzed not only for correctness but also for the accuracy of students' confidence in their judgments. For each problem solved, students' confidence of judgment was classified as either accurate, somewhat accurate, or inaccurate. Table 1 summarizes how the accuracy was assessed for each confidence of judgement. Student’s judgment was considered accurate if the absolute value of the difference between their confidence of judgment represented as a fraction and score for the problem represented as a

fraction was less than or equal to 0.25. Judgement was considered somewhat accurate if the result from that calculation was greater than 0.25 but less or equal to 0.5. Judgement was considered inaccurate if the result from that calculation was greater than 0.5.

Accuracy = |confidence of judgement represented as a ratio – solution score represented as a fraction|

The closer the difference is to zero, the more accurate is the students' confidence of judgement. Some examples of the calculations are shown in Table 1. Students could be accurate, overconfident, or underconfident in their solution to a word problem.

Table 1. Evaluation of Students' Confidence of Judgement

Accuracy of the Judgement	**Examples of Calculation |predicted-obtained|**	**Example of problem**
Accurate: Value is less or equal to 0.25	|0.3-0.1|=0.2	Student was 30% sure of the correctness of the solution and solution was 10% correct (0.5/5 score)
Somewhat accurate: Greater than 0.25, but less or equal to 0.5	|0.7-0.4|=0.3	Student was 70% sure of the correctness of the solution and the problem was 40% correct (2/5 score)
Inaccurate; student in overconfident: Greater than 0.5	|0.8-0.1|=0.7	Student was 80% sure of the correctness of the solution and the problem was 10% correct (0.5/5 score)
Inaccurate; student was underconfident: Greater than 0.5	|0.1-1|=0.9	Student was 10% sure of the correctness of the solution and the problem was 100% correct (perfect score of 5/5 score)

Figure 1 illustrates some of these scenarios in terms of accuracy of judgement.

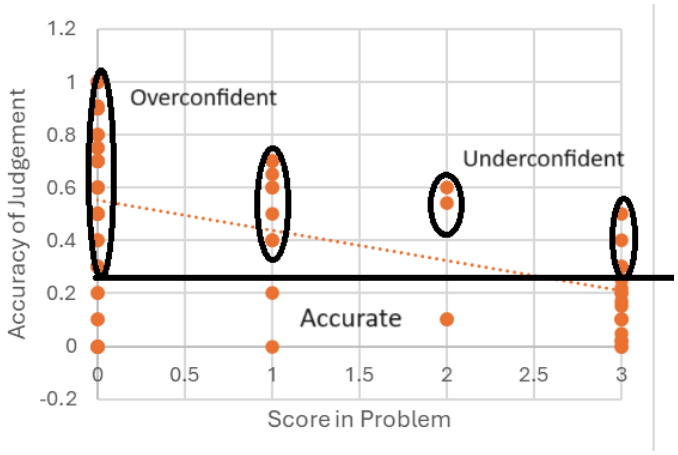

Figure 1. Students' confidence of judgement. The maximum score was 3 points.

To further explain the process used to evaluate students' judgement of confidence, several examples of mathematical problems are presented:

Problem 1: A model rocket is fired in a vertical plane and the velocity v(t) is measured as shown in the following figure:

V(t) [m/s]	t [s]
34.3	0.5
19.6	2.0

The velocity satisfies the equation $v(t) = v_0 + at$, where v_0 is the initial velocity in m/s and a is the acceleration in m/s^2.

Find the equation of the line $v(t)$ and determine both the initial velocity v_0 and the acceleration a.

Problem 2: A circular swimming pool, 20 feet in diameter, is enclosed by a white wooden deck that is 3 feet wide. What is the area of the deck? How much fence is required to enclose the deck?

Problem 3: Two pumps of different sizes, working together can empty a fuel tank in 5 hours. The larger pump can empty this tank in 4 hours less than the smaller. If the larger pump is out of order, how long will it take the smaller one to do the job alone?

Students were asked to rate on a scale from 0 (no confidence) to 100 (fully confident) how confident they were that their solution to each problem was correct.

Results

Figure 2 describes the accuracy of confidence judgement as a function of score obtained in the problem. Based on the results, we observed high levels of overconfidence and under confidence in all pre-assessment problems. The percentage of students that their confidence level accurately predicted their score in those problems were 58% for problem 1 and 31% for problem 2 and 54%

for problem 3. The level of difficulty of the problem seems to affect students' ability to accurately predict the correctness of their solution. More problems are being analyzed to determine if this pattern continues. Moreover, these students also solved engineering word problems, and those problems are being analyzed.

One of the overall goals of this work is to help students calibrate their judgement after solving a word problem. In this study, we are looking at the accuracy of the students' confidence of judgement and at how accurate students' judgement is in first semester first-year students. Good calibration is essential in making proper decisions as it helps students evaluate the risks and benefits of different options based on their confidence level.

Although the analysis for this paper was completed using mathematics word problems, we are currently analyzing engineering word problems. These problems combine engineering concepts with math topics of varying levels of difficulty. These engineering word problems were embedded in the material discussed in an engineering problem solving course, including in the in-class activities and the homework.

Figure 2. Accuracy of Judgement as a function of score per problem. The maximum score was 5 points for problem 1, 3 points for problem 2, and 5 points for problem 3.

This information is being used to understand students' problem-solving capabilities and their ability to accurately judge their solution to a problem. An intervention to improve students' accuracy of judgement was developed by the investigators and is currently being tested in first year engineering students. This work will be presented in future publications.

Conclusions

To summarize, we have observed both overconfidence and under confidence in the judgement of first-year engineering students. The accuracy of student judgement varied based on the level of difficulty of the problem. The relationship between the level of difficulty of the problem and the accuracy of student judgement is currently being studied. A good and accurate judgement is essential in engineering. Improvements in the accuracy of judgement could lead to better grades in courses, as students will be better at judging their knowledge and at identifying their deficiencies in knowledge.

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References

1. D.H. Jonassen, "Designing research-based instruction for story problems," Educational Psychology Review, 2003, pp. 267-296.

2. D.H. Jonassen, "Toward a design theory of problem solving," Educational technology research and development, vol. 48, no. 4, 2000, pp. 63-85.

3. D.L. Dinsmore and M.M. Parkinson, "What are confidence judgments made of? Students' explanations for their confidence ratings and what that means for calibration," Learning and Instruction, vol. 24, 2013, pp. 4-14.

4. L. Bol, et al., "The calibration accuracy of middle school students in math classes," J. Res. Educ., vol. 21, 2010, pp. 81-96.

5. J.D. Huff and J.L. Nietfeld, "Using strategy instruction and confidence judgments to improve metacognitive monitoring," Metacognition and Learning, vol. 4, no. 2, 2009, pp. 161-176; DOI 10.1007/s11409-009-9042-8.

6. G. Schraw, "Measuring metacognitive judgments," Handbook of metacognition in education, Routledge, 2009, pp. 427-441.