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The Effect of Context on Student Performance on a Homework-Style Problem

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Abstract

Homework problems can be designed with different levels of context, that is, different amounts of narrative, visual elements, and additional information (whether pertinent or not). The level of context in a problem might be beneficial or detrimental depending on the learner's level of understanding and the instructor's learning goals. It stands to reason, for instance, that a problem with only basic and pertinent information might be beneficial for someone wrestling with a particular analysis for the first time, whereas a problem that better resembles a real-life scenario might provide a learner the opportunity to practice far transfer with a skill that is nearly mastered.

In this work-in-progress, student performance on a problem-solving task is studied. Two groups of students are presented with fundamentally the same problem. However, one group's version of the problem contains only the information necessary to solve the problem, while the other group's version contains additional details in the form of further narrative description and a figure. Each student is asked to rate how well they can connect the problem to principles and methods previously discussed in class and how confident they are that they can solve the problem. Students then time themselves solving the problem.

Analysis of student responses shows that students presented with even a low level of additional problem context will report decreased confidence in their ability to connect the problem to past learning and in their ability to solve the problem. Additional context also increases the time students take in solving the problem, but does not seems to have a statistically significant impact on performance, as measured by arriving at a correct solution.

Introduction

Expert problem-solvers know that the most important step in solving a problem is often the first one: properly defining (or understanding) the problem [1-3]. This can take different forms in different contexts, but it usually it involves separating relevant from irrelevant information and generating a problem representation that can be tied to prior knowledge. This "setting up" of a problem is a crucial part of any engineering design or analysis. Without a good problem definition, there will not be a good solution. However, defining a problem is a skill that takes time and practice to develop. Many undergraduate engineering students need both explicit instruction and careful guidance to become effective at defining problems.

Unfortunately, the end-of-chapter practice problems found in many text books short-circuit the process of understanding or defining a problem. Usually these homework-style problems are written with terse descriptions that only contain information relevant to solving the problem. They may also include a visual representation that is already simplified or idealized when compared to the physical system being investigated. These problems can be considered context-poor problems, because they have had background information that would be present in a real-world problem filtered out. Such background information could include more elaborate narrative, additional, unnecessary information, and/or visual representations of the system that are closer to its physical realization.

In many ways, making homework-style problems context-poor is logical. Because these problems present only pertinent details, they should reduce cognitive load [4-5] by limiting student need to process additional information and decide what is useful. This should help students focus on features of the problem that are important for its solution and make the problem-solving process easier. However, this also means that students no longer have opportunities to practice sifting information in order to understand or define the problem, and may therefore be at a disadvantage when dealing with more context-rich, ill-structured problems later in their education or as practicing engineers.

In fact, work done in the physics community suggests that there are many advantages to having students work with context-rich problems [6-7], including increased use of diagrams and conceptual thinking. Some research has even considered having students transform context-rich problems to context-poor problems to teach them about the problem-solving process [8]. For these reasons, engineering education should consider the use of more context-rich problems and research in this area should be expanded. In one early study, Prince and Hoyt [9] identify many of the issues with homework-style problems, including omission of the critical problem definition stage and potential difficulty in transferring learning to real-life scenarios. In fact, they suggest context-rich problems as an "intermediate" stage of a 3-tier curriculum for teaching problem solving. However, they do not offer any study of these types of problems or provide evidence regarding their effectiveness. Antonenko et al [10] also identify context-rich problems (which they term "multi-faceted problems") as a middle ground between typical homework-style problems and real-world challenges. They use specialized software to track how students tackle such problems to try and understand how students develop more expert-like problem solving strategies. However, they do not consider the impact of added context on student perceptions or performance, leaving the question of advantages and disadvantages of context-rich problems open.

Thus, this study investigates student self-efficacy and performance on a problem-solving task presented in both context-poor and context-rich versions to see if additional context impairs student problem-solving effectiveness. This work builds on an earlier study [11] that did not consider performance aspects. Student self-efficacy is assessed through self-reported ratings of ability to connect the problem to prior knowledge and confidence in ability to solve the problem. Student performance is assessed by whether the problem is solved correctly and how long it takes to arrive at a solution.

Methodology

Fourth-year students in a system dynamics course participated in this study. Individual students were presented with either a context-poor or context-rich version of a problem that involved using a transfer function to determine the amplitude of a system's response to a particular sinusoidal input. The context-poor version of the problem included only necessary information, whereas the context-rich version of the problem included additional narrative description and an image specifying that the problem was about sensitive electronic components mounted in an engine compartment. Both versions of the problem are shown in Figure 1.

A)

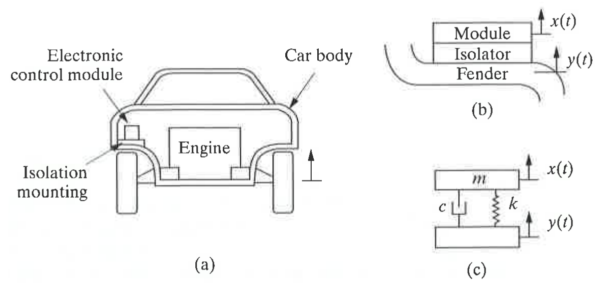
The transfer function between a particular system's input $y(t)$ and output $x(t)$ is given by

$$\frac{X(s)}{Y(s)} = \frac{0.8s + 400}{s^2 + 0.8s + 400}.$$

The response of this system should not exceed an amplitude of 4. Will it remain within this specification when it experiences an input of $y(t) = 10\sin(30t)$?

B)

Sensitive electronics used to control an automobile engine are to be housed inside an engine compartment as shown in the figure below. The electronics need to be isolated from the motion of the car body to protect them from damage and fatigue. Thus, the module is mounted on an isolator.



The transfer function between the electronics displacement $x(t)$ and the car body displacement $y(t)$ is given by

$$\frac{X(s)}{Y(s)} = \frac{0.8s + 400}{s^2 + 0.8s + 400}.$$

If the electronics can tolerate vibration 4 mm or less in amplitude and the input from the car body is given by $y(t) = 10\sin(30t)$ mm, will the electronics be sufficiently protected by the isolator?

Figure 1: Sinusoidal transfer function problem. Context-poor version (A). Context-rich version (B). Image is from Inman's *Engineering Vibration* [12]. Reprinted by permission of Pearson Education.

Students received a particular version of the problem to work as an individual homework exercise. The problem packet consisted of three pages. The first page was a cover sheet instructing students to complete each page in order and to use a stopwatch or other device when performing the timed task. It also included the following information about the study (which was also read aloud prior to handing out the packets):

> This survey is part of a study regarding the design of quantitative problems in engineering. Each person has been assigned a problem. Please review your problem and indicate how much you agree or disagree with the statements that follow. Because different people may receive different problems, please do not consult others during the survey and do not allow your problem or responses to be viewed by anyone else. Should you wish, you may choose not to participate. Thank you in advance for taking part in this exercise to better understand engineering education.

The second page of the problem packet showed the problem, in either of the forms shown in Figure 1. Students were asked to respond to prompts about the problem without trying to solve it. The complete list of prompts presented to students as well as the five-point Likert scale for response is shown in Figure 2. Here a response of "Strongly Disagree" was coded as a one, with subsequent responses increasing by one up to "Strongly Agree" which was coded as a five. The prompts related to self-efficacy focused on in this paper are Q2: I can see which principles and methods discussed in class are relevant to this problem and Q5: I am confident that I could solve this problem.

Q1: I am interested in this problem.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
☐	☐	☐	☐	☐

Q2: I can see which principles and methods discussed in class are relevant to this problem.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
☐	☐	☐	☐	☐

Q3: The scenario presented in this problem seems realistic.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
☐	☐	☐	☐	☐

Q4: I am curious about the solution to this problem.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
☐	☐	☐	☐	☐

Q5: I am confident that I could solve this problem.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
☐	☐	☐	☐	☐

Q6: A practicing engineer might need to solve this problem.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
☐	☐	☐	☐	☐

Figure 2: The prompts for surveying students about their perceptions of the problem presented on page two of the packet.

On the third page of the packet, the same version of the problem was reproduced, along with space to attempt its solution. Students were also provided a fill-in-the-blank space to indicate the time they spent attempting the problem.

The study was designed so that approximately half of the students surveyed received the context-poor version of the problem and half received the context-rich version. Due to uneven response rates, 19 students provided responses to the context-poor version while only 14 students provided responses to the context rich-version.

Two-tailed Student's t-tests were used to determine if there was a significant difference between the responses of the context-poor and context-rich student groups in terms of the self-efficacy prompts, the time spent working on the problem, and the correctness of the final solution. Here solution correctness was coded as either correct (1) or incorrect (0).

Results

Figure 3 shows the percentage of students responding to the prompt “I can see which principles and methods discussed in class are relevant to this problem” with a particular Likert score. These charts demonstrate that students with the context-poor problem were better able to connect the problem to class content. A t-test confirms a significant difference (p-value=0.002) between the average Likert score for the context-poor problem (4.79) and the context-rich problem (4.21).

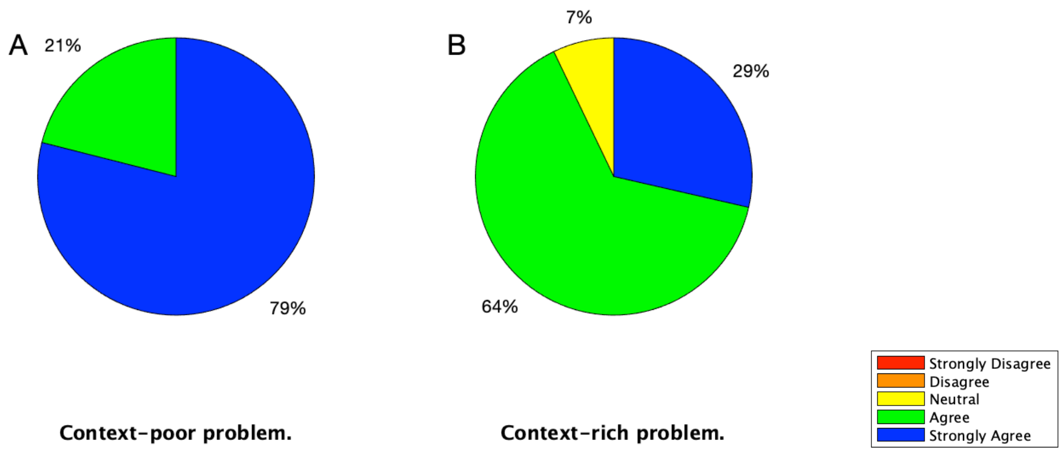


Figure 3: Student responses to the prompt regarding establishing connections between the problem and class.

Figure 4 shows the percentage of students responding to the problem “I am confident that I could solve this problem” with a particular Likert score. These charts demonstrate that students with the context-poor problem were more confident in their ability to solve the problem. A t-test confirms a significant difference (p-value=0.040) between the average Likert score for the context-poor problem (4.26) and the context-rich problem (3.64).

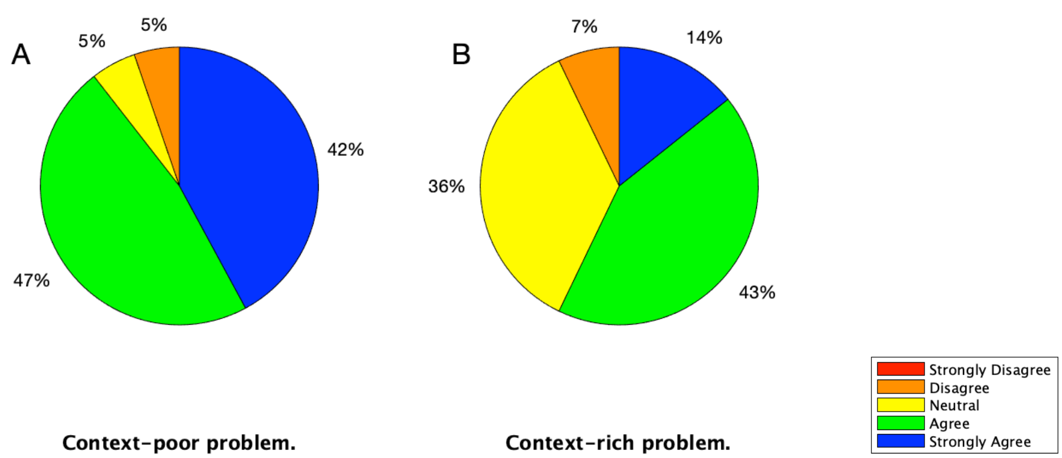


Figure 4: Student responses to the prompt regarding confidence in being able to solve the problem.

Figure 5 shows the time taken by students to solve the problem for either the context-poor or context-rich version. Students with the context-poor version took an average of 4.6 minutes to solve the problem while students with the context-rich version took an average of 7.7 minutes. Note that this is ***after*** removing an outlier from the context-rich data that would have make the average context-rich time 9.3 minutes. (The outlier student took 30.5 minutes on the problem.) A t-test confirms a significant difference (p-value=0.006) between the average time taken for the context-poor problem and the context-rich problem.

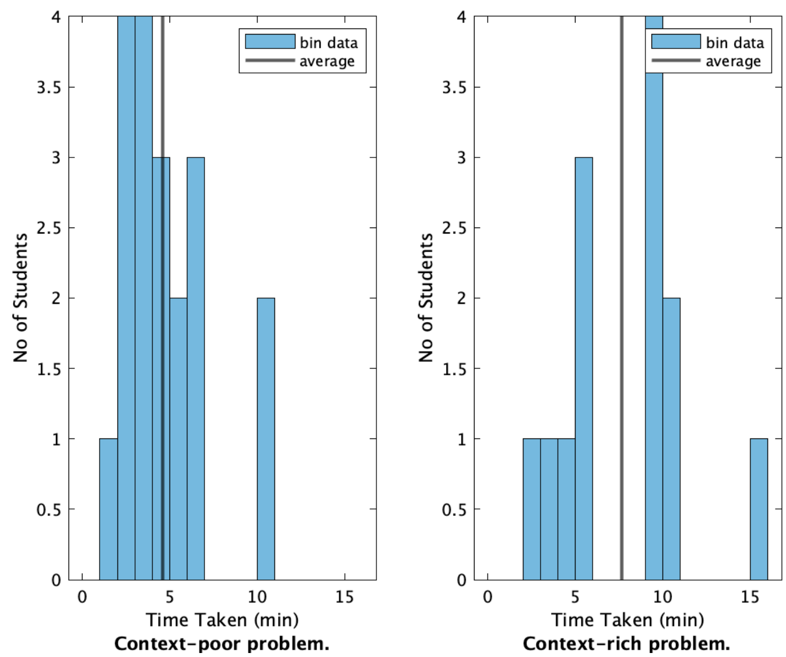


Figure 5: Amount of time taken by students to solve the problem.

Finally, Figure 6 shows the total number of students who solved the problem correctly in either the context-poor or context-rich case. A smaller percentage of students were able to solve the problem correctly when presented with the context-rich version vs the context-poor version. However, a t-test does not indicate a significant difference in this case (p-value=0.335).

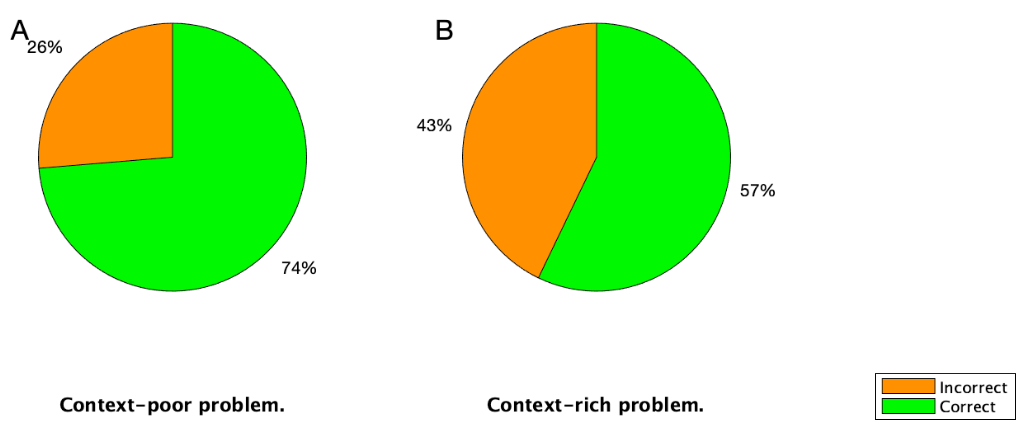


Figure 6: Percentage of students solving the problem correctly and incorrectly.

Discussion

The results presented in the previous section support the assertion that additional context in a problem-solving scenario reduces students' self-efficacy. This verifies results from [11]. However, the timed problem-solving aspect of the results also suggests that additional context impairs actual problem-solving performance. Thus, in terms of self-efficacy, additional context seems to reduce both (1) student ability to link a problem to known principles and methods and (2) student confidence in a successful outcome. In terms of problem-solving performance, additional context increases problem-solving duration and may also lead to fewer correct solutions.

Based on this survey, additional context seems to serve as a barrier to successful student problem solving. This is perhaps unsurprising, but it is also important. Unlike homework-style problems, most real-world problems solved by practicing engineers are inherently context-rich. Such problems have narrative in some form defining the problem and making the case for its solution. This narrative will normally contain details that are both important to immaterial to the problem solution. It may also involve representations of the problem or system that vary in both type and level of abstraction. Part of an engineer's job is to sift through available information, abstract the problem using the relevant information, and then connect the abstracted representation to engineering science to find a solution. If engineering students find context a significant barrier to solving problems, this suggests the need for more instruction and practice in a context-rich environment in order to prepare new engineers for the workplace. Students need context-rich examples and practice problems in order to promote far (or at least further) transfer of learning.

If introducing more context-rich problem solving in engineering education seems warranted, one area in which to be cautious is assessment. If context-rich problems are more imposing to students and take more time, then these types of problems are ill-suited to traditional timed assessments like quizzes and exams. In the testing environment, it probably makes sense to try to reduce context as much as possible to enable students to show they understand concepts and methods of analysis without getting bogged down by details. Obviously, another way to address this issue is to shift assessment away from testing and towards more open-ended assignments and projects. Context-rich problems are perhaps an even more natural fit in this arena.

Not addressed in this study is ***why*** additional context seems to reduce both student self-efficacy and actual problem-solving performance. More study in this area is needed, but it seems likely that cognitive load [4-5] plays a role. It seems reasonable to hypothesize that as students have to process more information to connect a problem to things about which they know, more time and effort will be required and the perceived outcome will be less certain.

Although this paper focuses on the self-efficacy prompts, responses to the other prompts for a wider variety of problems and classes is detailed in a prior publication [11]. In this study, results for the interest and curiosity prompts (Q1/Q4) were consistent with this earlier work, demonstrating that students are more motivated by context-rich problems. This indicates that additional context impacts students in a somewhat contradictory way, drawing them to such problems but also making them less confident and perhaps less able to solve them successfully.

Directions for Future Research

This study is a preliminary, work-in-progress involving a single problem. Future research is needed to confirm that the findings presented here are consistent by considering additional problems. This study also has a small sample size and considers only fourth-year students in mechanical engineering. Additional research could be carried out to see if similar outcomes occur for larger class sizes, different class years, and other engineering disciplines.

Another direction for future work concerns how to improve students' ability to manage context-rich problem-solving environments. Are there best practices for teaching students how to approach problems so that they can sift through details and define a problem well? What type of instruction can help students make connections to prior knowledge and be confident in their ability to arrive at a solution? Not much is currently known about these issues.

Conclusions

This study provides evidence that context-rich problems decrease student self-efficacy vs context-poor problems. Students reported less ability to connect a problem to prior knowledge and less confidence in obtaining a solution when the problem had additional context. Students also spent a greater amount of time solving a problem with additional context. Because these types of context-rich problems more closely resemble problems from engineering practice, this suggests students need more instruction and practice managing context-rich problems. It also suggests context-rich problems should be used with caution on assessments like quizzes and exams, where additional context may inhibit student demonstrations of learning.

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