Students' Perceptions of Case-Reuse Based Problem Solving in Algebra-Based Physics

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Abstract. Problem solving is an important goal in almost all physics classes. In this study we explore students' perceptions and understanding of the purpose of two different problem solving approaches. In Phase I of the study, introductory algebra-based physics students were given an online extra credit problem-solving assignment. They were randomly assigned one of three problem-solving strategies: questioning, structure mapping and traditional problem solving. In Phase II of the study, eight student volunteers were individually assigned to work problems using one of the strategies in two sessions of semi-structured interviews. The first session investigated students' general problem solving approaches a few weeks after they had completed the online extra credit assignment. The second session investigated students' perceptions of problem solving strategies and how they relate to the extra credit assignments. In this article, we describe students' perceptions of the purpose of the activities and their underlying problem solving techniques.

Keywords: problem solving, algebra-based physics, conservation of energy, students' perceptions, physics education research
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INTRODUCTION

Problem solving is regarded as an important cognitive function used in all manner of contexts, including Physics [1, 2]. Research has shown that programs combining several interrelated instructional strategies are more effective than single-strategy programs [3, 4].

In this pilot study, we combine the use of several problem solving strategies for short-term treatment in an introductory algebra-based physics course. Our objective was to gauge how students might perceive certain problem-solving strategies -- their purpose, ease of use and overall value in problem solving and how these compare with traditional strategies that they may already use. In this report, we address the following research questions:

- To what extent do students find these strategies to be useful in problem solving?
- How well are these strategies aligned with students' existing problem solving technique(s)?
- To what extent do students understand the purpose of these strategies?
- To what extent do students find these strategies difficult to implement?

We acknowledge that students can acquire procedural automation of a strategy over long term exploration, assimilating it into their problem-solving repertoire [5]. However, long term implementation of any strategy for a large enrollment class is a logistically difficult task, so it was important to conduct this pilot study to determine how students might respond to the treatment design before implementing it for the long term.

LITERATURE REVIEW

In this study we examine the use of Case-Based Reasoning (CBR) in problem solving. CBR is the process of using analogies to solve real-world problems [6]. Case reuse is a strategy which helps promote CBR by employing problem pairs that share similarities in deep structure [7]. Here we examine how case reuse can be implemented in conjunction with two other strategies: 'Questioning' and 'Structure Mapping.'

The 'Questioning' strategy refers to Graesser's psychological model of question asking [8]. Graesser generated generic questions based upon the level of knowledge the question was looking to answer. A few of these questions were: *What does X mean?*

(Taxonomic), *What does X look like?* (Sensory) and *What causes X?* (Causal) We adapted this questioning strategy for implementation with case reuse such that the questions were asked based upon a pair of analogous problems. Declarative questions such as, *What quantities are given,?* were followed by causal questioning such as, *Which of the following quantities change,?* for each problem in each problem pair. We also added questions that asked students to modify and extend the given problems such that the resulting problems were most similar to one another, thus compelling students to compare and contrast the two problems.

The 'Structure Map' is best described as a visual representation expressing functional interdependency between concepts and quantities [9, 10]. The structure map for this project was produced by three experts knowledgeable in physics education and educational psychology. Students use the structure map by marking quantities that are given in a problem, the quantity that is to be found and quantities that must be calculated to proceed from what is given to what is to be found. Figure 1 shows an example. This strategy too was adapted to include problem pairs.

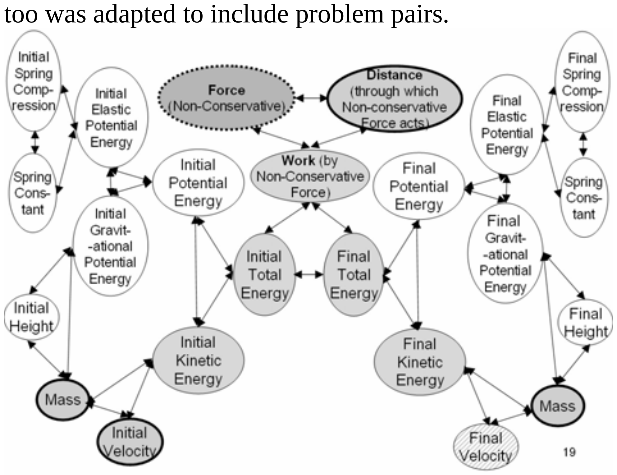


FIGURE 1. A structure map used for the following problem. What average force is exerted by the brakes to stop a 1250 kg car traveling at 30 m/s over a distance of 20 m?

There were two treatment groups: Questioning and Structure Mapping. The control group was asked to solve unpaired problems without being given extraneous help through questioning or structure maps.

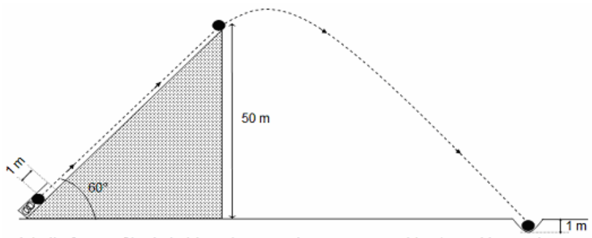
METHODOLOGY

Participants for Phase I included 150 students enrolled in algebra-based physics at Kansas State University in spring 2007. All enrolled students were given the opportunity to participate in this study for extra credit and all were evenly assigned into one of three groups at random: Questioning, structure mapping and control. Students were asked to access their assignment online. Each group worked with three types of problem pairs: work-energy theorem problems, potential energy problems and conservation of energy problems. The structure mapping group was also given a training document prior to being asked to complete the three problem pairs. The training document built the structure map using the work-energy domain and worked through an example of using the map with a simple work-energy physics problem. (See Fig. 1 for exact example) Once students assigned to either group involving questioning or structure mapping completed the three problem pairs, they were given three different problems to solve and hand in, one from each type. The control group was asked to solve and hand in six problems, two from each type. All students in the class were also given a transfer problem on their course examination, attempting to assess the influence from previous extra credit exercises.

Phase II involved two 50-minute sessions of semi-structured interviews for each of eight volunteers. The students were selected based upon the extra credit assignment they completed. Two students each were selected from the questioning strategy group and structure mapping group, the remaining four were from the control group. The first interview session investigated students' general problem solving approaches. Students were asked to work through a work-energy problem (Fig. 2). They were allowed to use their course textbook and a calculator. After each student completed their attempt to solve the problem, we asked them questions about their work.

Students returned for a second interview one or two weeks later. The second interview focused on acquiring information about students' perceptions of the strategies. For students in the structure mapping or questioning strategies group, we asked them to recall their extra credit assignment as best they could. If they were capable of recalling any part of the extra credit assignment, they were asked to apply what they remembered to the problem they were provided during the first interview. If they were unsuccessful, they were given a copy of the extra credit to reexamine. Once participants were given time to reacquaint themselves with the assignment, we concentrated our interview questions on students' views about the intended purpose behind the map or question strategy. If time allowed, students were asked to use their strategy while attempting for a second time to solve the problem given in the first interview.

The control group was asked similar questions during their interview sessions, but they spent no time reviewing their own extra credit, since their extra credit assignments did not include either of the strategies. Instead, in the second interview they were first explained one of the two strategies and then asked to apply it to the interview problem from the first interview.



A ball of mass 2kg is held against a spring compressed by 1 m with a spring constant of $k = 3 \times 10^3$ N/m, and sits at the bottom of a ramp 50 m high. The ramp is inclined at an angle of 60°. When the ball is released, assuming a frictionless ramp and no wind resistance, the ball will hit a pit of sand. The depth the ball sinks into the sand is 1m.

(a)At what speed will the ball leave the ramp?
(b)What is the average force on the ball by the sand?
(c) Is there any information provided in the problem that you did not need to in (a) and (b)? If so, what information?
(d) If 'k' is reduced, what happens to the depth the ball sinks into the sand?

FIGURE 2. Interview 1 Work-Energy Problem.

RESULTS

Phase I showed no statistically significant difference between the three treatment groups. This result is consistent with previous studies which suggest that students given a short term treatment of any problem solving strategy do not show marked improvement [10].

The first session interviews of Phase II were not initially relevant to the treatment groups, but were important to gaining insight into the development of students' strategies for solving problems during the second interview. Students consistently used the *working-backward* approach during the first interview session and so it became apparent when students reverted back to that approach while working the interview problem for the second time [11]. In the second interview session, several themes emerged regarding the students' perceptions of these strategies which are discussed below.

Questioning Strategy

The questioning strategy was worked out by four of the eight interviewees. All four students determined the strategy was purposeful and similar to their own problem solving techniques. When asked to explain the possible purpose of the questioning strategies, all interviewees replied similarly,

QS1: "the purpose? Mm… to help us um visualize the problem, um to help us think of what we should take into account, and get us thinking of what shouldn't be taken into account because there's answers on there [questioning strategy] that don't apply to the problem, so it helps us to decide what we can apply to the problem to help figure out what we need to know about the problem"

Interviewees were also asked to explain how the questioning strategy varied from their own strategies. Responses showed students believed the strategy was designed to mimic good question asking procedure and said that they already ask themselves the same or similar questions when they solve problems.

QS2: "Well, I always ask myself this, which is what I am given, or what's implied in the problem. So like this, it's talking about how far the arrow went, I'd have to take in gravity, but it's not given in the problem, but I know what it is…"

Responses also showed question miscommunication when asked to identify from a list, concepts, laws and/or theories applicable to the problem. Three out of four responses reflected interviewees' use of equations in the process of identification of concepts.

QS3: "Umm, on this one (question 2), I usually try to find the equation I'm using from what I'm given or I try to find an equation with a lot of what I'm given in it and try to see if there is something missing that I need…."

Overall, students responded affirmatively when asked if they felt the questioning strategy was helpful for solving physics problems and if they felt comfortable using the strategy. Furthermore, all students who used the questioning strategy recognized that the problems were paired in the extra credit assignment. Three of the four students articulated reasoning for the paired problems:

QS4: "Umm…they're both dealing with the same uh…work and energy but they're showing it in different ways, like this one is using a spring compression in order to move the arrow and this one is just using a human just throwing it and it tells you the initial speed, but it's still using the same type of equations."

Structure Mapping

The structure map was highly regarded, yielding praise from all four of the interviewees who used the strategy. When asked to compare this strategy with the one that they used, all students found that the structure mapping strategy was quite different from their own problem solving technique, nevertheless they found structure mapping helpful in understanding "*what you need for a problem."* None of the students expressed any difficulties about using the structure map. Three students liked how the map represented all of the problem information. Two students liked the way all quantity relationships were apparent.

SS1: "..half the time its hard for me to figure out what equation to use, but like when you figure out like what it gives you and then how to figure out what equation to use from the arrows, helps, like it doesn't give you the equation but it tells you what you need in order to figure out how to get the answer."

Overall, students felt the structure map was easy to use after given the appropriate PowerPoint training slides. At the end of the second interview session, all four students worked out the interview problem using the structure map. Unlike the questioning strategy, all four students' solutions improved from the previous interview. Only one student from the structure mapping interviews recognized the problems were paired. He found the pairings useful for comparing question answers between the two problems. Other students, when asked if there might be a reason why the problems are paired responded,

SS2: "I think there is a reason, I just don't know what it is."

SS3: "I haven't really thought about that, umm, prolly (sic) because they are similar problems but your given different information, I think it would be just as helpful if they were on separate sheets."

CONCLUSIONS

Overall, our results indicate that students believe these strategies are helpful in giving them good problem visualization and facilitating their ability to identify important information from the problem. Students from the questioning strategy group believe the questioning strategy is similar to their own problem solving techniques, providing well structured questions that attempt to draw important information from the problem statement. Students from the structure mapping interviews believe the structure maps are not comparable to their own problem solving techniques, but still feel the strategy is an effective tactic for representing problem information.

All eight students agreed that the purpose of the strategies was to help them work out problems, though the intended purpose of some of the questions from the questioning strategy was not clear to the students. When asked to implement the strategies to solve a problem, students showed difficulty expressing differences between concepts and equations, providing equations that fit some or all of the quantities provided in the problem as an appropriate means of defining problem concepts. Finally, the results of this study suggest the structure mapping and the questioning strategy, interlaced with case-reuse, were well-liked and user-friendly.

LIMITATIONS & FUTURE WORK

The goal of this study was *not* to assess the effectiveness of the strategies, since the effectiveness of any strategy can only be gauged in the long term. The goal here was to examine how students perceived these strategies. The next phase of our research is to adapt the strategies based on our results and implement and assess these strategies in class over the long term.

Based on our results, the questioning strategy will require several adaptations prior to implementation. The intended meaning of the questions was sometimes misaligned with student interpretation. Questions asking students to identify concepts, theories or laws were ultimately answered with equations containing quantities identified in the problem. These questions will be reworded in the future such that students may not phrase their answer in terms of an equation. Following these adaptations we will include long term quantitative and qualitative investigations of students' performance on these strategies.

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