

# Student Categorization of Problems – An Extension

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**Abstract.** As part of gathering baseline data for a study on problem categorization, first-year engineering honors students who had recently completed a two-quarter sequence in physics were interviewed. The primary task in this interview was much like the problem categorization study described by Chi et al. There were, however, at least two distinct modifications: 1) in addition to the problem statements, solutions were included on the cards to be sorted 2) the problems were written such that they could also be grouped according to the nature of information presented in the problem statements and/or the number of possible solutions. The students in this baseline study, although similar in background to the novices described by Chi et al., in many ways performed more like experts. Several possibilities for this behavior are discussed.

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## INTRODUCTION

Previous work proposed a problem categorization scheme that is based upon the nature of the information provided in the problem statement (insufficient, exactly sufficient, or excess) and the nature of the problem's answer (no answer, one answer, or multiple answers). [1] This scheme is independent of the problem's content and is connected to problem-solving skills that students will use in the "real world," such as approximating, estimating, assuming, filtering, or optimizing.

As part of collecting baseline data to assess the effectiveness of implementing this scheme in a course for honors engineering students at The Ohio State University, an interview task was developed based upon the groundbreaking work of Chi, Feltovich, and Glaser. [2] In their study, subjects were asked to sort cards containing problem statements. The expert physicists in the study (PhD physics students) sorted the cards according to the principals needed to solve the problem, or the problem's deep structure. The novices (students who had just completed a semester of introductory physics) sorted the cards by the surface features of the problems.

This paper describes some unanticipated results from this baseline study, along with a small probe to gather more information on what led to these preliminary results.

## CONTEXT OF THE STUDY

The subjects in the current interview sample were 3<sup>rd</sup>-quarter students enrolled in Ohio State's Fundamentals of Engineering for Honors (FEH) program. [3] The FEH program consists of coordinated courses in engineering, math, and physics throughout the students' first year of college. Ohio State is on the quarter system. The instructors meet on a weekly basis to discuss opportunities to link the courses. The bulk of students participate in one of two math sequences, depending upon their level of calculus readiness. Almost all students take two nontraditionally taught physics courses, which will be described in more detail below; some take a third quarter, and even students with AP credit are strongly encouraged to take at least one of the physics courses. All students in the program take engineering courses in graphics and computer programming, and the program culminates with a quarter-long design-and-build project in the spring quarter.

The physics courses include nontraditional elements such as interactive lectures in the style of Etkina and Van Heuvelen's ISLE program, conceptual questions with personal response systems, cooperative group problem-solving exercises, group midterms, and lab exercises utilizing VPython. [4,5]

## THE INTERVIEW TASK

A set of 18 problems was developed for subjects to sort. These problems were written such that subjects would be able to group them by deep structure, surface features, the nature of the information provided, or the nature of the answer. To make sure that all of these sorting options were equally represented on the cards, each card included the problem's solution. A sample card is shown in Figure 1.

<p><b>Problem:</b>          A 1-kg cannonball is launched so that it slides up the deck of a pirate ship angled 30 degrees to the horizontal. The ball's initial velocity is 5 m/s. How fast is the cannonball going after it has traveled 3 meters up the deck? Assume the deck is frictionless.</p>
<p><b>Solution:</b>          Apply conservation of energy.          Initially: <math>K_i = \frac{1}{2}mv_i^2 = \frac{1}{2}(1kg)(5m/s)^2 = 12.5 J</math></p> <p>At 3 meters up the ramp:  <math>U_{g,3m} = mgh_{3m} = mg(3m)\sin 30^\circ</math>  <math>= (1kg)(9.8m/s^2)(3m)\sin 30^\circ = 14.7 J</math></p> <p><math>K_i + U_{g,i} = K_{3m} + U_{g,3m}</math>  <math>\Rightarrow 12.5J + 0 = K_{3m} + 14.7J \Rightarrow K_{3m} = -2.2 J</math></p> <p>Negative kinetic energy isn't possible.          The cannonball can't get 3 m up the ramp!</p>

FIGURE 1. Sample Card For Card Sorting Task

Notice that it involves the surface features of a cannonball, pirate ship, and inclined plane, and contains the deep structure of energy conservation. The nature of the provided information is that there is excess information (since the mass is not needed to solve the problem). The nature of the answer is that there is no solution to the question asked. All problems were written with a fair amount of context, since the students were accustomed to seeing problems of this sort in their physics courses. The problems contained a wide distribution within each of these features, as summarized in Figures 2 through 5.

Concept	# of Problems Containing
Energy Conservation	3
Newtons Laws and Kinematics *	3
Projectile Kinematics	5
Momentum Conservation	3
Relative Velocity	4

\* These problems required application of both concepts in the solution.

FIGURE 2. Card Distribution According to Deep Structure

Surface Feature	# of Problems Containing*
Car	5
Pirates	4
Ball	5
Block	3
Inclined Plane	6
*a few problems have multiple features	

FIGURE 3. Card Distribution According to Surface Features

Nature of Provided Information	# of Problems Containing
Insufficient	4
Exactly Sufficient	9
Excess	5

FIGURE 4. Card Distribution According to Provided Information

Number of Answers	# of Problems Containing
None	5
One	8
More than One	5

FIGURE 5. Card Distribution According to Nature of Answer

## INITIAL RESULTS

The initial interviews were of ten honors engineering students at Ohio State. These students had completed rigorous courses in mechanics and electricity and magnetism, and a few were enrolled in

a course on waves, quantum mechanics, and optics at the time of the interviews. The subjects were selected from a pool of volunteers, such that they would represent a range of physics achievement, as measured by their final course grades.

As part of the interview, the students were asked to sort the cards into categories while thinking aloud. [6] If a subject indicated that he or she could think of multiple ways to sort the cards, they were asked to sort the cards first in the way they liked the best, then to repeat the sort according to the other criteria they had considered. Subjects were also asked to name the categories into which they had sorted the cards.

All but one of the students sorted the problems according to the deep structure, largely titling the groups with similar language to that used in Figure 2. Some grouped all kinematics problems together, and a few talked about how many dimensions were involved. One grouped all conservation problems together. The tenth subject sorted based on his perceived difficulty of the problem, which involved whether trigonometry was needed to solve the problem, the length of the text, and whether the problem contained an impossible situation.

One striking aspect of the results was that the amount of time these students had spent learning physics was much closer to that of the novices in Chi's study than the experts, but that the performance of the vast majority on the task was more like what one might expect from her expert subjects. Based upon prior work, it had been expected that there would be more variation in the sample than this. The expectation was that there would be some students appearing much like novices, others like experts, and several somewhere in transition. [7]

## SUBSEQUENT RESULTS

One possibility for this behavior was that the initial statement in the solution ("Apply  $x \dots$ ") was viewed as such a compelling feature of the card that subjects relied heavily on it. Given that not all of the students named their groupings strictly according to the concepts listed in the solutions, it seemed somewhat unlikely that this was the only cause, but it was something that should be probed to make sure. To test this theory, the experiment was repeated with a comparable group of students from the same population, but this time this initial statement identifying the concept was removed. Other than this modification, the cards remained identical.

The results from the second group were largely the same. In this case, all subjects sorted based on the problem's deep structure. The most noticeable difference apparent in the initial analysis of the data is

that the subjects tended to group the problems slightly differently. In this second set of interviews, the subjects were more likely to group all of the projectile kinematics and relative velocity problems together in one group designated "kinematics" or sometimes "position and velocity." Additionally, students were less likely to mention the kinematics in the problems that also involved Newton's laws. Some took friction into account when sorting the Newton's law problems. The majority easily recognized the energy and momentum conservation problems. The most unique approach in this set was by a student who initially sorted based on methods (energy and work or kinematics), then sorted again based on the surface features. When asked which method he would choose if he had to pick one, he said that he would use the more conceptual-based approach as his primary sorting.

## INTERPRETATION

The results of the two studies together clearly show that the students in the interview pool sorted the problems in a way that is consistent with the experts in Chi's study. There are several possibilities for what drove this behavior that need to be considered in more detail before broader conclusions can be drawn.

One is that something in the way the physics courses were taught to these students made them behave more expertly. Given that the population is honors students and that the physics sequence has a many-year history of achieving significant student gains on conceptual evaluations like the FCI and CSEM, this is not an incredibly farfetched possibility. Could it be that the exposure to alternative problem types is having an impact on this aspect of their problem solving? Could some other factors in the course be fostering this maturity in viewing problems?

Of course, another possibility is that because these students are honors students, they already possessed some expert-like problem-solving skills when they arrived at the university, and that the courses had nothing to do with it. As part of the larger study, there are already plans to repeat this interview with incoming students in the fall, and the answer to this question will be known shortly.

A third possibility is that the differences between these cards and those in the Chi study were significant enough to cause this difference in behavior. The major differences are the more involved contexts of these problems and the provided solutions. Perhaps one or both of these changes caused students to ignore the surface features. Again, more should be known about these possibilities once the fall interviews are conducted. If the students in the fall behave similarly,

the team may elect to repeat the interviews without the solutions on the cards and see if the results are different.

Closely related to this, the possibility exists that the modifications made to the task make it different enough from the Chi study that experts may behave differently than expected, as well. At some point in the future, the task may be repeated with physics faculty.

Until these areas are fully probed, it would be unwise to make any sweeping statements or generalizations about the findings to this point.

## FUTURE DIRECTIONS

Regardless of the answers found by probing the possibilities above, the data collected thus far give a solid baseline for the larger problem categorization project. This study will continue in the next academic year, as the new categorization strategy is introduced to the students. The card sorting task will be repeated several times during this period. As mentioned above, incoming students with similar profiles to those already interviewed (in terms of gender, class rank, ACT scores, AP credit, etc.) will be interviewed within the first few days of their college experience.

Comparable groups will be selected to perform the card sort at the conclusion of the mechanics and electricity and magnetism courses. At that point, it will be seen if students exposed to the new categorization scheme look at the nature of information provided in the problem or the number of possible answers when sorting problems into categories.

The interview protocol also includes a series of questions about problem solving skills and strategies, and analysis of these questions will shed additional light on the student behavior observed during the card sorting task.

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