Expert-Novice Comparisons to Illuminate Differences in Perceptions of Problem Solutions

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Comparing the performances of experts and novices on particular problem solving tasks has been a popular technique in problem solving research, uncovering differences in the ways the two groups categorize, approach, and solve problems. Applying this technique, two samples of students and one sample of experts categorized pre-written solutions to a mechanics problem. The responses reveal differences in how the beginning college students, more experienced college students, and physics instructors view solutions. Students focus on the solutions' surface features and presentation, while instructors look more closely at the deep structure. These differences indicate that instructors should consider modifying the way in which in-class and handed out problem solutions are presented to students.

Introduction

The history of expert-novice comparisons in physics problem solving research is rich. Previous studies have revealed differences in the ways experts and novices classify problems [1], organize their knowledge [2], and approach problem solving tasks [3]. Good's work has also shown one particular difference in perceptions of problem solving between the two groups: experts view it as a process, where novices tend to view it as a recall task. [4]

This paper describes a more recent set of expert-novice comparisons that shed more light on the perceptual differences of experts and novices regarding problem solving.

Study Design

Three samples, one of experts and two of novices, analyzed 12 different solutions to the same problem to determine whether each solution was written by a student in an introductory mechanics course or by an physics instructor. The expert sample consisted of 12 experienced Ph.D. physics instructors; all but one were professors. The first novice sample was 18 3rd-quarter students enrolled in Ohio State's Freshman

Engineering Honors (FEH) program. All of these students had completed two quarters of nontraditionally taught physics, including interactive lectures, cooperative group problem solving exercises, and design labs. The second novice sample consisted of 6 FEH students in their second week of college. These students had sufficient high school experience to understand the physics applied in the problem solutions.

As part of a longer think-aloud interview, subjects were given a stack of 12 solutions to a moderately complex mechanics problem involving conservation of momentum and then either conservation of energy or Newtonian dynamics with kinematics, depending upon the solution method. When presented with the solutions, subjects were told, "Here are 12 solutions to a problem that was given on a 131E final exam. Some of these solutions were written by FEH students; some are by physics instructors, who were given a packet of problems and told to solve them like they were taking a test. Tell me which ones you think are by students and which ones are by instructors, and why."

No information was given about the number of instructor or student solutions in the stack.

The solutions had been carefully chosen to contain many different features that might serve as cues to the subjects, including diagram usage, answer correctness, checking of the answer, listing of given information, number insertion, solution neatness, clarity of fractionation, logical progression, written explanations, solution method, and omissions.

Analysis

All interviews were transcribed. Analysis centered upon the criteria subjects used in making their final decisions about whether each solution was by a student or instructor. In the transcripts, many subjects observed several characteristics of a solution while working up to their decision. Only criteria specifically cited as contributing to their categorization were included in the analysis. Often subjects would give several reasons for their decision; if so, each criterion was coded separately. Since each subject viewed 12 solutions, it was therefore possible for each criterion to be cited 12 times per interview.

The analysis yielded 32 different criteria used by subjects in making their decisions. In addition to the characteristics listed previously, subjects looked at things like handwriting, solution length, unit usage, and notation. Ninety-eight percent of these criteria were able to be grouped into three broader categories: deep structure, surface features, and presentation features. (The other two percent were too ambiguous to be accurately classified as falling into any of these areas.)

For a reason to be categorized as deep structure, it had to include evidence that the subject was looking at the methods employed in the solution. A surface feature comment was one that had no tie to the actual solution method. For instance, the observation, "There's a free-body diagram, so it must be an instructor" does not indicate that a subject has looked deeply at the methods employed in solving the problem and would be categorized as a surface feature criterion. However, stating that an extra force is on a diagram and

so it probably is by a student indicates that the subject has examined how the problem was solved and would be classified as deep structure. The presentation features category came from the substantial number of comments regarding a solution's logic, organization, clarity, or completeness.

Results

The numbers of citations in each category by each sample are shown in Table 1.

	deep	presentation	surface	other
1st qtr. Freshmen (N=6)	25	66	71	1
3rd qtr. Freshmen (N=18)	87	80	75	9
Instructors (N=12)	80	21	25	1

Table 1: Criteria Cited in Sorting Problem Solutions

These were converted to fractions, graphed in Figure 1 (at the end of the paper). As the figure shows, the experts made the majority (63%) of their decisions based on deep structure elements. The3rd-quarter students' decisions were rather equally split between the three categories, but the 1st-quarter students based only 15% of their decisions upon deep structure, relying more heavily on presentation and surface features. The graph also indicates that a transition occurs as one becomes more experienced with physics problem solving, from looking primarily at surface features and presentation elements of solution to focusing on the actual solution structure.

To test this transition theory, three chi-squared analyses were run (one for each pair of samples) with the raw numbers of criteria citations. Table 2 summarizes these results. All three pairs of samples were found to be independent at the p<<.0005 level, further indicating that this transition does indeed occur.

	chi-	
	squared	p value
1st qtr & 3rd qtr	20.7	<<.0005
1st qtr & instructors	70.7	<<.0005
3rd qtr & instructors	25.8	<<.0005

Table 2. Chi-squared Tests for Sample Independence

Interpretation

How does this relate to previous research? First, the transition away from a surface feature dependence and towards more reasoning based upon deep structure is consistent with Chi et al.'s findings. [1] The existence of the third category, presentation features, was unexpected, but may be explained by the fact that the presentation features the subjects (in all samples) tended to look upon favorably were clarity, written explanations, logical progression, and labeling. All of these aspects are, in a sense, surface features of expert problem solving.

With this interpretation, the data indicate that students with high school physics experience analyze problem solutions by looking primarily at a combination of surface features of the solution, perhaps favoring the "outright" surface features slightly over the presentation surface features. As they gain experience during introductory university physics, they begin to look more closely at the deep structure and less at the obvious surface For those who go on to teach features. physics, the shift continues, and the deep methodological structure of the solutions becomes the area of focus. However, there is still something attractive about the surface features, even to experts, since 20% of the criteria cited by them fall into this category. Unlike the other results, which may be viewed as extensions of previously known work, this is somewhat surprising.

A look at individual students in the "novice" samples reinforces this transitional interpretation. During the task, some students showed more expert views than others. A particularly wide variety of views was evident in the 3rd quarter sample. Some students based almost all decisions on handwriting, sloppiness, or other obvious surface features.

However, some students approached the task in a methodical expert way; one student even did a first sort of the solutions based upon the principle applied, deciding that instructors would probably apply energy methods instead of kinematics. Further, this intermediate group made more comments that were unable to be classified than the others, possibly another indication of transitional thinking.

Instructional Implications

What, if anything, about the physics instruction of the students in this sample influenced them to look at the surface features and presentation of the solutions? Many introductory physics classes, particularly at the high school level, contain numerous instances of instructors working example problems for students. Further, example problems in textbooks and many solutions handed out to students are presented very clearly and logically, often incorporating explanatory words. The students apparently recall these features more readily than the application of the physics in the solutions.

The good news about this is that the effort physics instructors put into presenting solutions well is not wasted. However, the clear presentation perhaps eclipses the actual intentions. What should instructors do? It is difficult to make solid suggestions without further observation and analysis of instructional techniques, but it seems clear that instructors need to think about enhancing their presentation of problem solutions.

Certainly problem solutions still need to be clear and comprehensible for students, but modifications are needed to focus students more on the physics in the solutions. The easiest modification may be to stress the physics issues more frequently while working in-class examples. Instructors may want to ask students key questions while solving the problem (e.g., "What principle should we apply here?" "How can we check this to see if it's reasonable?") It is suspected that most instructors do some of this already, but that it may become less frequent as courses progress. It seems to be important to continually stress this aspect of problem solving. Additionally, these sorts of questions could be written in solutions handed out to students. Seeing these issues explicitly raised in several contexts hopefully will raise students' awareness of their importance.

Another idea to consider is presenting students with a task like the one used in these interviews, such as giving them a written solution to "grade." Since evaluation tasks are at the top of Bloom's taxonomy, experience of this sort may influence the way students apply this kind of knowledge to their own solutions.

In any case, further research is needed to find if these modifications have any impact on teaching students what instructors believe to be desirable in a physics problem solution. [5]

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References

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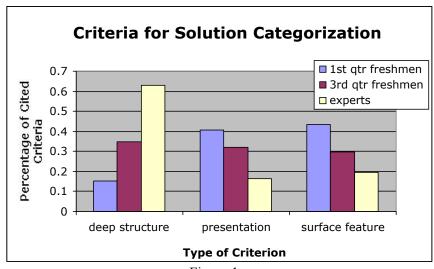


Figure 1