ARGUMENTATION WITH CONTRASTING CASES: FACILITATION OF DEEP STRUCTURE LEARNING

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Prior studies have revealed that both contrasting cases and argumentation tasks can support deeper learning and problem solving skills. Yet, these studies suggest that appropriate scaffolds are need for these instructional strategies to be successful. We investigate alternative forms of writing prompts (similarities and differences, invent a unify statement, and argumentation) for two cases that addresses the momentum principle. Results suggest that prompts for identifying similarities and differences within cases tended to promote identification of surface features irrelevant to solving the problems. However, argumentation prompts to evaluate competing theories tended to support deeper understanding of underlying principles and appropriate application of principles.

Keywords: Physics, Argumentation, Problem Solving

INTRODUCTION

Many undergraduate physics students have difficulty with problem solving (Tuminaro & Redish, 2007). Studies have shown that while experts tend to group problems based on “deep structure”, novices rely on “surface features” (Chi, Feltovich, & Glaser, 1981). Experts typically identify the underlying principles to a, while novices resort to means-ends strategies (Leonard, Dufresne, & Mestre, 1996)

Contrasting cases have been shown to facilitate students to move from focusing on surface features to underlying principles (Sidney, Hattikudur, & Alibali, 2015). In using contrasting cases, asking students to invent a unifying explanation across cases is more effective than comparing similarities and differences (Chin, Chi, & Schwartz, 2016).

Studies have shown that argumentation can enhance science understanding and problem solving (Driver, Newton, & Osborne, 2000). While most U.S. students struggle to construct or evaluate arguments, scaffolds, facilitate students to compose stronger arguments (Cho & Jonassen, 2002). Textbook problems often do not contain argumentation prompts and there have been few attempts to infuse argumentation in undergraduate physics. In our prior research, we (Rebello, Sayre, & Rebello, 2012) that using construct and evaluate argument tasks with prompts produces higher argumentation and conceptual quality on physics problems. Evaluate prompts outperformed construct prompts on many topics.

Here we utilized contrasting case along with argumentation to improve problem solving skills. We investigate which prompts would best facilitate students in “deep structure” understanding and what patterns emerge in relation to level of principle understanding, attention to surface features, and scientific appropriateness.

METHODS

This study was conducted at a large, USA public university; in a semester-long (16 week) calculus-based physics course for honors engineering and physics majors, with an enrollment of 71 students. The course used *Matter and Interactions* (*M&I*) (Chabay & Sherwood, 2015) curriculum which is designed to promote principle-based learning. The course consisted of three recitation sections taught by the same teaching assistant. Each recitation was randomly assigned to one of three conditions: *Compare* – identify and describe all relevant similarities and differences across problems, *Invent* – create a single unifying explanation to address how the problems are solved, and *Argument* – evaluate hypothetical student responses as to how the problems are solved. Each case included two analogous problems to solve and one worked example problem seen previously. Two cases were provided to students during the second (Recitation 02) and third week (Recitation 03) of the semester. All cases emphasized strategies based on the 'momentum principle', but contained different surface features, requiring different assumptions. Each recitation received the same cases with writing prompts corresponding to their condition (Table 1). Students worked in groups of four to solve the cases. They reflected on their process across the cases and used the prompts (Table 1), to write about it.

Written responses were transcribed and coded using a three-point rubric reflecting three physics problem solving dimensions: *Structure* -- coded as either Deep (=3), Moderate (=2), or Low (=1) depending on the level of identification and application of relevant principles, system and surroundings, and appropriate approximations and assumptions made. *Surface Feature* – coded similarly as High, Moderate, or Low based on level of descriptive detail and amount of problem features identified within and across problems. *Scientific Appropriateness* -- coded as either Correct Reasoning, Some Correct Reasoning, or Incorrect or No Reasoning.

Table 1. Writing prompts provided in each condition.

'Compare' Prompts	➢ Identify and explain all relevant similarities and differences across the given problems. • You may want to focus on features of the problems, the way in which the problems are solved, and/or problem solutions. • You may also consider other problems solved in the course and describe how they are similar to or different from the given problems.
'Invent' Prompts	➢ Create a single, unifying explanation that will address how the problems are solved in any given case that would work across all of the given problems.
'Argument' Prompts	➢ Which explanation provided best addresses how the problems are solved in any given case that would work across all of the given problems? Or, do you have a different explanation. Explain, elaborate, and justify your preferred explanation. HINT: In your response, consider: • What evidence and reasons supports your selection? • Explain your reasoning for not choosing the alternative solution(s). What are the weaknesses in the alternative argument(s)? • How might a classmate supporting another explanation disagree with your preferred solution and how would you respond to them?

Written responses were coded by two independent raters, who reached 100% agreement after discussion. To compare levels of structure, surface features, and scientific appropriateness in each of the three conditions, a multivariate analysis of variance (MANOVA) was performed. Univariate analysis of variance (ANOVAs) determined if the conditions (invent, argument, compare) have a significant effect on each dependent variable (structure, surface feature, and scientific appropriateness).

FINDINGS AND ANALYSIS

The MANOVA analysis revealed a statistically significant difference among the three conditions [Wilks' $\Lambda = 0.554$, $F(6.0, 132.0) = 7.562$, $p < .001$, $\eta^2 = 0.256$] for Recitation 02 and [Wilks' $\Lambda = 0.453$, $F(6.0, 122.0) = 9.868$, $p < .001$, $\eta^2 = 0.327$] for Recitation 03. Univariate ANOVAs revealed that condition had a significant effect on surface feature. Follow-up Tukey's HSD analysis with an overall alpha level of .05 revealed that compare condition statistically significantly ($p<0.001$) outperformed the other two conditions with regard to identifying the surface features of the problem. It seems that the prompts which asked students to compare the similarities and differences between hypothetical student statements led students to focusing on comparing and contrasting the features of the problems and their solutions. The analysis also showed that in Recitation 02 (Figure 1) there was no statistically significant difference between conditions in the structure dimension, however the argument condition significantly outperformed the other two conditions in Recitation 03 (Figure 1) in the structure dimension ($p<.05$).

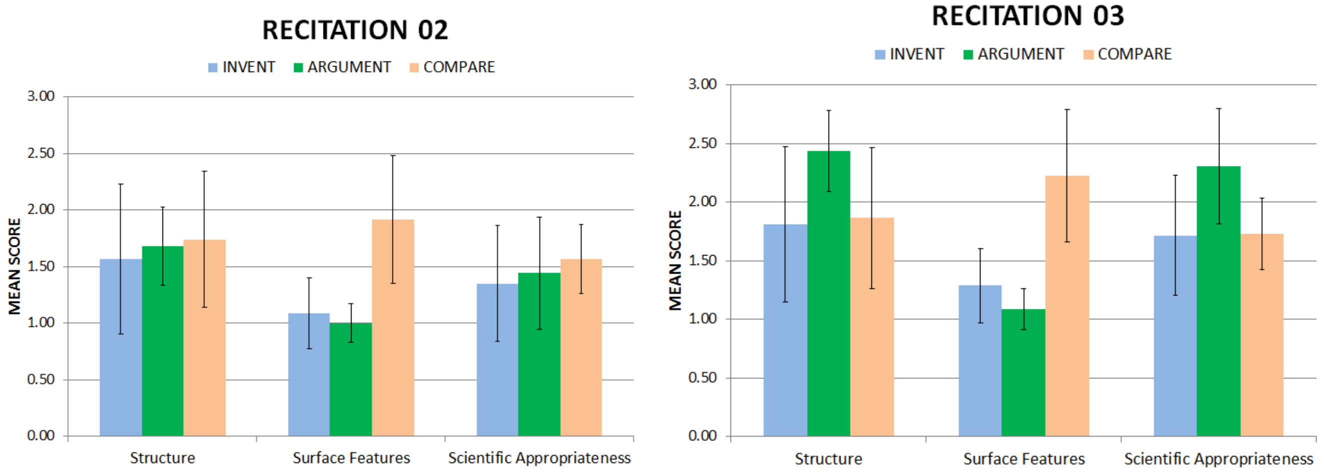

Figure 1. Mean rubric scores on each dimension for each of the three conditions. The error bars represent standard error.

The analysis also showed that in Recitation 02 (Figure 1) there was no statistically significant difference between conditions in the structure dimension, however the argument condition significantly outperformed the other two conditions in Recitation 03 (Figure 1) in the structure dimension ($p<.05$). In Recitation 03, the argumentation condition outperformed the other two conditions on the scientific appropriateness dimension ($p<.05$). Taken together these results seem to indicate that the argumentation condition did not just facilitate attention to the problem structure, but also facilitated students to use their knowledge of the principles correctly while analyzing the problems and their solutions.

CONCLUSIONS

As expected from literature, the compare condition consistently had higher scores for surface features for both cases. Hence students asked to compare problems will more likely focus on surface features. The argument condition, however, revealed significant differences for structure and scientific appropriateness in Recitation 03, suggesting that those in the argument condition are more likely to facilitate attention to principles and their appropriate applications to problems. It seems that learning to engage in argumentation effectively requires training, but pays dividends by helping students focusing more on identifying and using the principles that underpin the problems. Thus more research in this area is warranted to study the issue further.

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