Assessing Students' Epistemic Logic Using Clause Topics During Problem Comparison

Fran Mateycik and Kendra Sheaffer

Division of Mathematics and Natural Sciences, 3000 Ivyside Dr., Penn State Altoona, Altoona, PA 16601

Abstract. Physics courses ideally facilitate both students understanding of fundamental physical principles, as well as strengthen students' problem solving repertoire. In this study we look at how students divide and/or aggregate various elements of problem statements and how useful distinct principles and concepts, formulae, and general problem contexts are for pairing problems assigned in the same week. Students in an algebra-based physics course were asked to choose two problems from each of their homework assignments which they found to be most similar. The two problems selected were then explicitly compared and contrasted in writing. The written statements were then divided by clause topics and further categorized into levels of epistemic reasoning. This paper/poster presents the qualitative analysis used and provides observed trends that appear in students' homework responses.

Keywords: problem solving, algebra-based physics, case reuse, physics education research
PACS: 01.40.Fk

INTRODUCTION

The ability to identify important information within a problem is a key factor to effective problem solving. Research done by (Mateycik et al., 2009) and (Jonassen, 2000) suggested that compare and contrast strategies can assist students in identifying the important information within problems if implemented over a regular interval. When identified information is later retrieved during problem solving (Faltings, 1997), students tend to recall 'similar' information incorrectly because they base their retrieval on surface feature (i.e. what a problem looks like) similarity instead of deep structural (conceptually related) features (Catrambone & Holyoak, 1989; Chi, Feltovich, & Glaser, 1981; Reed & Bolstad, 1991). Chi et. al. further solidified educators' recognition of students' surface feature emphasis, providing evidence that students grouped problems based upon surface features while experts group problems based upon the deep structure of the problem (Chi, Feltovich, & Glaser, 1981).

Our goal is to facilitate students' ability to tie deep structure elements of previous problems to newly encountered and related problems. For this study, we use explicit and recurring compare and contrast activities in two physics classes. The communication of comparison and contrast is used to assess how students' level of epistemic reasoning change throughout a semester of compare and contrasting activity treatments.

METHODOLOGY

Data were collected from introductory algebra-based physics courses taught during the spring of 2011. These students studied electromagnetism, circuits, light and optics, and modern physics. All students enrolled in both classes were required to complete a compare and contrast treatment that was incorporated into their weekly homework assignments. The students were given three, one-hour lectures per week, and one, two-hour laboratory per week. There were 45 students enrolled in the class, 27 of which were science majors with concentrations in life sciences. The remainders of students were distributed across a multitude of other majors including mechanical engineering technology, kinesiology, and undeclared science.

The weekly homework assignments consisted of 10-12 problems for both courses. From these assignments, students were asked to compare and contrast two problems by writing out the similarities and differences between them and then rank those similarities and differences in order of how important they are to a comparison of problem solutions. The problems chosen for comparison were self-selected by the students each week. Students were encouraged to have peer-to-peer and peer-to-instructor discussions about the problem comparisons during the first few weeks of class to emphasize the importance of the task and to ensure comparisons were being completed thoroughly. Through verbal communication, students were instructed that the researchers were interested in their authentic understanding of the problems similarities and differences. After the first two weeks, if students failed to complete the problem comparison component of their homework or if the task was not taken seriously their final course grade was penalized by 2% for each occurrence up to a maximum penalty of 12% overall (The total percentage allotted to homework for the course). Students were given written feedback on their homework comparisons on a weekly basis. Feedback often encouraged students to consider different aspects of the problems when completing their comparisons.

ASSESSMENT

Previous research done in science education indicated that developmental patterns can be observed in student explanations (Driver et al., 1996; Metz 1991). Driver's work provided evidence that younger students (middle-school age) often struggled to construct scientific explanations of phenomena, and were unable to clearly communicate the relationship between variables or distinguish between variables.

In order to examine the nature of student explanations, we modified the epistemological reasoning categories proposed by Driver and her colleagues to include a fourth, intermediate category. The reasoning categories were ranked in a hierarchy of understanding, but it should be noted that each level of reasoning, no matter how basic, has its own beneficial value to problem solving in physics.

The four epistemic levels of reasoning used in this assessment were the following, in order of highest reasoning level to lowest reasoning level: conceptual-based, relationship-based, equation-based, and appearance-based reasoning. Driver's original cognitive hierarchy would have placed 'equation-based' and 'appearance-based' reasoning under one category.

Students that justify a similarity or difference between two problems using a physical concept, or physical principle, are considered to be using conceptual-based reasoning. If students determine that the relationship between two variables is comparable between problems, then they are using relationship-based reasoning. When students determine that the equation or set of equations used to complete the solution are comparable between the two problems, they are using equation-based reasoning. And finally, if they justify the similarity or difference between a pair of problems by comparing a surface feature (diagram, picture, type of physical object), then they are using appearance-based reasoning.

Students' written explanations were divided into smaller meaningful clauses. Each clause was an organizational unit that represented a form of student thinking or reasoning. These clauses were then categorized by clause topic. Each clause topic was then assigned a code that represented the function of the clause. For example, all clauses that represented the belief that the same equation was used to solve both the problems being compared would receive the letter code of "m". A total of 17 different codes were identified in students' comparison statements. Each code was then placed into one of four levels of epistemic reasoning. Table 1 provides a list of the clause topics generated and their assigned code letter. Table 2 provides a list of codes associated with each of the four levels of epistemic reasoning. Please note that not all clause topics identified below were generated from statements made on the homework comparisons. Problem comparisons were also done by these students during laboratory and during problem survey activities collected at the beginning and end of each semester. This paper focuses on the homework comparisons.

TABLE 1. Clause topics with their associated code letter.

Topic of Clause	Code
Same concept in problems	A
Different concept in problems	B
Same information given	C
Different information given	D
Different topic	E
Same topic	F
Solving for different variables	G
Solving for the same variable	H
Appear the same (surface-feature)	I
Appear the same (principle)	J
Appear the same (unknown)	K
Different in appearance	L
Same equations or mechanistic procedure	M
Different equations or mechanistic procedure	N
One problem is more complex or gives more information	O
Same level of complexity	P
Problems different in principle	Q

TABLE 2. Epistemic levels of reasoning with their associated code letters.

Epistemic Level of Reasoning	Codes							
Appearance (ABR)	C	D	I	K	L	O	P	
Equation (EBR)	M	N						
Relationship (RBR)	G	H	J					
Conceptual (CBR)	A	B	E	F	Q			

Students' responses were individually coded by clause topics with an initial observed percentage of agreement of 91% between the two researchers. All disagreements between codes were resolved between the researchers after discussion.

RESULTS

In the first two weeks of the semester, students often cited reasoning which represented appearance based reasoning. For the first homework assignment 48.6% of the codes cited fell into the appearance based reasoning category followed by 34.2% of the responses representing relationship-based reasoning. The following is an example of a student explanation from a week one homework categorized as appearance-based reasoning:

"They both have three different particles with three different charges."

As the semester progressed, students' reasoning developed to include greater citations of equation based reasoning and relationship based reasoning. During the fourth, fifth, seventh, eighth, ninth, and tenth homework assignments either relationship- or equation-based reasoning were used to describe the highest ranking similarity and/or difference. It was common to see statements such as,

"#37 & #42 both involve the equation for the Brewster angle to find the index of refraction."

This quotation was pulled from a student's written statement from a week nine homework assignment and classified as an 'm' type clause topic.

Appearance based reasoning remained observable and constant throughout the semester.

Each type of epistemic reasoning was further analyzed by calculating the statistical significance of any changes in percentage cited over the ten homework sets. The rise in equation based reasoning clauses was statistically significant over the semester progression, but the remaining reasoning types showed no statistically significant difference. For appearance based-reasoning and conceptual-based reasoning, this was not a surprise. Appearance-based reasoning diminished minimally from the homework code counts. It was the significant rise in equation based reasoning counts that was more notable. The conceptual-based reasoning was the most difficult type of epistemic reasoning level to capture through students written comments. There were a multitude of clauses which could have been interpreted to contain a deeper, more conceptual oriented reasoning, but without further proof in writing, these statements were coded for lower levels of reasoning. Table 3 provides the regression significance values.

TABLE 3. Significance of any observational changes in each level of epistemic reasoning over time.

Epistemic Reasoning	Sig. Val.	Significant (Yes/No)
Appearance	0.084	No
Equation	0.049	Yes
Relationship	0.450	No
Conceptual	0.674	No

Based on the numerical distribution of codes it was apparent that different physics contexts elicited different types of primary epistemological reasoning. Figure 1 provided below shows how each level of epistemic reasoning (percentage) contributes to the comparison between homework problems of each assignment.

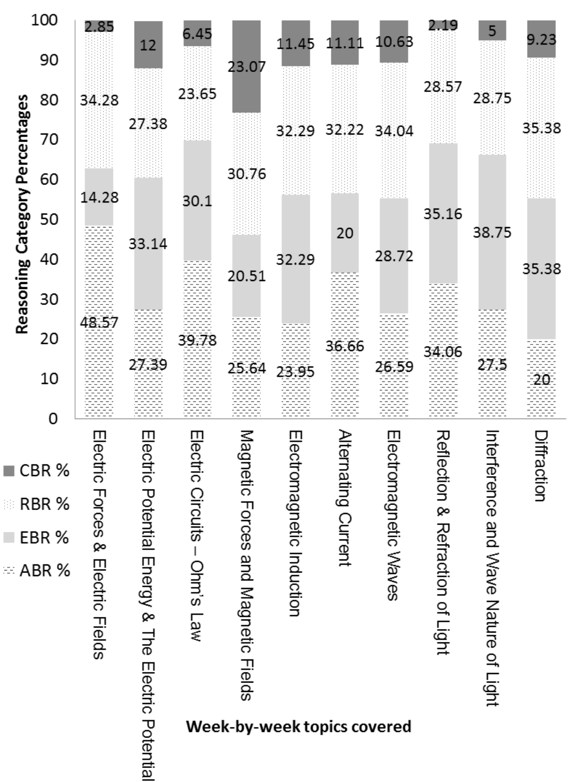

Figure 1. Topics covered for each homework assignment and the percentage contribution of each level of epistemic reasoning to the problem comparisons.

The first homework assignment covered electric forces and electric fields and for this assignment, 48.6% of student reasoning fell into appearance-based reasoning followed by 34.2% of the responses being relationship based reasoning. For the second homework assignment, students completed electric potential energy and the electric potential problems, and a distinct drop in appearance-based reasoning occurred. During this week, equation based reasoning was cited more often than appearance-based or relationship-based. Electric circuits-Ohms law brought about a surge in appearance-based reasoning. This is not surprising given that this assignment includes circuit analysis and Kirchhoff's laws. The recognition of parallel and series combinations is important to the resolution of problems of this type. During this week, students cited appearance based reasoning as the primary ranking epistemic category.

This trend occurs again in the sixth week while working with AC Circuits. For the remaining weeks, Equation based and Relationship based reasoning remained the top ranking epistemic levels for clauses cited for similarities and differences in problem pairs.

CONCLUSIONS & LIMITATIONS

Our goal was to determine how students' level of epistemic reasoning change throughout a semester of compare and contrasting activity treatments. General trends from our data revealed the following:

1. Students consistently use appearance-based reasoning to explain similarities and differences between compared problems. Though appearance-based reasoning is a lower-level of epistemic reasoning, it is important even to the most robust problem solving repertoire.
2. Students' clauses progressively became more equation-based reasoning oriented. This is a higher level of epistemic reasoning as compared to appearance-based reasoning. There is also a notable, though not statistically significant, rise in relationship-based reasoning.
3. Students' use of different types of reasoning is dependent on context. Circuit dependent problems were ranked with higher counts of appearance-based reasoning clauses. This is not necessarily a sign of epistemic 'regression.' Circuits are often represented using diagrams, and may rely heavily on visual cues.

It is important to note that this assessment did not determine the success of the treatment activity, but to simply determine whether there is a successful transition from low to higher order epistemic levels.

Our next step will be to determine how effective, if at all, the activity may be in the observable epistemic change. This will require future replications of this study with larger participant numbers. Further statistical analysis is currently underway to determine how levels of epistemic reasoning may be different between gender, and whether the epistemic trends differ between high achieving and low achieving course performers.

ACKNOWLEDGEMENTS

This project is supported by the Division of Mathematics and Natural Sciences at Penn State Altoona. Special Thanks to Daisy Phillips for her assistance with the statistical analysis.

Project adheres to the OHR and IRB policies of Pennsylvania State University, IRB#33928.

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