Splits Between Student and Expert Attitudes and Beliefs about Physics

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Introduction

Most in the field of physics education research believe that student attitudes and beliefs have a strong effect on how students will learn, and are interested to know how and why. Also, educators often have implicit or explicit goals of teaching students something about the nature of science and learning, and the role of physics in everyday life, among other things, which E. F. Redish calls the "hidden curriculum" [1]. In order to assess what effect student beliefs will have on their performance, or evaluate the effectiveness of teaching goals which aim to shape student belief, researchers in the field have created surveys that may be implemented easily in the classroom [2-4]. The Colorado Learning Attitudes about Science Survey (CLASS) was developed by researchers at the University of Colorado for the purpose of extending on previous surveys which probe student attitudes and beliefs [5,6].

With the Maryland Physics Expectations (MPEX) survey [2], Redish and fellow researchers showed that, unless the elements of the hidden curriculum are attended to specifically in the course, students will generally develop attitudes which move further *away* from those their teachers hope to develop. They conjectured that students may need to develop attitudes and practices different from the more sophisticated attitudes of experts in the field in order to succeed. Traditionally taught courses may in fact produce a split between what students learn to do and what they actually believe. McCaskey, et al. [7] used the content assessment survey, the Force Concept Inventory (FCI), in an effort to probe the effects on assessment due to splits between belief and understanding. To do this, they asked students to complete the survey twice, first according to what "they really believe," and then according to how they thought a scientist would answer. The students they tested indicate splits in belief on many of the questions. The evidence of so many splits on student's beliefs about the content of physics suggests there would also be many splits in students' attitudes about learning physics.

In this paper, I examine the results of the CLASS in which students were asked to answer its questions in two different ways: according to what they believe, and according to how they think a physicist would answer. Specifically, I look at discrepancies between the students' answers in these two perspectives, and how accurately students were able to predict expert opinions. I discuss the significance of the discrepancies in light of others' research on the differences between expert and novice attitudes and beliefs.

Data

The CLASS survey was administered to a large-university, algebra-based introductory physics course, with an enrollment of approximately 175 students. The majority of the students were pre-med-related majors, many in the life sciences. The data consist of aggregate data collected from the post- results of the CLASS survey given in this course, in which the students were asked to answer survey questions in two ways: first, according to their own beliefs, and second, according to how they believe a physicist might answer. Each response falls into one of the five Likert-scale responses (strongly agree, agree, neutral, disagree, strongly disagree).

In addition, there are video recordings of interviews with five of the students from the class, in which the interviewer goes through each question of the survey, asking students to answer in these two different ways, and to clarify both their interpretation of the question and why there might be differences in the student's own beliefs in comparison with the student's predictions of a physicist's beliefs. Among the students interviewed, there are three women and two men, most of whom are in the first or second year. All of the students were enrolled in the course in order to satisfy a requirement for a major other than physics. The interviewer asked each student a similar set of questions, about his year, major, whether he enjoyed the lectures and labs, how he studied, and how much time he typically spent per week working on the class. The interviewer then asked each student to go through each question on the survey, to answer in the two different ways described above, and to provide a brief explanation for how she came to her decisions.

The raw data are included as an appendix, including the CLASS questions, the expert responses, and the numbers of each type of response by the students, for each of the two ways they answered the questions.

Analysis

For clarity in analysis of the data, the students' responses will be simplified as follows: there will be no distinction made between strongly (dis)agree and (dis)agree, leaving only three categories of responses: overall agreement, overall disagreement, and neutral. The CLASS was administered to a group of experts [5] in order to define the expert response for each question. In order to examine the splits between a student response and the expert response to each question, I have plotted only the questions for which the expert response was overall agree or overall disagree, leaving out the three questions on which the expert response was neutral (# 7, 24, and 29). These specific questions are examined in a different way below. This way, the student responses will either be favorable (indicating the same as the expert response), unfavorable (indicating the opposite of the expert response), or neutral.

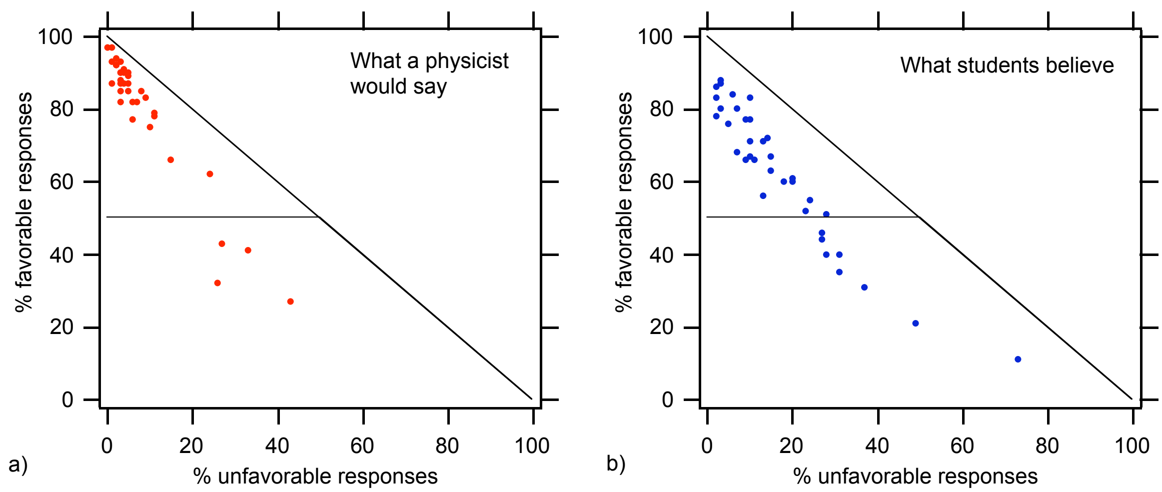

Fig. 1. A summary of student responses to the CLASS, indicating the percentage of favorable and unfavorable responses for each question. a) What students thought a physicist would say and b) what student themselves believe.

Figure 1 shows a summary of students' responses to the questions on the CLASS. Each point represents one question of the survey, with the vertical axis showing the percentage of favorable responses to the question, and the horizontal axis showing the percentage of unfavorable responses. The horizontal line represents where the points would lie if all of the responses were either favorable or unfavorable. The distance of each point from the diagonal line then represents the number of neutral responses. Figure 1a) displays students' answers according to what they think a physicist would say, and Figure 1b) displays students' own beliefs.

Out of the 35 questions plotted, there were 29 for which students were able to predict correctly how an expert would answer, with greater than 75% of students giving a favorable response. For most of the ideas probed on the CLASS, students were able to predict expert opinion quite accurately. However, there are a few notable exceptions. In both plots, a horizontal line demarcates the questions for which less than 50% of the responses were favorable. These questions, for which students had a significant number of unfavorable responses, I refer to as split questions. When students were asked to answer according to what they thought a physicist would say, there are four split questions, and when they were asked to answer according to what they believe, there are eight. Below are the split questions from both sets of responses, along with the percentage of favorable/unfavorable responses.

Splits between experts and what students think experts would say

10. I cannot learn physics if the teacher does not explain things well in class. (27/ 43)
23. It is important for the government to approve new scientific theories before they can be widely used. (41/ 33)
31. The best way for me to learn physics is by solving many problems rather than by carefully analyzing a few in detail. (32/ 26)
38. When studying physics, I memorize important information the way it is presented. (43/ 27)

Splits between experts and what students believe

1. A significant challenge when learning physics is being able to memorize all the information I need to know. (40/ 31)
5. After I study a topic in physics and feel that I understand it, I have difficulty solving problems on the same subject matter. (35/ 31)
10.
12. I study physics to learn knowledge that will be useful in life. (44/ 27)
23.
30. Spending a lot of time figuring out and understanding the derivations or proofs of formulas is a waste of time. As long as I know a formula works it doesn't matter where it came from. (46/ 27)
31.
38.

One interesting thing to note from these lists is that when students indicated unfavorable responses for predicting expert opinion (questions 10, 23, 31, and 38), they also indicated unfavorable responses for their own opinion. This may indicate that these questions probed a fundamental epistemological belief. In other words, not only do students maintain this belief about the nature of physics and learning, but they also believe that experts share their opinion. They are evidently unaware that this is an unsophisticated belief. Three of these four questions relate to how they best learn physics. Students who answered questions 10 and 38 unfavorably may exhibit the novice tendency to unquestioningly accept information that is given to them by authority [1,2]. One of the students who was interviewed said that "it's difficult for me to go outside what other people think,"

while another said about physics equations,

Student: "you get some, like, direction, understanding, whatever, but some of them, like, I don't get, I've just got to accept."

Interviewer: "Yeah. But you still can use them right?"

Student: "Yeah."

Students who answered question 31 unfavorably may exhibit a novice approach to solving problems [8,9], based on surface features of the problem, rather than by recognizing the secondary concepts or principles involved.

There were additional questions on which the great majority of students gave favorable responses for expert opinion, but then a large percentage of the students gave unfavorable responses for their own opinion (questions 1, 5, 12, and 30). In this case they have knowingly split from expert opinion. This may indicate areas which students believe separate them from the expert physicist. Indeed, some of the interviewed students made reference to the fact that some of the ideas may be applicable to physicists, but not to themselves. For example:

"for, say, someone who's at a very high level of physics, because maybe they're able to connect all these things that I don't know how to, that seem really distant from each other… I guess I'm just not at that level to really draw any correlations."

Or, regarding being able to derive equations that haven't been memorized:

"they say you can derive equations, um, I'm not at that level"

In their paper in which they discuss what constitutes a "sophisticated" epistemology [10], Hammer and Elby distiguish between beliefs which are correct and those which are productive for students. Perhaps when students indicated an unfavorable, or unsophisticated, belief, they were displaying ideas which are productive for them, even though they knew that a physicist believes otherwise.

Another thing which stands out from these plots is that students tend to be more tentative about their own beliefs than what they think a physicist would think. In figure 1b), the points are generally farther away from the zero-neutral-response line than in figure 1a), indicating that more of the students chose a neutral position. The average percentage of neutral responses for what a physicist would say is 12%, while for students' own belief the average is 21%. One reason for this is that if the students knew what the expert opinion would be, they may have been ambivalent about their beliefs on this idea, trying to decide between what they knew to be the sophisticated response and the novice response which may more closely reflect their belief. Another possible reason is that they may have been ambivalent about the question depending on how they interpreted it. Among the interviewees, many took longer to answer question 23, and often actually changed their answer, after considering different interpretations of the question. For a majority of the questions on what they think an expert would say, there are very few neutral responses. Students may have believed that there was a right or wrong answer to the questions, according to what an expert would believe.

Listed below are the questions for which the expert response was neutral. Table I. lists the percentage of student responses for each question.

7. For me, reading the text in detail and working through many of the examples given in the text is necessary to learn physics.
24. Knowledge in chemistry is independent of knowledge in physics.
29. Since Einstein's theory of relativity is just a theory, scientists may believe it's completely wrong tomorrow.

	What an expert would say			What they believe		
Question #	Agr.	Neu.	Dis.	Agr.	Neu.	Dis.
7	58	26	17	52	23	25
24	18	17	65	20	25	55
29	46	24	31	43	26	30

Table I. Percentage of student responses on questions for which the expert response is neutral.

For question 7, the majority of students agreed, for question 24, the majority of students disagreed, and for question 29, a slight majority of students also agreed. The percentages are very similar between the student responses for what an expert would say and what they believe. However, the percentage of neutral responses for each question is greater than the average (12% for what a physicist would say, and 21% for students' own beliefs). Agreement with question 7 may again be an indication of an attitude which is more productive than sophisticated for students. For question 24, students seem to see more coherence between physics and chemistry than do experts. Question 29 is another question for which interviewees expressed ambivalence.

The CLASS was designed with groups of questions which probe specific ideas about learning. Six such categories were determined, and are listed in Table II, along with the questions in each category which were split questions.

Category	Split Questions
Understanding physics	1, 5, 30
Math	30
Sensemaking/effort	30
Real world appl.	none
Personal interest	12
Coherence	1
Concepts	5, 31, 38

Table II. CLASS categories of questions, and the split questions present in each category.

In the Understanding Physics category, there are three split questions, for all of which the split was between the student response and the expert. This is reflected in figure 2, which shows the percentage of favorable and unfavorable responses. While students indicated a difference between themselves and experts, the "physicist" and "student" averages for the Understanding Physics category are well separated. In fact, the "student" average for the Understanding Physics shows up on the plot as representing the least sophisticated student attitudes among all the categories. The other category for which there were three split questions was Concepts, and this is also apparent in figure 2. Two of the split questions in this category were ones for which students were unable to predict expert ideas, and it turns out that the "physicist" average for this category is the least favorable. Conversely, for Real World Application, which contained no split questions, both the "physicist" and "student" averages are highly favorable. It seems that the category averages also provide a way of determining the presence and degree of splits in belief and attitude.

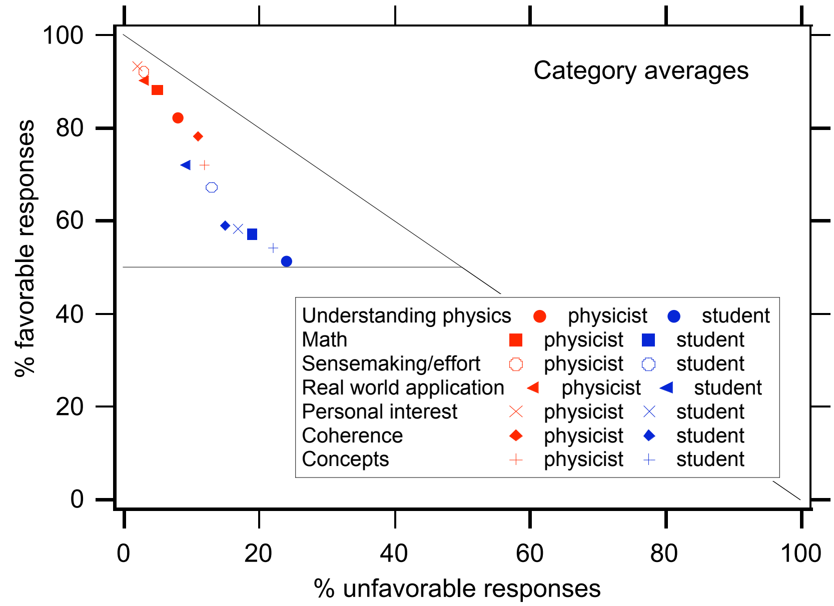

Fig. 2. A summary of student responses to the CLASS, in terms of the different categories which group questions on a similar topic. Red points indicate how students think a physicist would answer, while blue points indicate what students believe.

Conclusions

When asked to answer the Colorado Learning Attitudes about Science Survey questions in two ways, according to what they believe, and how they thought a physicist might answer, students were able to predict expert opinion with great accuracy, but with a few notable exceptions. These splits from expert belief took two forms, where students predicted expert belief incorrectly, and where students knowingly split from expert belief. These splits are also apparent when looking at the idea categories of the CLASS, groups of questions which probe a specific attitude. The splits seem to indicate that students have a novice attitude toward physics regarding conceptual understanding, and that they knowingly split from experts regarding methods for learning physics. Interviews revealed that some of the splits were due to an ambivalence through multiple interpretations of the questions.

There are many directions of study this type of survey administration could take. Analysis of this data, given more information about the students' profiles, might show trends that would interesting to follow up on. For example, McCaskey et al. [7] found that there were gender differences in the rates of splitting on questions, specifically that women tended to split more often than men. Another thing to look at would be to correlate student success in the course with their tendency to split with expert belief. It might also be interesting to compare the results of the survey when the students are given the survey with no additional instructions to the results when they are asked to answer in two different ways. The question here would be whether or not suggesting to students that there could be a difference between their own opinion and expert opinion affects the way they respond. One could also look to see if the splits change between pre- and post- administration of the survey. Since Redish [2] found that student attitudes tended to be less sophisticated after one term of instruction, it might be interesting to see if there are more splits as well.

References

1. E. F. Redish, *Teaching Physics with the Physics Suite*, Wiley 2003

2. E. F. Redish, J. M. Saul, and R. N. Steinberg, "Student Expectations in introductory physics," Am. J. Phys. **66**, 212-224 (1998).

3. I. A. Halloun, "Views About Science and Physics Achievment: The VASS Story," In the Changing Role of Physics Departments in Modern Universities: Proceedings of the ICUPE

4. A. Elby, Epistemological Beliefs Assessment for Physical Science, http://www2.physics.umd.edu/~elby/EBAPS/home.htm

5. W. K. Adams, K. K. Perkins, M. Dubson, N. D. Finkelstein, and C. E. Wieman, "The design and validation of the Colorado Learning Attitudes about Science Survey," submitted to PERC Proceedings 2004.

6. K. K. Perkins, W. K. Adams, S. J. Pollock, N. D. Finkelstein, and C. E. Wieman, "Correlating student attitudes with student learning using the Colorado Learning Attitudes about Science Survey," submitted to PERC Proceedings 2004.

7. T. L. McCaskey, M. H. Dancy, and A. Elby, "Effects on assessment caused by splits between belief and understanding," AIP conf. proc. 37-40 (2004).

8. M. T. H. Chi, P. J. Feltovich, and R. Glaser, "Categorization and representation of physics problems by experts and novices," Cognitive Science **5**, 121-152 (1981).

9. J. Larkin, J. McDermott, D. P. Simon, and H. A. Simon, "Expert and novice performance in solving physics problems," Science **208**, 1335-1342 (1980).

10. A. Elby and D. Hammer, "On the Substance of a Sophisticated Epistemology," *Science Education*, **85** pp. 554-567 (2001).