

Probing Students' Epistemologies Using Split Tasks

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Abstract. Do students really believe the physical principles they learn in class? To explore this question, we gave an FCI “split” task in which students indicated the answers they think a scientist would give and also indicated the answers they really believe. To interpret the splits that students indicated between what they believe and what they were taught, we interviewed students about why they split. It turns out that a split does *not* indicate that the student disbelieves the scientist's answer. The splits actually arose for other reasons, one of which was students indicating a discrepancy between what they were taught and what makes sense to them. For this and other reasons, we devised a new split task focused on these discrepancies between “what makes sense” and what a scientist would say. The results of this new experiment, including validation interviews, will be discussed briefly. Evidence suggests that students are more willing to reconcile physics concepts with their everyday experience if epistemological development is an explicit goal of instruction.

INTRODUCTION

Do students really believe the answers they give on physics assessments? Students can (and often do) become facile at memorizing and repeating back information. However, most assessments don't gauge whether a student is giving answers that make sense to them. Since students try to tell instructors what they want to hear, they might answer questions in a way that contradicts their beliefs or intuitions.

Since the Force Concept Inventory (FCI) [1] is a popular assessment of physics concepts, we used it as the basis for a new probe called a split task, as explained in detail in previous work [2]. We'll briefly review the main points. At the beginning of the semester, our introductory algebra-based physics students, most of whom had taken high school physics, took the FCI with the following additional instructions:

*Please **circle** the answer **you really believe**. Please draw a **square** around the answer **you think scientists would give**.*

The instructions included a sample question marked up in this way and also made clear that students could circle and square the same answer, if appropriate. When the student's belief differed from the answer he

thought a scientist would give — i.e., when he circled and squared a different answer — we called it a *split*. Our findings were intriguing. The average split rate was 24%, which means the typical student split about seven times out of thirty questions. Individual students' split rates ranged from 0% to 90%. Also, we found that women split more than men. Concerning the four FCI items dealing with Newton's third law, we found that even among the students who indicated the correct scientists' answers to *all* of those items, 80% of students (including all of the women) split on one or more of those items. These results led us to hypothesize that students — especially women — often do not believe the “accepted scientist answers” they give on assessments. Our previous work [2] ended there.

Since then, we have conducted validation interviews to get at the meaning of these splits. We wanted to know why students split and whether different students split for similar reasons. The interview data disconfirmed our initial interpretations of the splits. A split never indicated that the student disbelieves the scientists' answer. Their reasons for splitting were more nuanced and varied from student to student, as discussed in more detail below. Many times, students said that their circled (“belief”) answers correspond to their intuition.

For mainly this reason, we have subsequently changed the “circle” instruction to “circle the answer that makes the most intuitive sense to you.” We hoped that examining when and why students split on this new task, and how “worrisome” they find these splits to be, will help us probe students’ epistemological views about the role of common-sense ideas in learning physics. Our validation interviews confirmed that focusing on these “intuition splits” does indeed provide insight into students’ propensity and ability to reconcile intuitive ideas with scientific concepts.

Analyzing FCI post-test results for traditionally taught Maryland students vs. students in our epistemologically focused reformed course, we found evidence that epistemologically focused instruction helps students reconcile. By looking only at students who got the FCI Newton’s 3rd law questions correct (on their “scientists’ answers”), we found that the reform-taught students split a far lower percentage of the time. This is true even though a much smaller — and therefore more selected — percentage of the traditionally-taught students got the scientists’ answers right on those items.

VALIDATION INTERVIEWS

We now discuss our interviews associated with the “old” split task, where students indicated the answer they “really believe” vs. the answer they think a scientist would give. As discussed below, we designed an interview to determine why students split and their more general epistemological views about accepting knowledge from authority. For example, it is possible that students who split frequently are epistemological relativists, people willing to accept the “truth” of their own ideas *and* of the scientists’ ideas, even when those ideas conflict. Such students would have no motivation to reconcile the conflicting sets of ideas. Along these same lines, it is possible that students who split rarely are either (i) great learners who have fully reconciled their own ideas with classroom physics concepts, or (ii) people who accept scientific authority and quickly adopt those beliefs as their own without trying to make sense of it all. It turns out, however, that none of our interview subjects fit *any* of these profiles.

Interview Protocol

We interviewed nine volunteers, eight of them women, for a half hour each. The sample included people who split frequently (“high splitters”) and in-

frequently (“low splitters”). We asked our subjects the following introductory questions:

- What’s your major/year in school?
- Why are you taking this course?
- Had you had physics in high school?
- If so, do you feel you got a lot out of the class?
- How do you know someone is an expert?
- What do you do when experts disagree?
- How do you know when you understand something?¹

The next part of the interview was tied to each student’s survey responses. We started by asking if the task made sense to the student. Then, for individual splits, we asked:

- Why do you believe the answer you circled?
- Why do you think a scientist would give the square answer?
- Is it worrisome that there’s a difference?
- Do you think the scientist could be convinced to see your point of view? If so, how?
- Do you think you could be convinced of the scientist’s view? If so, how?

Results And Discussion

Several patterns emerged from the interview transcripts. Low splitters typically did not think our task made sense. They often wondered why anyone would split on the FCI questions. Sarah² gave a typical version of this sentiment:

“The only thing I didn’t like was that every time I thought an answer would be right, I figured that’s what a scientist would say too, so a lot of them ended up being a circle and square around the same one.”

We had hoped that splits would indicate real differences between a student’s belief and the answers she thought to be scientifically “correct.” However, splits often corresponded to instances where the student did not have confidence in her belief. “Emily” clearly expresses this:

“...for the ones where my circle and square were on different choices, I thought maybe it was just my intuition-based answer, so then a scientist might say something different because it wouldn’t... they would be basing their answer on... facts, I guess.”

¹ The last three questions are adapted from Belenky, et al [3].

² All student names are pseudonyms.

Not only does this response indicate a lack of self-confidence in Emily’s “belief” thinking, it also contains an epistemological statement. Emily seems to believe here that scientist answers are based on facts and intuitions are not. In other students, this distinction between scientific and everyday reasoning is more pronounced. Christine’s statement epitomizes a viewpoint expressed by several subjects:

“It is true, if you listen to a scientist talk, a lot of times, you don’t understand everything, and so if I didn’t understand everything in the answer, it seemed like a plausible scientist explanation.”

Relativism seemed to be absent from our interview data. No matter how many splits people indicated, they often believed the squared and circled answers *could* be reconciled; almost all the subjects said that only one answer could be right in the real world. (In addition, differences between a student’s belief and scientist’s answer often worried the student because they know that only one answer is acceptable on a test.) The strongest hint of relativism we spotted came from Sarah, responding to the question about splits being bothersome:

“Well, just because then I wouldn’t know which was correct, or anything, and I’d wanna know which one was, you know? There can’t be two different answers. Well, I know that... I know that there’s two different ways... if you can explain things and support your answers, I know there can be two different answers, but I would prefer to be saying the same thing.”

For a moment, Sarah seems to say that there can be two different “right” answers to a question; but she quickly clarifies that the two “different” answers should actually be two ways of saying the same thing. Like our other subjects, Sarah thinks there should be one right answer to a given introductory physics question. But these subjects were not authority-driven absolutists. When discussing the nature of expertise and understanding in the context of politics, or cutting-edge science, they assert that there’s no one right answer and that knowledgeable people can disagree. (We lack space here to give quotations supporting this conclusion.) So, students’ epistemological views about the source and certainty of knowledge are more nuanced and context-dependent than are the categories we outlined above.

The interview questions about splits focused on subject matter students had not yet covered in class. In cases where the students had received a tutorial on the relevant topic between the initial survey and the inter-

view, they often nullified their split. Questioning revealed that those students had, indeed, refined their intuitive ideas to be consistent with the physics concepts. More important from our perspective, however, was the expectation most students expressed that they eventually *would* be able to achieve a similar reconciliation regarding topics they hadn’t yet covered.

A NEW SPLIT TASK

The above results suggest that (i) there are not “real” splits between students’ beliefs and the answers they think scientists would give; (ii) even when instructed to indicate a “belief split,” students gravitate toward expressing splits between their intuitive ideas and the answers they think scientists would give; and (iii) examining these “intuition splits” could provide insight into students’ epistemological views concerning the reconcilability of informal and formal knowledge. For these reasons, we then decided to study intuition splits rather than belief splits.

The new survey task is the same as before, except the circle instruction now says,

*Please **circle** the answer that makes the most intuitive sense to you.*

We gave the survey to a group of second-semester introductory physics students at the University of Maryland. A total of 153 students took the survey. Most (108) had taken a reform-oriented course during their first semester (the term where FCI material is covered), while the other 45 students came from a traditional first-semester class. The reform course incorporated tutorials and interactive lecture demonstrations designed to foster both conceptual *and epistemological* development.

The two groups behaved quite differently. Table 1 shows the average (and standard deviation) for each category.

TABLE 1. New split task data for UMD class

1st semester background:	Reformed	Traditional
N	108	45
Circle score	17.9 (6.2)	11.4 (5.5)
Square score	19.0 (5.4)	11.0 (6.4)
Number of splits	4.6 (5.6)	6.1 (3.8)

The difference in splits is marginally significant statistically ($p=.06$), while the score distributions are more

significantly different, with $p \ll .0001$ for both circles and squares.

New Validation Interviews

New validation interviews were conducted for this intuition-split task. Seven students went through a similar interview protocol as our previous interview subjects. Most of these agreed to be interviewed for an hour. The differences in the protocol consist of the wording change in the new split task and additional background questions (for subjects willing to stay the full hour). Also, the Belenky questions were removed because they do not explicitly probe attitudes about reconciliation.

The results indicate that intuition-splits are much easier to interpret than belief-splits; the intuition splits really do indicate a discrepancy between a student's common-sense ideas and the answer he thinks a scientist would give.

Newton's Third Law

As instructors, we are most interested in the splits that arise when the student gets the scientist's answer correct, since those splits indicate a lack of reconciliation between the student's common-sense ideas and what she has *successfully* learned in class. To get at this issue, we focused on the FCI's four questions on Newton's Third Law (numbers 4, 15, 16, and 28). As expected, the reformed class performed better on the N3 questions, getting the scientist's answer right 85% of the time vs. 42% for the traditionally taught students. This result is nothing new. Previous studies, however, have not addressed this more subtle question: Is there a conceptual and/or epistemological difference between the traditional students who got the N3 scientist's answers correct and the reform students who got the N3 scientist's answers correct? Of the correct N3 responses among the traditional students, 41% had splits. By contrast, among the correct N3 responses given by the reform students, only 12% had splits. Low split rates indicate that the students believe they have reconciled Newton's 3rd law with the intuitive ideas. The interviews discussed above, along with students' written work on exams, suggest that the reform students don't just *think* they've reconciled; most of them have actually done so. Compared to the traditional students who answered the questions correctly, the reform students are more inclined and/or able to reconcile their intuitive ideas with Newton's 3rd law — an intended result of our N3 tutorial. In this sense, the traditional students who "learned" Newton's

3rd law didn't learn it as deeply as the reform students did. To confirm this interpretation, future work will analyze videotapes of students working through the N3 tutorial. For now, though, it's reasonable to hypothesize that even when traditional instruction "works," it works differently from epistemologically focused, reform-oriented instruction.

SUMMARY

Our old split task, which asked students to differentiate between their belief and a scientist's answer, yielded results that were difficult to interpret. A new split task asking for "the answer that makes the most intuitive sense" rather than a "belief" turns out to be more focused. With this new task, comparing traditional to epistemologically focused, reform-oriented instruction, we found that the reform students not only learn Newton's 3rd law better in the sense of learning the correct answer, but also reconcile that law better with their intuitive ideas.

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