Teaching, Learning and Physics Education Research: Views of Mainstream Physics Professors

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Abstract. This paper presents the preliminary results of interviews with four thoughtful senior faculty who are not part of the Physics Education Research (PER) community. The interviews focused on their general beliefs about teaching and learning as well as their use of and attitudes towards PER and PER-based instructional strategies. We found that these instructors have beliefs about teaching and learning and instructional goals that are more PER-compatible than their self-described instructional practices. We hypothesize that one factor impeding more complete incorporation of PER is instructors' either misinterpreting or having a low opinion of the trustworthiness of educational research results.

INTRODUCTION

Substantial time and money has been spent developing research-based instructional strategies for introductory college physics courses. Despite wide availability, existing evidence suggests that these strategies and materials are only fully incorporated into a small number of introductory physics courses. Perhaps some physics instructors don't care about teaching or what their students learn, but our experience is that most physics faculty take their teaching responsibilities seriously. What then is preventing these instructors from more fully adopting the results of educational research? Common suggestions [1] include satisfaction with current practices, unawareness of alternatives, and incompatibility of goals and beliefs with alternatives. This paper suggests that these factors do not predominantly explain the slow adoption of research-based strategies by introductory physics instructors and hypothesizes about other important factors.

RESEARCH METHOD AND ANALYSIS

Semi-structured, exploratory interviews were conducted with four tenured physics faculty from three different institutions who had no formal connections with the Physics Education Research (PER) community and, in our opinion, were particularly thoughtful and reflective teachers. If, as is commonly stated, the goal of the physics education reform movement is to create a critical mass of instructors using reformed pedagogical approaches, this type of instructor can be expected to form the core of that critical mass. Each interview lasted over 1 hour and contained questions about instructional goals, current and past instructional practices, attempts to change practices, and familiarity with educational research. The analysis focused on identifying (1) expressed beliefs about teaching and learning, instructional goals, self-described instructional activities, and inconsistencies between these three aspects; (2) current and past efforts to change instruction and factors that facilitated or hindered such changes; and (3) knowledge about and attitudes towards PER-compatible instructional strategies.

Instructional Goals

Each instructor was consistent in describing his or her instructional goals throughout the interview. Similar to other studies [2], all described their primary instructional goals as developing students' understanding of physics principles and ability to solve problems related to these principles. None of the instructors felt their students were fully achieving these goals, with three expressing the belief that many of their students were falling far short.

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PER-Compatible Beliefs and Traditional Practices

Based on the research literature [3] and our own experiences, we developed a list of 8 instructional practices (see Table 1) and 14 instructional beliefs (e.g., What should students learn?, What should be explicitly taught?) that differ between traditional instruction and PER-compatible instruction. Each author independently rated the beliefs of each instructor and then compared. Differences in ratings were minimal and were resolved through discussion.

TABLE 1. Comparison of Practices

Traditional Practices	PER Compatible Practices
Teacher ideas are center of classroom activities, students are allowed to be passive (e.g., lecturing, teacher-centered discussion).	Student ideas are center of classroom activities, students are often required to be mentally active (e.g., individual reflection, small group discussion).
Encourage or support competitive/individualist learning modes (e.g., grading on a curve, only individual assignments)	Encourage or support cooperative learning modes (e.g., grading based on preset standard, expectation of working with others)
External Motivators (grades, testing)	Internal Motivators (connections to student interests or needs)
Assess for quick and accurate performance in solving a set of familiar problems or in recalling a set of facts and principles.	Assess for thinking/problem solving skills in conjunction with meaningful understanding of facts and principles (i.e., open-ended or novel questions)
External definition of success for all students, same instruction for all, diversity seen as a problem.	Treat students as unique individuals with different needs, value all students
Grades/testing used to sort, rank, certify	Assessment for feedback
Major decisions made by teacher (content, focus, how class time spent)	Students contribute to decisions about what/how they learn (e.g., projects).
Explicitly teach only physics content.	Explicitly teach learning, thinking, and PS skills in addition to physics content.

We found that instructor beliefs were generally PER-compatible or mixed (instructor expressed both types of beliefs). At least one other study has also found that instructors have beliefs about how students learn that are more compatible with PER than with traditional instruction [4]. In contrast, three of the instructors had a majority of self-described teaching activities consistent with traditional practices. The fourth instructor described a mix between traditional and PER-compatible teaching activities. This closer alignment of practices to beliefs, however, occurred recently and is described in a separate paper [5].

For example all of the instructors expressed the belief that one of their main goals was developing students' problem solving and thinking skills. They also all agreed that the best evidence of problem solving skills (as well as an understanding of physics principles) is a student's ability to solve novel problems. In practice, however, most of the instructors explicitly taught only physics content and wrote exams that contained problems very similar (or identical) to ones students had already seen.

This can be seen in "Gary's" interview. When he was asked to describe his main goal for the course, he said: *"I think I'm teaching problem solving. And I'm probably teaching in the broader sense, I'm teaching problem solving in life as much as physics, physics is kind of incidental, almost."* Later, when he was asked how he knew when his students had developed their problem solving skills he responded: *"If they are encountering a new application they're showing problem solving skills in physics, other than just repeating a solution they've done before, they've seen me do before."* Gary had already mentioned that most of his exam questions come directly from a study guide he provides. When probed on this issue, Gary recognized the inconsistency in his belief and practice and commented: *"I know that most of my students are not learning problem solving. If I change the situation they think it's a whole new problem."*

This type of inconsistency was common. Although the instructors held predominantly PER-consistent beliefs and goals, their practices were predominantly traditional.

Instructional Change and PER

If the goals and beliefs of these instructors are generally compatible with the results of educational research, what is preventing them from using more research results in their practice? Part of this inconsistency between beliefs and practices arises, no doubt, from the difficulties involved in translating abstract beliefs and goals into concrete instructional actions. PER, however, provides many examples of how this can be accomplished.

This lack of more fully PER-compatible practices cannot be explained by unfamiliarity with PER. Three of the instructors were reasonably familiar with PER, They were aware of the names and basic practices

involved with innovative curricula such as Peer Instruction, Workshop Physics, Physlets, University of Washington Tutorials, and several other research-based strategies. The fourth instructor, while not explicitly familiar with PER had been exposed to general research-based teaching techniques through a residential grant-sponsored program. All instructors were similar, however, in that none use educational research as recommended by curriculum developers. It is always modified. Sometimes these modifications are consistent with the underlying workings of the innovation, but often they are not. For example, Terry believed that *"every student has a different way of learning and my challenge, every teacher's challenge is in fact to find a variety of ways that can engage those students."* He knew about Peer Instruction [6] and described using ConcepTests in his teaching. However, he did not implement the peer interaction aspect of Peer Instruction. Thus, although he was familiar with Mazur's book [6] in which Mazur carefully describes how to manage the class and argues that peer-to-peer interaction is a good way to handle diverse student learning needs, he was not convinced enough of the usefulness or practicality of peer interaction to incorporate it into his instruction.

PER is not always well received: Although all of these instructors reported having changed their instruction, often in ways compatible with PER, it became clear in the interviews that instructors' perceptions of PER and the PER message may be preventing more rapid dissemination of PER. This section will present results from the three instructors who indicated explicit familiarity with PER.

All three instructors expressed the opinion that PER sends the message that there is only one way to teach and fails to account for different instructional situations and instructors. For example, Terry said that *"All of those people [PER researchers] seem to think that their way is the only way. . .That the only way that a student's going to learn is if I stop doing this and start doing that. And I argue that in fact that's unfair to both teachers and students. I think that . . . teachers teach well in many different ways . . . and I think that the one size fits all is not very good for the whole physics community."*

All three instructors expressed a lack of trust in certain PER results. There were three types of reasons that they gave for this lack of trust.

1) PER uses non-scientific research methods: *"Some of the research I find very useful and well done and some of it I find, uh, almost counterproductive because it seems it was done in such a fashion as to throw doubt on all the research." "All of these studies tend to be done with people who are very concerned about teaching, very interested in it, and are putting a lot of effort into their teaching at the time because they are making changes. And, all of those things alone could make a really big difference in how effective a class is."* - Mary

2) PER places too much emphasis on conceptual inventories like the FCI.

3) PER curriculum developers only present good results and do not present difficulties: *"I went to [a particular university] and learned what [the PER] group does. None of that really seemed applicable frankly. . . You know when I'd asked the graduate students who'd been teaching them, they didn't think they were all that great for that audience."* -Harry

PER may also make some instructors feel disrespected by insinuating that they are bad teachers who are harming their students. Threats to self-esteem have been identified in the literature to cause resistance to new ideas [7]. For example, Terry said that *"The first word out of their [a typical PER presenter] mouth is you're not doing things right." "If you tell me that you think my teaching is bad that automatically sets up a barrier. If I tell you that the only really good way to teach introductory physics is X, I've again set up some kind of barrier. . . I think there's just too much of that going on right now."*

Beware of language use: Another related issue that may hinder communication between PER and instructors is vocabulary. In analyzing the interviews we found several cases where instructors were using educational words with clearly different meanings than educational researchers. Words such as "coaching", "asking questions", "discussing", and "interactive" were all used to describe instructional practices that were more traditional than the language would suggest to an educational researcher. For example, Terry describes his interactive teaching style: *"I stay out in front of the bench and not behind the bench and I wave my hands at them all the time, I mean you know it's a very interactive class."* Other instructors used the word "interactive" in a similar manner that appeared to mean that the instructor was interacting with their students. It did not necessarily mean that the students were interacting back or with each other. A possible explanation for this phenomena is that these instructors are unconsciously misinterpreting their instructional practices to be more in line with their PER-compatible image of desired practices. Regardless of the cause, it suggests that educational researchers need to be aware of this issue when communicating with instructors.

DISCUSSION

Although these instructors should be ideal consumers of educational research (compatible goals, many compatible beliefs, dissatisfaction with current outcomes, and familiarity with alternatives) they indicate only modest influence of this research on their teaching. Often it is hypothesized that instructors' strong traditional beliefs about teaching and learning are the dominant factor in their resistance to implementing PER-based curricula. These instructors, however, had beliefs that were more consistent with PER than their practices. At least one other study [8] has suggested the possibility of a similar "disjunction between the stated aims (promotion of critical thinking) and educational practice (unimaginative coverage of content and testing of factual recall)" of college faculty (p. 110). We hypothesize that, while traditional beliefs do appear to play a role, they are not the dominant resistive factor. As described in this paper, more complete incorporation of PER appears to be hindered by instructors' either misinterpreting or having a low opinion of the trustworthiness of educational research results. In addition, instructors must also contend with significant external constraints on their instructional practices. These are discussed in a separate paper [5].

These instructors have beliefs and goals that are largely compatible with PER. Thus, there is no need for PER researchers to convince these instructors of the weaknesses of traditional lecturing. They are already convinced. It might be better to affirm their PER-compatible beliefs and goals and help them find ways to put these beliefs into practice. As Terry put it: *"I think . . . that we've set up in some ways a straw man. That what everybody talks about is the poor bedraggled faculty member and all that that person does, he or she, is stand at the blackboard and writes on the blackboard for 50 min of every class period. And I'll be honest, I've never taught in a place where that's happened. So I don't know if that person exists."*

These instructors were critical of the way PER results were presented and of some of the results themselves. Although it is easy to dismiss critical comments as being uninformed we would be wise to do our best to understand and correct this image problem if we expect instructors to expend the time and energy necessary to understand and use our research results.

These faculty often misinterpreted the PER message. We should be careful about trying to oversimplify the PER message in an attempt to communicate with instructors. We should also not assume that just because they use the same words as we do that they mean the same things.

Finally, these instructors did not take PER curricula and implement them "as is". They took pieces from a variety of sources that they felt were valuable and compatible with their unique instructional situation and personal conditions. Thus, we should not insist that they use the curricula that we developed, but give them information about a wide range of PER-based ideas to help them design their own instruction. Redish provides a good example [9].

Of course, the findings of a small exploratory study such as this one are appropriately used primarily to develop hypotheses for testing in larger, more focused studies. We intend to use the results in this manner.

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