

New Directions for Physics Education Research: A Broad Perspective Analysis

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Abstract. In this paper we introduce a framework that can be used to categorize instructional practices. We then use this framework to identify areas where mainstream Physics Education Research (PER) has embraced alternative ideas and areas where mainstream PER is more traditional. As an example we argue that while PER has embraced the practice of interactivity, it has neglected the practice of student autonomy. This is despite student autonomy being consistent with the goals of PER and being supported by research in other fields. We offer insights and implications based on this analysis.

Keywords: Educational Change, Higher Education, Self-Directed Learning

PACS: 01.40.Fk, 01.40.Gm

INTRODUCTION

Physics Education Research (PER) operates under a set of implicit paradigms and assumptions. While we ask instructors to reconsider their assumptions and practices (for example, transmission based instruction) we rarely reconsider our own. In this paper we begin to examine PER from a broader perspective. In what ways does mainstream PER deviate or not deviate from traditional instruction?

Because PER is somewhat ill-defined, for the purposes of this paper we will define it as the curriculum, teaching methodologies, and research findings promoted in Redish's recent book, "Teaching Physics With the Physics Suite" [1]. This book was intended to be a general overview of the field and represents mainstream and generally accepted ideas from the community.

FRAMEWORK FOR ARTICULATING PRACTICES AND BELIEFS

Based on both an analysis of interviews with faculty and a review of the literature, we have developed a framework to categorize traditional and alternative practices and beliefs relevant to physics teaching. We do not have the space here to either discuss this process in detail nor to show the full

Instructional Practices	
Generally Traditional Practices	Alternative Practices
Passive Students	Interactive
Teacher Control	Student Autonomy
Knowledge Transmission	Knowledge Development
Fixed expectations of students	Adjustable expectations of students
Competitive/individualist learning	Cooperative learning
External Motivators	Internal Motivators
Knowledge-Based Assessment	Process-Based Assessment
Knowledge-Based Content	Broad Content
Knowledge-Driven Instructional Design	Student-Driven Instructional Design
Traditional Problem Solving	Alternative Problem Solving

TABLE 1. Outline of traditional and alternative practices.

framework. However, an outline of the main areas of practice is shown in Table 1.

HOW ALTERNATIVE IS PER?

Our framework includes many alternative ideas that are uncommon even in most "reformed" curricula.

It was our intention to include a wide array of research-based alternatives, not just those typically found in the reform discourse. This allows the framework to be useful not just for describing individual instructors but also for describing, the extent to which whole curricula, approaches, and even research communities, deviate from traditional practice. For example, using the framework, we can consider what kinds of reforms are strongly promoted by the PER community and what kinds of reforms are not strongly supported. This type of analysis is useful for framing the field in a broader context as well as identifying potentially productive new lines of inquiry.

In viewing PER through the framework, we find that PER embraces many of the alternative practices to some extent, but that there are alternative practices embraced only weakly. Below we comment on what we believe to be the most and least embraced practices.

PER Strongly Embraces Interactivity

An area strongly embraced by PER is the practice of interactivity (Table 2). Much of the discourse in PER shuns the traditional lecture-based approach characterized by students sitting quietly taking notes in favor of a classroom where students talk to each other, share their ideas and even engage in hands-on activities during class time. This is an area strongly embraced by researchers and curriculum developers.

Available evidence suggests interactive practice results in higher learning gains [1] and that the more alternative the practice, the greater the gain [1, 2] – see Figure 1.

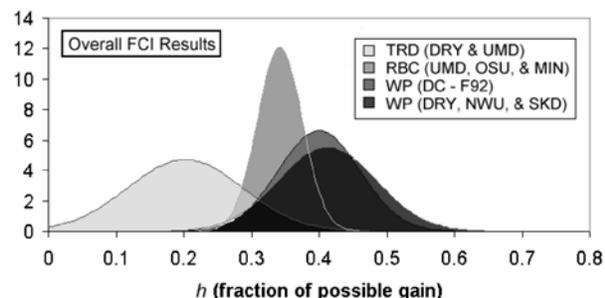


FIGURE 1. FCI results from nine schools with varying degrees of interactivity: traditional lecture classes (TRD), lecture classes supplemented with research-based activities (RBC), and Workshop Physics classes (WP). (from ref [2], p. 12.)

PER Does not Embrace Student Autonomy

The development of interactivity has proven to be a very successful and important aspect of most PER

Minimal Degree of Interactivity (Passive Students)	Significant Degree of Interactivity
Teacher does most of the talking. Few students talk (Lecture)	Students and teacher share talking. Most students talk (Conversation)
Most discourse is teacher-student	Significant student-student discourse
Discourse focuses on teacher's ideas (e.g., students ask clarifying questions and teacher asks rhetorical and/or closed questions)	Discourse focuses on students' ideas (e.g., students and teacher ask and answer conceptual and/or open-ended questions)
Students primarily write teacher's ideas (i.e., take notes)	Students primarily write their own ideas
Students are physically passive.	Students are physically active (e.g., interacting with equipment or materials)

TABLE 2. Details of Interactivity Dimension.

curricula. It seems prudent, then to ask what alternative practices the PER community has not embraced? Are there other changes in practice that offer the potential of better reaching goals we have for our students?

If we consider this question through the framework, we find that the least embraced practice is student autonomy (See Table 3). Along this dimension, PER has not strayed far from traditional practices. In fact, PER is sometimes more “traditional” than traditional instruction because PER-based curricula often remove autonomy over the learning process by strongly directing student behavior. In fact, one of the complaints that some physics faculty have about PER-based curricula is that they attempt to force students to engage in particular learning activities. [3] Faculty voiced concerns about forcing students to interact with each other, enforcing the use of a specific problem solving framework, or calling on students in class. For example one of the instructors we interviewed [4] stated that he did not require peer to peer interaction as it limits student autonomy. *“That is my observation over many years of teaching, yes. That if I try to do it the other way, I think they think they are being forced to do something they don’t want to do... I think the different kinds of students want to do things in different ways.”* (Terry)

Should PER Support Student Autonomy?

There is, of course, nothing wrong with being on the traditional side of practice. After all, our goal is to

improve student learning, not to be as alternative as possible. However, the extent to which practice is traditional or alternative should be an intentional choice. It is worth asking the question, are the goals of PER better supported by control or autonomy?

Consider the goal of helping students become independent learners and thinkers who have the ability and confidence to critically examine ideas. For example, Redish [1, p. 7] states that *“The task of the physics teacher today is to figure out how to help a much larger fraction of the population understand how the world works, how to think logically, and how to evaluate science. This is doubly important in democratic countries where a significant fraction of the adult population is involved in [making decisions].”* Students are not going to develop the ability or confidence to think for themselves if they are not given the opportunity. If we are always telling them what and how they should learn and behave, then we can not expect them to one day be a proactive democratic citizen. Autonomy is more consistent with this goal. In contrast, control is more consistent with the goals of encouraging respect for authority and teaching discipline. If the goal is to teach students to accept expert opinion without question, then it makes sense to have the teacher make decisions that the students are expected to respect. The goals of PER are more consistent with autonomy than control. As Karplus [5] stated *“Students get a sense of control and responsibility [when given autonomy] that will encourage them to take more intellectual initiative in their studies and investigations in the future.”*

Certainly many physics faculty and researchers have written about their dislike of having to exert so much control over students in order to get them to learn. A recent article by physicist Singham [6], for example, describes the coercive nature of the modern syllabus describing how he built up a very *“comprehensive, detailed, and authoritarian”* syllabus over the years. Initially he was happy because students were behaving as directed. However, he realized that this was limited to very specific things and that it was actually counter productive to his larger goals. He concludes that authority is not able to *“make students care about the work, be creative and original, be considerate of others, or write and speak well.”*

Although the goals of PER are generally consistent with autonomy, certain beliefs pull curriculum toward control. For example, a common belief is that students cannot effectively learn physics content without lots of direction. *“Well they actually can’t do it, the open-ended things completely overwhelm these students.”* (Interviewee) There is also the belief that students must be forced to learn, *“If you want students to learn something, you have to test them on it.”* [1, p.75] In

Teacher Control (Teacher makes all instructional decisions)	Student Autonomy (Students have input in instructional decisions)
Teacher decides on content and depth of course	Students influence content and depth of course (e.g., individual projects, changes based on questions/interests of students)
Teacher decides how class time will be spent (e.g., lecturing or other highly structured activities/labs)	Students decide what they will do in class (e.g., student designed-activities/labs, centers)
Teacher decides when and how students will be assessed.	Students have choice over types and/or timing of assessment.
Teacher decides what knowledge is valued (e.g., students expected to learn and use physicists’ terms, definitions, conventions, etc.)	Community knowledge is valued (e.g., students develop own language to discuss ideas, students share experiences and perspectives with goal of learning from one-another)
Class structure decided by teacher and/or school (e.g., bolted down chairs/tables, length of class/semester, class size, etc.)	Student have choice in class structure (e.g., flexible room arrangement, independent study courses)

TABLE 3. Details of Autonomy Dimension.

addition, a modernist view of knowledge, that knowledge is absolute, lends itself to control. *“But the students I don’t think [should] decide what they need to learn and at what pace, because one, they don’t know what they need to know.”* (Interviewee). In contrast the postmodern view of knowledge, that knowledge is socially constructed and dynamic is more consistent with both constructivism and autonomy.

However, just as there is research-based evidence that increasing the amount of interactivity increases learning, there is also research-based evidence that not only can students effectively learn when given freedom, but that their learning is improved. Research [7] indicates that when given choices students work faster, produce higher quality work, remember tasks better, are willing to work for longer periods, take greater pride in their work, are more creative, are more motivated, perform better on standardized tests, and improve their reasoning skills. In addition, there are a handful of schools that operate primarily around self-directed learning, such as Sudbury Valley, a school with no academic requirements. From a follow-up study of the graduates of Sudbury, Gray [8] reports that graduates *“have had no apparent difficulty being admitted to or adjusting to the demands of traditional*

higher education and have been successful in a wide variety of careers. Graduates reported that ... the school benefited them by allowing them to develop their own interests and by fostering such traits as personal responsibility, initiative, curiosity, ability to communicate well with people regardless of status, and continued appreciation and practice of democratic values."

Given the success PER has found by embracing other alternative practices, the research-based support for student autonomy, and the obvious contradictions between many goals embraced by education researchers (e.g. critical, independent thinking) and the outcomes of teacher control, it seems reasonable to give further consideration to more deeply embracing student autonomy.

Moving towards instruction that supports student autonomy is possible. Small steps can be made, for example, by deemphasizing grades as a motivation to learn [9] or by having students submit questions that they have about their assigned textbook reading rather than administer a reading quiz [10].

CONCLUSION

We have demonstrated how our framework of traditional vs. alternative teaching practices can be used as a tool to examine the practices embraced by PER and identify potentially productive alternative practices that PER should consider. As an example, we showed that PER has strongly embraced interactivity over passive students but has not embraced student autonomy over teacher control. An "outside the box" analysis of PER illuminates many alternative practices the PER community should consider more seriously. These practices appear to support goals (such as critical thinking) generally held by members of the community better than practices currently embraced and are often supported by research findings in other fields.

We are not arguing that this will be easy to do or is guaranteed to work. In fact, genuine attempts to incorporate more student autonomy are likely to be met with systemic resistance [11]. While autonomy is consistent with developing independent thinking, independent thinking does not always support the economic goal of producing a workforce. As both Schmidt [12] and Mahajan [13] have pointed out, students preparing to be workers must learn to accept employers goals, values, problems, and methods and be externally motivated (by grades or money) to work hard. The needs of the economic system have been shown to play a defining role in actual educational practice [14] regardless of the beliefs of individuals involved.

However, student autonomy offers much promise as an unexplored and potentially fruitful area in physics teaching. Just as many instructors do not embrace interactive instruction because they do not think that it could possibly work in their classrooms, we as a field should not discount the potentially fruitful rewards of embracing freedom.

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