

# Seeding Change: The Challenges of Transfer and Transformation of Educational Practice and Research in Physics (Part I)

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**Abstract.** Academia appears to do a remarkable job at producing the next generation of research faculty. The long-anticipated shortage of well-qualified researchers has not appeared [1]. At the same time, while there are calls to reform educational practices in college and university classrooms, we are not widely preparing our future faculty to develop or implement these research-based educational practices. What mechanisms exist to foster the development of such practices and promote the field of PER more generally? These coupled papers examine the interrelated problems of supporting the development of the field, and the ‘transfer’ of what is known from PER to the more general populace of physics instructors. The first of these coupled papers outlines a framework of professionalism and faculty attitudes that is applied in the second paper in order to examine two programs designed to address the challenges of including education into the broader physics culture.

## INTRODUCTION

In physics there is an asymmetry between research and education. This asymmetry is evident in the practice of current physicists and the preparation of future ones, in the attitudes and beliefs of physicists, and in the hiring and promotion practices at the most prestigious physics departments. In these papers we characterize this asymmetry and explore ways to reduce it. We focus on the role of graduate school, which we identify as a critical experience in the preparation of future physicists and a key point of leverage in attempts to integrate teaching and education research into the broader physics culture.

In Part I, we discuss physics graduate school in terms of preparing physics professionals. Using the notion of *professional*, we examine the relative roles of teaching and research in physics graduate school. We also consider faculty attitudes and beliefs about education and about research on education, and how these shape graduate experiences and the practices of the community. In Part II, we discuss two programs designed to integrate education into the core practice of physicists and examine the impact of these programs on the participants.

## PHYSICS PROFESSIONALS

Graduate and postdoctoral programs in physics are designed to prepare professional physicists. Providing we agree upon what *professional* means, few would argue with such a statement. Professionalism as a concept embodies far more than a mastery of given content domain, such as theories of early star formation, or the trapping and manipulation of atoms. While there are many aspects to the professional life of physicists, here we focus on two critical elements: research and teaching. Though teaching may not be seen as within the traditional corpus of physicists’ professional practice, we argue that, indeed, it is. Physicists may or may not be in professional environments that require explicit teaching (such as the university, college or pre-college environments); however, most physicists engage in various forms of teaching when broadly considered (whether it includes training within the work place, or sharing work with others in the form of presentations). More subtly, by including teaching and education within our conception of the core practice of physicists, we explicitly state the value and importance of education. Education is the process by which we produce more physicists and the means by which we share what is

known and useful in our discipline with the rest of society (including those that vote, fund, and set policies for our work and society). While universities adequately prepare graduate students for their professional roles as researchers, our efforts at preparing these same students in teaching and educational practice in physics are lagging. By more thoroughly defining the characteristics of professionals, we highlight the achievements and shortcomings of our efforts in the preparation of graduate students and postdocs as physics professionals. In Part II, we examine two programs that successfully augment the traditional training that graduate students and postdocs receive and consider the issues involved in order to include these programs in an integrated and sustainable manner.

## Six Characteristics of Professionals

Shulman considers a profession to 'describe a special and unique set of circumstances for deep understanding, complex practice, ethical conduct and high-order learning, circumstances that define the complexity of the enterprise and explain the difficulties of prescribing both policies and curriculum in this area' [2]. Professionalism has both technical components and ethical or moral components. It is an evolving rather than prescriptive domain of practices. Shulman characterizes six critical (necessary but not sufficient) conditions of professional learning: service, understanding, practice, judgment, learning, and community [2]. We examine these six characteristics of professional learning to explore how we might include education more thoroughly within the preparation of future physicists.

**Service:** Service is the goal of a profession – to augment and contribute to society using specialized skills, knowledge, and judgment bound to a particular community and domain of inquiry. Professional physicists serve society (by characterizing and shaping our world). Our graduate students, with thorough preparation in research are well trained to serve in this manner, by advancing the field of physics and expanding what is known and practiced. Service in *teaching* physics is a muted theme in our graduate programs – it is represented by paltry teaching requirements, limited or absent training programs, and an area of minimal supervision or feedback. Graduate school is complete when a student contributes research to advance the field (in service to the sub-domain and society at-large). Teaching is either considered an obstacle, or an addendum.

**Understanding:** The body of knowledge, the scope of what is known, tested, debated, and developed is

one of defining characteristics of the profession. Understanding Beowulf, while critical to some scholarly and professional pursuits, is generally *not* considered within the body of understanding necessary for the professional physicist. Through courses in particular domains of inquiry, and particularly through laboratory and research apprenticeships, graduate students develop an understanding of the research domain of physics. When it comes to teaching, in general, graduate programs provide remarkably few opportunities to promote student understanding of teaching, what is known in the growing field of physics education research, or the rich literature of educational practice.

**Practice:** The practice of physics may be considered the purpose, or ends, of knowledge. To apply, to test, and to further what is known in the field requires the *practice* of physics. Ultimately, the practice of research is the hallmark of a graduate program – through a fairly explicit model of apprenticeship, graduate students become professional researchers through practice. Teaching, in contrast, remains highly variable in terms of opportunity to practice (requirements vary between no and 3 terms of teaching, generally). It remains largely de-coupled from other aspects of professional learning and the lack of feedback and support of teaching turns the practice of teaching from a form of professional preparation to a stunted form of practice, a mechanism to fund graduate pursuits or fulfill requirements.

**Judgment:** Judgment bridges understanding and practice. Judgment is based on the ideological commitments of a profession, and distinguishes between prescriptive labor (following defined tasks) and professional activity. One of the defining characteristics of professional physicists is their ability to define problems and simplify questions in order to identify appropriate physical mechanisms that shape the investigation of our world. Through coursework, participation in research labs, colloquia, conferences, and professional journals, graduate students develop a sense of judgment about what research questions are appropriate, and how and when to revisit and revise a particular research approach. Meanwhile, little or no coaching on judgment in teaching is present, and too often teaching is approached *ad hoc* (for graduate students have little understanding upon which to base their practice).

**Learning from experience:** Learning from practice serves to inform academic understanding, practice, and judgment. This cyclic process in physics allows physicists to revise and revisit theories, challenge paradigms, and develop new forms of inquiry.

Research experiences and feedback, in the form of group meetings, conferences, and papers, shape graduate student preparation in research. In teaching, relatively few mechanisms for reflecting on educational practice exist. Students tend to teach as they were taught without much reflection on the process. Only in the exceptional cases is teaching recognized in graduate preparation (with teaching prizes, or punishment). In the normal course of events, there are no opportunities to reflect upon teaching practice other than to recognize that these duties have been discharged.

**Community:** A community of professionals has distributed expertise across and responsibility for a domain. This community holds the reins to validate new forms of understanding, practice, and judgment. In physics, when these community values are breached (e.g. when data are falsified), it is a scandal and the community rejects the work and the individual conducting the work. The research community is well defined for graduate students. They participate as a cohort of students taking classes, then in a research group, as conference participants and members of a discipline, and ultimately as contributors to the field (through presentation and publication). Teaching has no such established or built-in community in graduate preparation, despite it being a widespread practice of the professionals they seek to become.

## FACULTY ATTITUDES

The asymmetry between teaching and research is not limited to graduate preparation; it is also reflected in faculty attitudes and practices. These two elements of university education are interrelated: faculty attitudes influence the focus of graduate school, while the attitudes of future faculty are shaped by the graduate experience. We first consider physics faculty attitudes and beliefs about teaching and learning, and then turn to attitudes and beliefs about *research on* teaching and learning. In Part II, we focus on the relationship between attitudes and graduate preparation.

### Faculty attitudes about teaching and learning

It is generally acknowledged that instructors' attitudes and beliefs have a major impact on classroom practices and consequently on student learning [3-6]. For instance, White and Gunstone note that university teachers' views of the structure of physics were overwhelmingly the dominant criteria for deciding

curriculum and pedagogy [7]. Instructors' beliefs about teaching and learning are formed by personal experience, experience with schooling and instruction, and experience with formal knowledge, including pedagogical knowledge [6]. Many beliefs about teaching and learning are established early and are strong and enduring [4,6].

Instructors' attitudes and beliefs about teaching and learning are particularly relevant in physics, where those attitudes and beliefs may constrain widespread use of the findings of PER. While PER provides guidance on effective instructional practices, it rests on a particular set of assumptions about teaching and learning that may be at odds with instructors' beliefs. Despite evidence that interactive engagement methods are more effective than traditional instruction [8], enthusiasm for using interactive techniques varies widely among instructors. We attribute this, in part, to differing attitudes and beliefs about teaching and learning. (Other constraints might include lack of resources, institutional support, or awareness [9].) For example, interactive techniques generally aim to improve the performance of all students, and particularly middle and low achieving students. If the instructor believes the purpose of the course is to 'find out who's good at physics' (as opposed to bringing all or most of the students to a particular level of competence), then he or she may feel that interactive techniques undermine the instructional goals. Additionally, if an instructor believes that physics is either something you 'get' or you do not, then he or she may not feel interactive techniques are worthwhile. We consider instructors' beliefs and attitudes about teaching and learning of central importance to widespread implementation of physics education research.

### Faculty attitudes about research on teaching and learning

Physics faculty are experts at using research methodologies to study physical phenomena. This expertise is developed through a lengthy graduate school apprenticeship; as discussed above, no analogous experience exists for education. At the same time, physicists readily seem to transfer their physics skills to new domains such as biophysics, finance, and consulting [10]. In fact, such flexibility is a point of pride among physicists. One might expect that this research expertise could be applied to education as well. While some physicists have done this and others make calls to do so [11], outside of PER, research on teaching and learning, and scholarship of teaching and learning remain rare.

In this section we consider some possible origins of resistive attitudes towards education research. We begin by considering the role of a framework for understanding education, the context of education and research in physics, and the culture of physics.

#### *A framework for understanding education*

Physics education research provides a framework for investigating physics education and shaping effective educational practice. It is unclear how much physics faculty know about PER [9], but a lack of pedagogical content knowledge and its practice seems widespread. As noted above, White and Gunstone found that faculty approaches to teaching physics were dominated by their views on the structure of the material [7]. The failure to consider presenting the material in a way that facilitates student learning suggests a view of teaching that focuses on the topic and the teacher, as opposed to learning and the student.

We find, anecdotally, that even when made aware of PER, many traditional physics faculty question whether such an approach to education is valid, productive, or within the purview of physicists. We attribute this rejection, in part, to attitudes and beliefs about teaching and learning. Furthermore, we believe these attitudes and beliefs are an expression of physics culture more broadly.

#### *Context of education and research in physics*

By definition, graduate preparation occurs in an institutional context of Ph.D. granting universities. This context informs the goals and practices of graduate students and faculty, but may be a mismatch for graduates bound for institutional settings with other goals and practices. We do not dispute the need for institutions that emphasize research, but wish to emphasize that the *minority* of graduate students become faculty at institutions similar to those in which they were trained [1]. Such a focused emphasis on research to the exclusion of other professional characteristics has consequences for the entire physics community.

In addition to institutional context, we can consider the domain of problems investigated by graduate students. Generally graduate students in physics develop their skills as researchers in the context of a single domain (studying physical phenomena). Is it unreasonable to think physicists could see how these skills can be applied to educational issues? Physicists, as a group, have had little difficulty applying research methodologies to other scientific fields (e.g., biophysics) [10]. This suggests that physics graduate

preparation is not context bound *per se*, but that the support of using these research skills depends on the target discipline. Our claim is that many (perhaps most) of the skills of analysis, reasoning, and experiment that are developed in graduate research may be productively levied in educational practice and research, *if* such pursuits are valued.

#### *Culture of physics*

The physics community at large considers teaching and research to be separate endeavors; ones that do not inform each other. Ultimately, this attitude can be viewed as a cultural feature of physics. This attitude is manifest in norms, practices and institutional structures such as the asymmetric treatment of education and research during graduate preparation. How and why this view becomes part of physics culture (and that of higher education generally) is a complex question that we begin to address by considering the process of graduate preparation. In Part II, we focus on the question of how to create a culture where teaching is included in the core practice of physicists and considered a researchable endeavor.

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