Physics education research at primarily undergraduate institutions

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The theme of the 2024 Physics Education Research Conference (PERC) was Bridging the Institutional Gap: PER at Primarily Four Year Institutions, Two-Year Colleges, and K-12 Levels. What exactly do we mean by the "institutional gap"? What are some strategies and resources to help bridge the gap(s)? Here I will provide my perspective on these questions and discuss the challenges and opportunities for physics education at primarily undergraduate institutions.

2024 PERC Proceedings edited by Ryan, Pawl, and Zwolak; Plenary, doi.org/10.1119/perc.2024.plenary.Docktor

I. INTRODUCTION

The theme of the 2024 Physics Education Research Conference (PERC) was Bridging the Institutional Gap: PER at Primarily Four Year Institutions, Two-Year Colleges, and K-12 Levels [1]. Based on an informal show of hands, most attendees at this year's PERC were either graduate students or faculty at large research universities (ones that offer a PhD in Physics). A very small number were from primarily undergraduate institutions (PUIs) or Two-Year Colleges, and nobody in the room indicated they were from the K-12 level. How does this compare to national data? The American Institute of Physics published a chart about Physics Departments at different types of institutions in 2020 [2]. Out of 754 physics departments nationally, 502 or 67% offered a bachelor's degree in physics as their highest degree, 53 institutions (7%) offered a Master's degree, and 199 (26%) offered a PhD. Bachelor's-granting institutions graduate on average 7.1 physics majors per year and have 6.3 full-time faculty members in the department, whereas PhD-granting institutions graduate 26.0 physics majors annually and have 30.1 full-time faculty members [2].

In my perspective the number of faculty in a small department versus a large department is a considerable difference – if you teach at a PUI, your entire department can likely gather around a table and have lunch together comfortably. If you are at a larger institution you might have connections with some members of your department but not all. We also learned from other plenary speakers at PERC that there are more than 1400 community colleges in the United States indicating there are numerous physics courses being taught at smaller institutions.

II. WHAT IS THE INSTITUTIONAL GAP?

What exactly do we mean by the "institutional gap"? One interpretation is that most Physics Education Research (PER) happens at large, research universities and not as much is being done at smaller institutions. After listening to conference talks from a variety of institutions throughout AAPT and PERC, I am uncertain whether this is true. Another possibility is that research at smaller institutions is not published at the same rate as at larger institutions and therefore not as visible to the research community. Perhaps research at smaller institutions is not regarded in the same way as research at large institutions. Yet another interpretation of the institutional gap is that the findings of PER produced by large research institutions may not "fit" the context and needs of smaller institutions.

In addition to these possible institutional gaps, the community is grappling with another important issue, what I call the research-practice gap. After decades of PER we have a wealth of knowledge about how students learn and experience physics classes along with curricula and research-based instructional strategies for teaching physics, yet many institutions still teach physics in a way that is very traditional [3]. Why aren't PER practices more widely implemented?

Finally, Physics as a whole discipline is experiencing a gap between our current reality and desired reality in terms of culture and climate. Most students perceive that physics is a very difficult subject and you need to be super smart to succeed in physics, and faculty perpetuate this notion with selective practices that weed out students who are not the best and the brightest. My desired reality for Physics is that it can be a more welcoming, inclusive environment where students have fun. I frequently teach physical science courses for future elementary and middle school teachers, and one of my primary goals is that they will walk away from my class saying, "That was actually a lot of fun!"

As I thought about each of these gaps, I came to realize that perhaps they are connected. If more physics education research takes place at smaller institutions and is applicable to a variety of contexts, then perhaps more faculty will be inclined to implement research-based instructional strategies in their classrooms. If more PER is happening in physics classes, then these transformed courses can impact the culture and climate for students who otherwise might assume they cannot succeed in physics.

Another important question is, what is OUR role as PER specialists in bridging these gaps? I will expand on these ideas in the next sections.

A. Gap 1: Physics education at large institutions versus smaller institutions

I teach at the University of Wisconsin – La Crosse (UW-La Crosse), which is part of a larger state system of institutions in Wisconsin. There are two research intensive universities as part of this system (UW-Madison and UW-Milwaukee), eleven four-year campuses that are primarily undergraduate institutions, and 13 two-year colleges that are affiliated with four-year campuses. UW-La Crosse has approximately 9,400 undergraduate students and over 900 graduate students, and 79% come from Wisconsin [4]. The student-faculty ratio is 19:1 and ninety-one percent of classes have fewer than 50 students. The student body is very very white (estimated near 89%). Our department currently has 7 tenured or tenure-track faculty and one instructional staff member (this is a bit lower than usual; we typically have between 10-12 instructors.) My workload is split 60% teaching, 20% research, and 20% service. The teaching load for tenure-track faculty is 12 contact hours per semester (roughly 3 courses) and for non-tenure-track faculty it is 16 contact hours. UW-La Crosse is a bit unique in that it is considered a "thriving" physics department and a top producer of physics majors among bachelor's only institutions [5]. Engaging students in undergraduate research is expected of faculty members in STEM fields.

What do you think are some of the challenges and opportunities of being at a PUI? I informally polled colleagues throughout the week leading up to PERC and asked the audience at my plenary talk to discuss this question. These were some of the challenges and opportunities brought up:

1. Challenges at small institutions

- Higher teaching and service load (limited time for grant writing and research)
- More limited resources or support for research (e.g. grants office and IRB office)
- Research progress is slower with undergraduate students (they might only participate for one or two semesters)
- Smaller numbers for statistics in quantitative studies
- Solo PER member (isolation)
- Stability (low-enrollment physics departments are under threat of closure)
- Each department member makes an impact

2. Opportunities at small institutions

- Conducive to implementing research-based teaching strategies (oftentimes the only person teaching a course, faculty are supportive of PER strategies)
- Scholarship of teaching and learning is valued
- Culture of assessment
- Smaller class sizes help you build relationships with students
- Important for PER as a whole (e.g. testing instruments across a variety of contexts)
- Each department member makes an impact

In my conversations throughout the conference, one colleague I spoke with highlighted how everyone in academia is busy, but our busy looks different at a smaller institution. We typically have a higher teaching load but might also be pulled into more service responsibilities. Isolation is a real issue, and one person told me they have felt "left behind" by the PER community since they started working at a primarily undergraduate institution. Another colleague also told me that there is a real irony to the situation – how instructors at smaller institutions might be more willing and supported to try research-based instructional strategies in their classrooms, but due to small class sizes may have more difficulty getting sufficient numbers for statistics desired in publishable quantitative studies.

I put *Each department member makes an impact* on both lists for challenges and opportunities. In terms of challenges, every time someone goes on leave in a small department (for example a sabbatical or maternity leave) the impact is felt by the whole department in trying to cover their teaching load. In addition, one negative faculty member can easily create a hostile climate for everyone else. In terms of opportunities, having a supportive colleague or chair can make a world of difference for PER and the department as a whole. UW-La Crosse was not always a thriving department; it was the actions of a former chair that built up a strong program.

What are some possible bridges for this gap between PER at large institutions and PER at small institutions? A few could be collaborations, community connections, and support for PER at smaller institutions. We already have quite a few examples of collaborations and community connections within physics, including the Physics Teacher Education Coalition (PhysTEC), Get the Facts Out, Learning Assistant Alliance, STEP UP, Partnership for Integration of Computation into Undergraduate Physics (PICUP), Organization for Physics at Two-Year Colleges (OPTYCS), Introductory Physics for Life Sciences (IPLS), and Advanced Laboratory Physics Association (ALPhA), among others. There are also several examples of PER partnerships between large research institutions and smaller institutions for collaborative research projects.

How can we initiate and participate in productive research collaborations? A first step is to meet people at your own institution and identify potential collaborators, such as faculty in discipline-based education research (DBER) or science education. You can also identify potential external collaborators by attending local AAPT section meetings for your state and neighboring states and attending national conferences. It is possible to join group meetings or seminars for another institution virtually, and perhaps visit in person during non-teaching times like summer.

How can we support research at PUIs? In another role, I serve as a physics division representative for the Council on Undergraduate Research (CUR). They have a publication called *Characteristics of Excellence in Undergraduate Research* (COEUR) which provides several recommendations [6]. I picked out a few to highlight: give faculty load credit for supervising undergraduate research (either directly or by having students register for research course credit), and reassigned time for research-related tasks like summer salary to write a grant proposal. Another trend I have noticed in Biology is Course-Embedded Undergraduate Research Experiences called CUREs, and perhaps we will see this idea start to develop in Physics in the near future.

B. Gap 2: The research-practice gap

After attending AAPT and PERC I will claim that PER is a thriving research community that continues to amaze me with its rapid growth. In spite of this observation, many of the physics departments I visit are still largely traditional in their approaches to teaching physics. How widespread is knowledge and use of PER strategies? Henderson & Dancy (2009) surveyed physics faculty about 24 different research-based instructional strategies (RBIS) and found that 87.3% of faculty know about one or more RBIS and 50.3% know about six or more [7]. Faculty at bachelor's institutions are

more likely to rate their departments as "very encouraging" toward teaching improvement compared to faculty at graduate institutions. They also found that nearly one half of faculty were currently using one RBIS and over a third were using two or more, but often with modification. Most of the strategies in use could be implemented into a lecture setting. They also learned that faculty often try an RBIS and discontinue its use, stating it did not work or did not fit their teaching situation [8][9]. They identified several individual and situational characteristics that can serve as barriers to RBIS, including expectations to cover content, lack of time to develop and implement RBIS, departmental norms, or student resistance. A study by Fraser et al. (2014) found similar themes about common concerns from their interviews with instructors but added that many faculty perceived teaching as more of an "art" than a science and therefore did not approach teaching with the same rigor as their own research [10]. Faculty in that study also questioned what is wrong with traditional lecture and whether focusing on conceptual understanding takes away from a focus on problem-solving skills. Throughout roundtable discussions at PERC, I also heard from faculty that PER is not perceived as "real" physics at their institutions, and therefore is not taken as seriously as other areas of physics. This struck me as concerning after all the work early physics education researchers did to establish PER as a subfield of physics.

What are some possible bridges for this research-practice gap? Henderson and Dancy suggest helping instructors gain awareness of situational barriers they could encounter and provide support during RBIS implementation [8]. Faculty also need time and resources to reform their teaching. Peer-reviewed publications are typically written for a research-focused audience, not necessarily instructors who might be implementing a particular approach. Communication matters, and developers need to listen to a variety of PER "consumers" to meet their needs and develop classroom-ready resources. There is also a need to change traditional academic cultures and institutional structures that present barriers to RBIS, but this is a slow and challenging endeavor!

Some resources to address the Research-Practice gap include the Faculty Teaching Institute [11], Physport [12], the Effective Practices for Physics Programs (EP3) guide [13], a review article on facilitating change [14] and a book about *Designing Educational Innovations for Sustained Adoption* [15]. An idea that came up during roundtable discussions at PERC was how perhaps the peer review process should acknowledge the benefit of replication studies and reconsider the way we rate manuscripts on their novelty/originality. Bridging the research-practice gap is going to take a large-scale effort, but I believe we have the resources and skills to take on this challenge.

C. Gap 3: Current reality versus desired reality

As stated in a National Academies report [3] , "*Too often, introductory physics has been cast as a subject that only a tiny elite could truly master. As a result, many students have viewed it as too difficult or unpleasant, and so have chosen not to pursue physics and other STEM majors. This has detrimentally affected not only the health of undergraduate physics and other STEM programs, but also the intellectual health of the nation.*" *p. 9*

How do we shift the culture and climate in physics toward one that is more welcoming and inclusive? The PER community has developed strategies for shifting perceptions and attitudes within our physics classes about how students view physics and their own identity, but how do we spread these ideas to other physicists? How do I convince my colleagues down the hall to care more about their students' experiences in physics? I do not have the answer, but I will point to the STEMM Equity Achievement (SEA) Change Departmental Program that seeks to create systemic, structural change in DEI at colleges and universities [16] and the Inclusive STEM Teaching Project edX course, which I highly recommend [17]. The Society of Physics Students (SPS) also has some resources for making an inclusive Physics and Astronomy community [18]. At UW-La Crosse we recently implemented some of these SPS recommendations; we started a mentorship program where we pair incoming students with an experienced physics major to help them become acquainted and welcomed into the department, we created a lounge space for physics majors and we are working on organizing regular low-stakes social events.

Smaller institutions can also serve unique and important roles that differ from larger institutions. One advantage of being at a primarily undergraduate institution is the small class sizes; the majority of classes I teach are around 30 students. Most semesters I can learn all my students' names and build relationships with them. If someone is absent from class I notice and check in with them. I also advise and mentor students on possible career pathways. This faculty-student connection can be important for students who struggle with the transition to college or need additional support.

III. WHAT IS THE ROLE OF A PER SPECIALIST?

Those of us who go through a PhD program specializing in Physics Education Research are typically trained at large research institutions, but most of us who stay in academia will end up teaching at smaller institutions like primarily undergraduate institutions or two-year colleges. What is our role as a PER specialist in these situations? In my own experience, untenured junior faculty typically do not have much say in departmental decisions – it takes some time to become integrated into the culture of a department. Being a productive scholar within the department can certainly help in elevating the perception of PER, such as bringing in grant money or producing publications.

After establishing myself as a contributing member of the department and gaining confidence in my skills, I have taken

on a variety of PER-related roles. For example, I have served as a sounding board for ideas and supported faculty during efforts to implement research-based instructional strategies. Last semester one of my colleagues decided to flip her electrodynamics class and wanted to talk through some of the decisions with me (even though I have never taught the course nor flipped a class). I have collaborated with other faculty members to develop presentation slides for the algebra-based introductory physics courses that incorporated conceptual questions for students to discuss during lecture. I have also served as assessment coordinator for our department and helped to document progress toward program goals.

Sometimes the role of a PER specialist is more challenging, and it can be important to have a PER voice at the table when making departmental decisions. For example, our department has gone back and forth about teaching calculus-based introductory physics courses in an integrated lab-lecture format. Since I will be teaching this course in the fall, I asked the chair if we can go back to the studio format. During a department meeting a faculty member questioned the decision stating it is a waste of time and resources, and the chair was able to defend the decision based on research that it will help improve our DFW rates and retain physics majors. Enrollment is currently a high priority of the dean, so the chair said she is willing to give this a shot.

As this example illustrates, one important finding from the PhysTEC project is the importance of having a "champion" for education efforts at an institution, but also the value of building a team that includes supportive department members in leadership roles. Eventually it is possible that a PER specialist can initiate and lead course reforms that have a lasting impact on the teaching and learning of physics at the institution, but this takes time.

IV. CONCLUSIONS

Throughout this paper I have shared some of my own experiences and perspectives from teaching and doing Physics Education Research at a Primarily Undergraduate Institution for the past 13 years. In my view there are many challenges being at a smaller institution, but there are also many opportunities. Research at small institutions is critical for advancing PER, and the peer review process should value replication studies that investigate the applicability of findings across different institutional contexts. Collaborations and community connections are important for PER, so I encourage you to initiate partnerships within and outside your institution, being sure to value the expertise of all partners. We also have quite a few resources for facilitating change in undergraduate instructional practices.

There are still unanswered questions: How do we shift the culture and climate of physics toward one that is more welcoming and inclusive? How can PER be more accepted and valued as a research subfield within Physics? What is OUR role in bridging institutional gaps?

I began this paper by asking what we mean by the institutional gap and presenting a variety of possible interpretations. Once we better define what we mean by this gap, we can start proposing and implementing solutions to the issues of physics education at a variety of institutions – both large and small.

ACKNOWLEDGMENTS

I would like to thank the 2024 organizers for the Physics Education Research Conference for inviting me to give a plenary talk on this theme: Andrew Mason, Carina Rebello, and Tianlong Zu.

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