Using theory to inform practice in the advanced physics classroom

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Abstract. Physics education research has focused much more on lower-level, introductory courses as compared to upper division and graduate physics education. However, there are general principles and findings that extend across all areas of learning, such as the strong evidence in favor of active learning environments. But taking the theoretical basis and pedagogical strategies generated by research at one level of education and applying it to create a learning environment appropriate to upper division and graduate physics courses requires careful consideration of the issues facing students, and the instructor, in such courses. For example, the motivations of students in an introductory course are very different from the motivations of students in a graduate course. The number of students in a classroom is often quite different. The size of the research base in student difficulties and the amount of research-based instructional resources available to an instructor will be different. In this presentation I will discuss several examples of the application of research-based techniques to classroom instruction in upper division and graduate physics courses, how the specifics of the student audience have resulted in modifications of the pedagogical approach, and the student response to these instructional strategies.

1 Introduction

Physics Education Research (PER) has produced an extensive body of knowledge relating to difficulties that student have in learning physics [1, 2], as well as a range of instructional practices and curriculum materials that can improve student outcomes [3,4]. These research-based instruction practices generally focus on creating an active learning environment, which has been shown to produce better conceptual understanding on the part of physics students [5,6]. It has been shown that these pedagogical innovations are transportable and that the effects are not dependent on the institution or instructor [7]. Moreover, the fundamental finding that an active learning environment produces, on the whole, better student outcomes is widespread and supported in other fields, such as Astronomy and Chemistry Education Research [8].

Much of this work in PER at the university level has been done in introductory courses, and this is true of other Discipline-Based Educational Research [8]. While there are examples of research into student understanding [9] and the applicability of research-based pedagogies at the upper-division and graduate level [10, 11], such work is a small fraction of the overall literature [8]. However, there is every reason to believe that the pedagogies and techniques that are effective in introductory courses would, with appropriate context-dependent modifications, also be effective in upper-division or graduate physics courses.

2 Investigating Advanced Student Response to Active Learning

In this study we will report findings from several different upper-division and graduate classes, specifically Modern Physics and Analytical Mechanics (undergraduate) and Classical Dynamics (graduate). We investigated the use of three techniques that are quite common in lower-division, active-learning physics classrooms: Peer-instruction [3], flipped classrooms [12] and collaborative problem-solving [13]. Classes were designed to use some or all of these techniques over a number of semesters. Data were collected through surveys and interviews to determine student response to these approaches. In the case of the graduate students, the departmental qualifying exam serves as an independent assessment of performance..

3 Conclusions

We find that on the whole the students had a very positive response to using these active learning techniques in advanced classes. There is one notable exception regarding the use of a flipped classroom structure. Students were mixed in their view of fully flipping the classroom, with a partially flipped classroom perhaps a better solution. This may be related to the difference in motivation among more advanced students who are physics majors compared to students in an introductory course who are generally not physics majors. Finally, the results of the graduate departmental qualifying exam suggest that students who took the active-learning Classical Dynamics performed better on the exam than the overall performance across the other subjects, which were taught in a traditional manner.

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