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PER in the Upper Division II

| **Type:** Inv/Con | **Organizer:** Mary Bridget Kustusch

Description:

Call for Papers:

Abstracts Submitted (# 12)

Abstract Title: A Sophisticated Learner’s View of the Connection between Mathematics and Quantum Mechanics

Paper Type: Contributed

Author: Vesal Dini
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Speaker Order: CJ02

Students’ physical intuitions and prior knowledge are critical to making sense of and solving problems in classical mechanics. In quantum mechanics (qm), coordinating concepts connected to everyday thinking becomes more difficult. How then can students develop coherence in their knowledge of qm? Consider how experts do it: they build meaning in, around, and through the mathematics of the theory. This view on the role of mathematics in the pursuit of knowledge is part of a larger set of views that constitute someone’s personal epistemology. The experts’ view noted above, which is one among many possible to take, seems most productive for qm. In our work to characterize student epistemologies that emerge in the context of qm coursework, we came to analyze one student who mostly adopted such a view until a shift in context moved him to express an alternative. We present his case and discuss important implications for instruction.

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Abstract Title: Developing a Quantum Interactive Learning Tutorial (QuILT) on the Double-slit Experiment

Paper Type: Contributed

Author: Ryan T. Sayer
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Speaker Order: CJ06

Learning quantum mechanics is challenging even for upper-level undergraduate students and graduate students. Interactive tutorials that build on students' prior knowledge can be effective tools to enhance student learning. We have been investigating student difficulties with the quantum mechanics behind the double-slit experiment and have developed a Quantum Interactive Learning Tutorial (QuILT) that makes use of a simulation to improve their understanding. We describe the common student difficulties with the double slit experiment and the extent to which the QuILT was effective in addressing these difficulties. We thank the National Science Foundation for support.

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Abstract Title: Embodied Action of Small Groups Answering the Quantum Mechanics Survey

Paper Type: Contributed

Author: Aureliano Perez
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Speaker Order: CJ08

The Quantum Mechanics Survey (QMS) is a research-based assessment of student understanding of quantum mechanics in one dimension [1]. In a first upper-division course in quantum mechanics, we observed students working in isolated small groups to answer the QMS. Students in this class were instructed in an interactive

lecture environment in which spatial visualization and gesture were encouraged. An understanding of the complex relative phase factor between components of a state is useful for some items on the QMS, and was meant to be enabled by the instructional use of pipe cleaners, which provide access to an "out-of-the-board" component for graphing wave functions. Previous studies [2] have shown that students can make substantive use of their bodies and material surroundings to think spatially about quantum mechanics. In this talk we present an overview, with some examples, of students' embodied action as a means for thinking about the QMS.

Footnotes: 1. G. Zhu & C. Singh, Am. J. Phys. 80(3), 252-259 (2012). 2. H. Close, C. Schiber, E. Close, and D. Donnelly, presented at the Physics Education Research Conference 2013, Portland, OR, 2013, WWW Document, (http://www.compadre.org/Repository/document/ServeFile.cfm?ID=13115&DocID=3664).

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Abstract Title: Investigating and Improving Student Understanding of Perturbation Theory in QM

Paper Type: Contributed

Author: Gina Passante
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Speaker Order: CJ05

Over the past several years the Physics Education Group at the University of Washington has been working to probe the difficulties students encounter with time-independent perturbation theory and has been developing tutorial curriculum to improve student understanding. Perturbation theory is often taught near the end of a junior-level quantum mechanics course. It is an important topic as it allows the solutions to the Schrödinger equation for simple potentials to be used to approximate solutions for more complicated, and often more physically realistic, potentials. In this talk I will discuss some of the changes to curriculum we have made over the last few years to improve student understanding. This investigation has also illuminated difficulties that students have in interpreting graphically the inner product of functions.

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Abstract Title: Investigating Quantitative Reasoning Skills in Upper Division Math Methods*

Paper Type: Contributed

Author: Michael E. Loverude
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Speaker Order: CJ01

Many upper-division physics courses have as goals that students should "think like a physicist." Among other things, these goals include quantitative reasoning skills: considering limiting cases, dimensional analysis, and using approximations. However, there is often relatively little curricular support for these practices and many instructors do not assess them explicitly. As part of a collaborative project to investigate student learning of mathematics in upper-division courses including the traditional "math methods" course, we have developed a number of written questions to investigate these skills. Although there are limitations to assessing these skills with written questions, they can provide insight to the extent to which students can apply a given skill when prompted, even if they do not help understand how and when students choose to activate these skills. Examples of student responses will be provided.

Footnotes: *Supported in part by NSF grant 1406035.

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Abstract Title: Investigating Student Difficulties with Position and Momentum Representations in Quantum Mechanics*

Paper Type: Contributed

Author: Emily M. Marshman
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Speaker Order: CJ03

Quantum mechanics is challenging even for advanced undergraduate and graduate students. We have been investigating the difficulties that these students have with position and momentum representations in quantum mechanics. We administered written free-response and multiple-choice questions to students to investigate the difficulties. We find that many students struggle with these concepts and share common difficulties.

Footnotes: *This work is supported by the National Science Foundation.

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Abstract Title: Investigating Transfer of Knowledge in an Upper-level Quantum Mechanics Course*

Paper Type: Contributed

Author: Alexandru Maries
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Speaker Order: CJ10

Transfer of learning from one context to another is considered a hallmark of expertise. Physics education research has often found that students have great difficulty transferring knowledge from one context to another. We examine upper-level and graduate students' facility with questions about the interference pattern in the double-slit experiment with single photons and polarizers in various orientations placed in front of one or both slits. Answering these questions correctly in the context of the double-slit experiment requires transfer of knowledge of concepts students had learned in the context of a tutorial on Mach-Zehnder Interferometer (MZI) with single photons and polarizers in various paths of MZI. We discuss the extent to which students who worked through the MZI tutorial were able to transfer their knowledge gained in that context to another context involving the double-slit experiment.

Footnotes: *Work supported by the National Science Foundation.

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Abstract Title: Learning from Mistakes in Upper-Level Quantum Mechanics*

Paper Type: Contributed

Author: Benjamin R. Brown
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Speaker Order: CJ11

Helping students learn to think like a physicist is an important goal of many physics courses. One characteristic of physics experts is that they have learned how to learn and they use problem solving as an opportunity for learning. In particular, physics experts automatically reflect upon their mistakes in their problem solution in order to repair, extend and organize their knowledge structure. Unfortunately, for many students, even in an upper-level physics course, problem solving is a missed learning opportunity. We investigated how well students in upper-level quantum mechanics learn from their mistakes and perform in the final exam when provided with explicit incentives to correct their mistakes in the midterm exams compared to those who were not given explicit incentives to correct their mistakes. Findings will be discussed.

Footnotes: *This work is supported by the National Science Foundation.

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Abstract Title: PER in Graduate Level Quantum Mechanics and Guided Group Work

Paper Type: Contributed

Author: Christopher D. Porter
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Speaker Order: CJ09

We are beginning to do PER at the graduate level at OSU, beginning with the graduate quantum mechanics course. A number of prevalent misconceptions and misunderstanding have been identified for undergraduates. A handful of studies have even looked at graduate quantum mechanics. We begin this project by verifying the presence of the difficulties already identified, and looking for new ones with pre/post testing done at the beginning and end of each semester. We review our findings. We also discuss our efforts to overcome these difficulties using guided group work. These weekly meetings are not mandatory except for a small subset of students, but are open to all students in the course. We present example content and give an overview of our approach. Although numbers are low, we make an effort to determine the effectiveness of these guided group work sessions using student attendance, student feedback, and weekly topical pre/post quizzes.

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Abstract Title: Reinforcement Effects on Student Understanding of Quantum Mechanical Concepts

Paper Type: Contributed

Author: Charles Joseph DeLeone
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Speaker Order: CJ07

Upper-division physics students often struggle with quantum concepts during their first exposure to full-blown quantum mechanics. Research into student learning of quantum concepts with tools such as the QMCA have exposed challenges associated with student learning of concepts such as superposition and time evolution of states. But does student learning of these concepts persist and/or improve with further exposure to quantum concepts in a second semester course? This talk presents the results of a study of upper-division students that addresses this question. Results concerning the robustness of student understanding of quantum concepts across representations and systems will also be discussed.

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Abstract Title: Student Difficulties with the Probability of Measuring Position and Energy in Quantum Mechanics

Paper Type: Contributed

Author: Chandralekha Singh
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Speaker Order: CJ04

Quantum mechanics is challenging, even for advanced undergraduate and graduate students. We have been investigating the difficulties that students have in determining the probability of measuring position and energy as a function of time when the initial wavefunction is explicitly given. We find that many students struggle with these concepts. We discuss some common difficulties. This work is supported by the National Science Foundation.

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Abstract Title: Upper-Division Quantum Students' Development in Physics and Mathematics

Paper Type: Contributed

Author: John D. Thompson
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Speaker Order: CJ12

As part of a larger study on how students' mathematical skills co-develop with their physics identities, we examine students' problem solving in upper-division Quantum Mechanics. Over a three-year span in which the course moved from highly traditional lecture to frequent bursts of in-class problem solving, we collected conceptual survey data on students' math skills and understanding of quantum topics. Additionally, we observed students ' problem-solving activities during class time. We present evidence of students' developing ideas about

the nature of physics and physics problem-solving as they travel through the course.

Footnotes: *Sponsored by Eleanor Sayre

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