APR15-2015-000870

Abstract for an Invited Paper
for the APR15 Meeting of
the American Physical Society

A Framework for Understanding the Patterns of Student Difficulties in Quantum Mechanics[1]

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Compared with introductory physics, relatively little is known about the development of expertise in advanced physics courses, especially in the case of quantum mechanics. We describe a theoretical framework for understanding the patterns of student reasoning difficulties and how students develop expertise in quantum mechanics. The framework posits that the challenges many students face in developing expertise in quantum mechanics are analogous to the challenges introductory students face in developing expertise in introductory classical mechanics. This framework incorporates the effects of diversity in students' prior preparation, goals and motivation for taking upper-level physics courses in general as well as the "paradigm shift" from classical mechanics to quantum mechanics. The framework is based on empirical investigations demonstrating that the patterns of reasoning, problem-solving, and self-monitoring difficulties in quantum mechanics bear a striking resemblance to those found in introductory classical mechanics. Examples from research in quantum mechanics and introductory classical mechanics will be discussed to illustrate how the patterns of difficulties are analogous as students learn to unpack the respective principles and grasp the formalism in each knowledge domain during the development of expertise. Embracing such a theoretical framework and contemplating the parallels between the difficulties in these two knowledge domains can enable researchers to leverage the extensive literature for introductory physics education research to guide the design of teaching and learning tools for helping students develop expertise in quantum mechanics.

[1]Support from the National Science Foundation is gratefully acknowledged.