Perspectives in Quantum Physics: Epistemological, Ontological and Pedagogical

An investigation into student and expert perspectives on the physical interpretation of quantum mechanics, with implications for modern physics instruction.

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The final copy of this thesis has been examined by the signatories, and we find that both the content and form meet acceptable presentation standards of scholarly work in the above mentioned discipline.

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ABSTRACT

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A common learning goal for modern physics instructors is for students to recognize a difference between the experimental uncertainty of classical physics and the fundamental uncertainty of quantum mechanics. Our studies suggest this notoriously difficult task may be frustrated by the intuitively *realist* perspectives of introductory students, and a lack of *ontological flexibility* in their conceptions of light and matter. We have developed a framework for understanding and characterizing student perspectives on the physical interpretation of quantum mechanics, and demonstrate the differential impact on student thinking of the myriad ways instructors approach interpretive themes in their introductory courses. Like expert physicists, students interpret quantum phenomena differently, and these interpretations are significantly influenced by their overall stances on questions central to the so-called *measurement problem*: Is the wave function physically real, or simply a mathematical tool? Is the *collapse of the wave function* an *ad hoc* rule, or a physical transition not described by any equation? Does an electron, being a form of matter, exist as a localized particle at all times? These questions, which are of personal and academic interest to our students, are largely only superficially addressed in our introductory courses, often for fear of opening a *Pandora's Box* of student questions, none of which have easy answers. We show how a transformed modern physics curriculum (recently implemented at the University of Colorado) may positively impact student perspectives on indeterminacy and wave-particle duality, by making questions of classical and quantum reality a central theme of our course, but also by making the beliefs of our students, and not just those of scientists, an explicit topic of discussion.

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