Amplifying Physics Student's Voices: How Learners Approach Wonky and Unknowable Quantum Mechanics

This work is supported by the University of Utah College of Education Research Incentive Seed Grant Program

Marc Whiting[1]
Lauren Barth-Cohen[1,2]
Adrian Adams[1]
Jordan Gerton[2]
David Stroupe[1]

Background Literature

Research-inspired epistemological approaches

Amplifying Physics Students' Voices

- In PER, there is a tendency to emphasize students' unproductive reasoning and deficits (Docktor, 2014).
- Building on students' prior understanding is more than a thoughtful consideration; it is foundational to effective instruction (e.g., Smith et al., 1994; Wittmann & Morgan, 2020).
- Recognizing students' underlying epistemological approaches helps elevate their voices and shapes QM learning (Bailey & Finkelstein, 2010).

Prioritizing students' perspectives over researcher-imposed judgments

Epistemological Approach

- Students' epistemological approaches can be observed in how they respond to their own articulated beliefs, such as the view that QM is fundamentally unknowable (Hammer, 1994).
- Epistemology centers students' views by shifting focus away from researcher-imposed judgment and prioritizing their interpretations for how they make sense of QM (Hammer & Elby, 2003).

Data Collection

Background & Student Demographics

Open-ended Interview Structure

- 10 undergraduates
- Solo or paired sessions
- Each session lasted one hour

Participants Self-Identified Gender

- 5 as women (4 cisgender, 1 transgender)
- 5 cisgender men

Course Background

- Range from introductory sophomore-level modern physics to junior/senior-level advanced undergraduates

RESOURCE THEORY

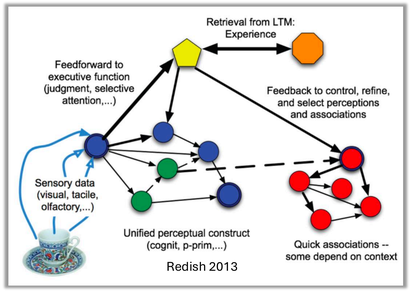
*What **intuitions & ideas** do learners bring to the quantum classroom?*

The study is situated in a **resource theory perspective** that assumes learners have a complex knowledge system for building new ideas (diSessa, 1993; Hammer, 2000).

In response to students' epistemological beliefs, that **Quantum, it's just different,** we identified three epistemological approaches:

- **Reasoning across scale boundaries.**
- **Relying on mathematics.**
- **Drawing on classical knowledge.**

The examples provided are color-coded to reflect the students' articulated epistemology.



Epistemological Approaches to Wonky QM

How do students' epistemological approaches shape their strategies towards making sense of QM?

Quantum, it's just different. Antares: *"And that's like the basics of quantum mechanics, right? **Like why does it do that? We don't know it just does it.** Um, but like, time evolution's pretty weird too. I don't know really, you know. Just things that I don't really, [whispers] understand."* (Senior undergraduate, solo interview).

Reasoning across scale boundaries. Donna: "*I think, what we just barely referred to as classical which is like physics one and two, things moving and things going in circuits and, the stuff that engineers need to know and then there's what physicists actually do and need to know, uh which is where physics starts to break down **when things are too big or too small or theoretical, and then things just kinda get wonky from there**.*" (Sophomore-level, pair interview).

Relying on mathematics. Amelia: *"so, like we were talking about the other day, like um, an electron, like, isn't spinning, but it has [enunciates] spin, to it, kind of thing that like, you wouldn't think it's not, like, intuitive, but like, **the math shows that that's the way it is kind of thing.** So, like, I guess it's the hard to explain or unexplainable, things that, just shouldn't be but are."* (Sophomore-level, pair interview).

Drawing on classical knowledge. Lily: "*I don't remember who said the quote but, they said, it's not remarkable, that the universe behaves the way quantum mechanics says it does, **what's remarkable is that, on, our scale of existence, um things behave classically.** Like the fact that you get classical mechanics out of quantum mechanics compounded upon quantum mechanics, you know, thousands, millions, trillions of times. That, you know is sort of the remarkable thing, but, of course, it's not our lived experience, which is why it's, I think difficult conceptually."* (Junior/senior-level, solo-interview).

Interview Questions

Example Questions Listed Below

Potential Wells & Waves

- What does the square well mean to you?
- How would you modify the square well?
- How might your modification impact the particle?

Math & Thinking Like a Physicist

- What is the role of math in physics?
- What is the role of math in QM?
- How is that similar or different from your experience with math in other classes?

For a comprehensive list, scan the QR code below.

Next Steps

Feedback appreciated!!

Ongoing Questions We Are Exploring

- What analogies serve as practical learning tools that help students navigate unfamiliar quantum ideas?
- How do learners conceptualize the boundary between classical and QM?
- How do we design quantum mechanics courses accessible to a broader demographic of learners?

WE SEEK YOUR INPUT!

- What considerations should we be aware of while preparing a manuscript for **PR PER**?
- What **frameworks** are being used to understand quantum education research?
- What data collection strategies are commonly used?

ACKNOWLEDGEMENTS & AFFILIATIONS

We thank the interview participants and the instructors/faculty from the Physics & Astronomy Department. We thank and acknowledge financial support from the Department of Educational Psychology.

1. University of Utah Department of Educational Psychology
2. University of Utah Department of Physics & Astronomy