Physicists' Epistemologies of Quantum Mechanics

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Motivation

Physics Education researchers say that intro physics student have some productive epistemologies and some non-productive epistemologies.

Non-productive: thinking that knowing physics means memorizing formulas and getting numerical answers

Motivation

Productive: using common sense, refining our intuition from everyday experience.

Is a productive epistemology for intro physics also productive for quantum mechanics?

What would constitute a productive epistemology of quantum mechanics?

Research Question

What are physicists' epistemologies of quantum mechanics?

What do physicists believe it means to know quantum mechanics?

Research Method

I interviewed physicists,
asking them to solve QM problems
and answer questions about QM

Four physics professors were interviewed

They are denoted as professors A, B, C, & D

Interview Question Topics

- Two-slit problem
- Conductivity
- EPR paradox
- Bose-Einstein condensate
- Types of physics theories
- Probability vs. Determinism

Professor D

- "Ultimately all theories of physics depend on two things. One is the set of experimental observations. The second is that mathematics provides us with a set of tools that we can use to describe and generalize these experimental observations."

Professor B

While working through the calculations he says,

- "I'm sure there's a physical way of thinking about this, but for me anyway I usually arrive at the physical way by trying to think it through formally, precisely, and then trying to understand physically what's going on."

After completing his mathematical work he says,

- "Now having done this I think I can say it in a much simpler way."

Professor A

- "Quantum mechanics…to me that's more like the kind of theory where I have observed these actors and they obey certain rules and I'm trying to understand these rules."

- "When I started to study quantum mechanics, the transition from classical mechanics to quantum mechanics…I said you shift the rules."

Professor C

- "We start with wave mechanics and we have a set of rules…then you sit and say I'm going to apply these rules, and then I'll discover how it fits together. Then I build the theory up from there."

A Common Theme

Each professor displayed a reliance on **rules** or **mathematical formalism** as a necessary part of what they believe it means to know quantum mechanics.

Interview Question Topics

- Two-slit problem
- Conductivity
- EPR paradox
- Bose-Einstein condensate
- Types of physics theories
- Probability vs. Determinism

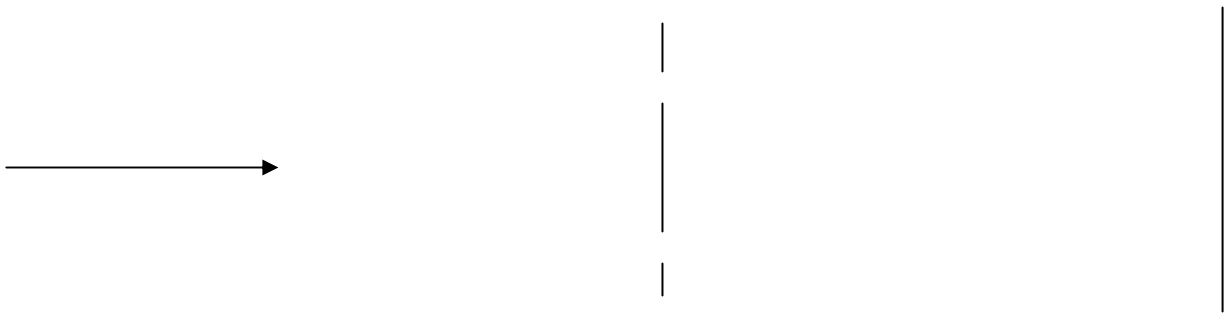
Two-slit Problem

- “Can you explain the two-slit problem?”

- “What happens if we put a detector in front of one of the slits?”

Professor A

Draws a diagram, discusses an electron traveling through the slits



Mentions the model in his head of the electron vs. the reality of the electron

Professor A

- "I became acutely aware of the fact that we could construct extremely elaborate scenarios inside of our heads and that these don't necessarily have anything to do with reality."
- "I think we get better and better approximations to understanding reality, but at the end of the day those approximations sit as models in our heads."

MODELS

Professor B

Goes to the board and starts writing variables and equations

- "The amplitude is the sum of two things…the amplitude here depends on the distance here so this is L_1 and L_2, the amplitude simply goes like exp (iEL_1), then this becomes the sum of these two things exp (iEL_1)plus exp (iEL_2)"

Professor B

- "We have recipes that work in practice for lots of things…they don't make sense when you push them too far."

- "In that case the recipe is that you're just supposed to add up the two contributions. On the other hand…"

RECIPES FIRST

Professor C

- "I sort of come to this interesting view that most of what we consider weird and unusual about quantum mechanics is not really weird and unusual at all. It's just wave mechanics…you just think of it in terms of wave mechanics."

Professor C

- "You disturb it. And you don't get a pattern anymore… if you perturb the thing you're going to disturb the coherence of the wave going through

WAVES

Professor D

- "I think most people really don't believe it. So in order to really affirm that in your mind you have to see an experiment that shows that that's a reasonable explanation of what's going on."
- "A beam of Na atoms are emitted from a furnace and are fired at a piece of metal with two slits."

Professor D

- "The act of carrying out an experiment forces the quantum mechanical description of the system into one of a range of possibilities."

EXPERIMENTS

Differences

The dominant aspect of each professor's epistemology

Professor A – models

Professor B – recipes

Professor C – waves

Professor D – experiments

These are NOT exclusive categories, only what each person emphasized the most.

Summary

Physicists

rely on mathematical formalism

as a framework for their knowledge of quantum mechanics even as they

hold varying beliefs

about what knowledge of quantum mechanics is.

Further Research

- More study of professors beliefs
- What do QM students believe it means to know QM?
- Does taking a QM course change their beliefs?
- Comparing what is productive for intro physics to what is productive for quantum