

How Students Organize Quantum Concepts and Representations: A Card Sorting Task

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Introduction

- Spin-first approach to teaching QM at OSU
- Spins first allows the opportunity to make the connections between discrete and continuous clearer.
- How do students characterize “discrete” and “continuous” in the context of QM?

Card Sorting Interview Task

(n=6) Participants thought aloud while they...

1. Identified each card
2. Grouped cards in whatever way they wanted
3. Grouped the cards in another way
4. Organized the cards into a “discrete” group and a “continuous” group

Cards always categorized as “discrete”

Discrete things...

- have only particular values possible
- have a separation between possible measurements
- return a single value
- are uncertain (probabilistic)

$$\begin{pmatrix} 1 \\ 0 \end{pmatrix}$$

$$(1 \ 0) \begin{pmatrix} 1/\sqrt{2} \\ i/\sqrt{2} \end{pmatrix}$$

$$\langle + | \psi \rangle$$

$$| + \rangle$$

$$|\langle + | \psi \rangle|^2$$

$$\begin{pmatrix} \psi(\Delta x) \\ \psi(2\Delta x) \\ \psi(3\Delta x) \\ \psi(4\Delta x) \\ \vdots \\ \vdots \\ \vdots \end{pmatrix}$$

$$\Delta x$$

$$|\langle E_n | \psi \rangle|^2$$

$$dx$$

$$\langle x | \psi \rangle$$

$$|E_n\rangle$$

$$|\psi\rangle$$

dx = 0.01

```
def Psi(x):
    return(np.sqrt(30)/L**2/np.sqrt(L)*x*(x-L))
```

```
L = 1
n = 1

sum = 0
for x in np.arange(0, L, dx):
    sum += np.conj(Phi(n, x))*Psi(x)*dx
```

```
def Phi(n, x):
    return(np.sqrt(2/L)*np.sin(n*np.pi*x/L))
```

Cards always categorized as “continuous”

Continuous things...

- are described by a function
- involve an x
- are a spectrum
- involve position or energy

$$\int \varphi_n^*(x)\psi(x)dx$$

$$|\psi(x)|^2$$

$$\psi(x)$$

$$\varphi_n(x)$$

“This gives us the value that [the spin-z] is $\hbar/2$, $-\hbar/2$, or something else depending on the system”

“You can only get, like energy comes in those packets. You can only get discrete amounts of energy each time. Like if you’re changing between electron orbitals, you have to have a certain amount of energy to move elsewhere”

“It’s continuous meaning like you can keep plugging numbers in for n for as long as you want. I mean, at least theoretically I think.”

“So, what I did was for like the continuous, I just put what had some kind of function of x. Normally with a function of x, you’re working with position which is a continuous thing.”

Find out more:

AAPT Talk: <https://beav.es/32D>
 Try the Activity: <https://beav.es/3Lo>
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