Affordances of Small White Board Questions (SWBQs) for Increasing Interactivity in Upper-Division Physics

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Abstract
The PER community has developed and studied many tools designed to increase interactive engagement in physics classrooms. We present a narrative of using Small White Board Questions (SWBQs) to achieve active engagement. The instructor used a sequence of SWBQs to help the students induce the full Hamiltonian for the hydrogen atom by starting from their knowledge of the Hamiltonian for a 1D particle-in-a-box. We highlight two affordances of this type of sequence: allowing students to build their understanding of a complex system starting from a simple question and providing for increased instructor responsiveness to students' ideas and questions.

SWBQ RITUALS

Decision to use SWBQ(s) → Goals → Prompt(s) → Observing → Choosing → Discussing Answer(s) → Wrap-up Discussion

Narrative
Narratives are a form of story-telling. A narrative reports interesting incidents that happened during a class period: what the students and instructor said and did during this time interval and commentary based upon insights articulated by the instructor, and perhaps colleagues, while watching a video of the interaction.

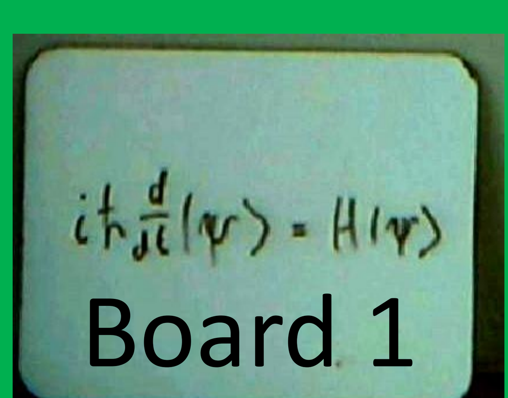
The Schrödinger Equation

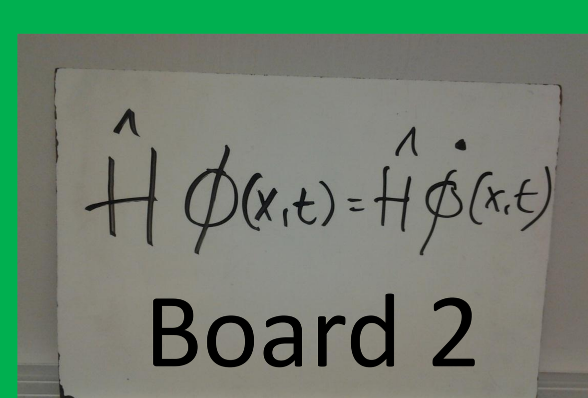
Goals: To ensure that students understand the importance of the Schrödinger equation and to give them a chance to wrestle with the details and with the differences between bra-ket and wave function notation.

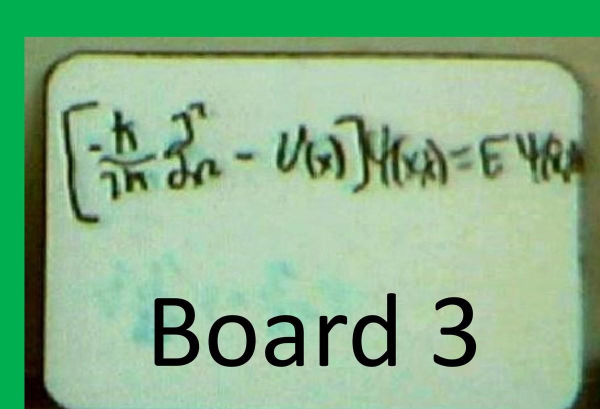
Prompt: "Write down the Schrödinger equation."

Observing:

Choosing:







Three boards that the instructor chose that highlight ideas in the room

Discussing Answers :
- Slow-paced discussion
- More time spent discussing students' answers
- Discussions happening all around the room (student to student and students to the instructor)

Wrap-up Discussion: The instructor connected these discussions to the next portion of the class which builds up to the complexity of the Hamiltonian of the hydrogen atom.

Building Up Complexity

Goals: To build a sequence of examples that increase in levels of complexity.

Prompts: "Write down the Hamiltonian of the ________system."

Electron in B_z
$$\hat{H} = -\vec{\mu}\cdot\vec{B}$$

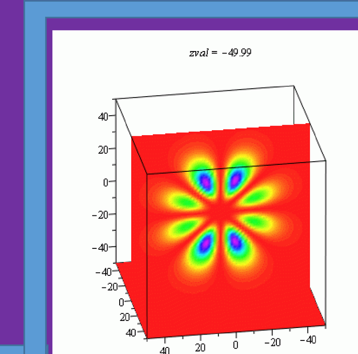
1 particle in 1-D box
$$\hat{H} = -\frac{\hbar^2}{2m}\frac{d^2}{dx^2}$$

2 particles in 1-D box
$$\hat{H} = -\frac{\hbar^2}{2}\left(\frac{1}{m_1}\frac{d^2}{dx_1{}^2} + \frac{1}{m_2}\frac{d^2}{dx_2{}^2}\right) + U(x_2 - x_1)$$

1 particle in 3-D box
$$\hat{H} = -\frac{\hbar^2}{2m}\nabla^2 + U(r)$$

2 particles in 3-D box
$$\hat{H} = -\frac{\hbar^2}{2}\left(\frac{1}{m_1}\nabla_1{}^2 + \frac{1}{m_2}\nabla_2{}^2\right) + U(|\vec{r}_2 - \vec{r}_1|)$$

H-atom



Discussing Answers:
- Fast-paced discussions
- Less time discussing students' answers
- Discussions dominated by the instructor and an individual student

Wrap-up Discussion: The instructor did an interactive lecture to connect these ideas and link them to the hydrogen atom.