APPENDIX A

Evolution of Online Survey Items

All surveys may be viewed in html format at:
http://www.colorado.edu/physics/EducationIssues/baily/dissertation/

SURVEY INSTRUCTIONS (FA08 – FA10):

Below are several statements that may or may not describe your beliefs or opinions.

You are asked to rate each statement by selecting a number between 1 and 5 where the numbers mean the following:

1. Strongly Disagree
2. Disagree
3. Neutral
4. Agree
5. Strongly Agree

Choose one of the above five choices that best expresses your feeling about the statement. If you have no strong opinion either way, choose 3.

A textbox follows each statement, asking you to explain the reasoning behind your answer (e.g. what is going through your mind as you formulate a response). Please note that, for some of the statements, the wording is deliberately ambiguous; we are particularly interested in how you interpret each statement, and any argumentation in support of your response.

WE ARE ASKING THAT YOU EXPRESS YOUR OWN BELIEFS. YOUR SPECIFIC ANSWERS WILL NOT AFFECT ANY EVALUATION OF YOU AS A STUDENT.

SURVEY STATEMENTS:

1. It is possible for physicists to carefully perform the same experiment and get two very different results that are both correct. **(FA08, SP09, FA09, SP10)**

1. It is possible for physicists to carefully perform the same measurement and get two very different results that are both correct. **(FA10)**

2. Uncertainty in quantum mechanics is mostly due to the limited accuracy of our measurement instruments. **(FA08)**

2. The probabilistic nature of quantum mechanics is mostly due to physical limitations of our measurement instruments. **(SP09, FA09, SP10)**

2. The probabilistic nature of quantum mechanics is mostly due to the limitations of our measurement instruments. **(FA10)**

3. An electron in an atom has a definite but unknown position at each moment in time. **(FA08, SP09)**

3. When not being observed, an electron in an atom still exists at a definite (but unknown) position at each moment in time. **(FA09, SP10, FA10)**

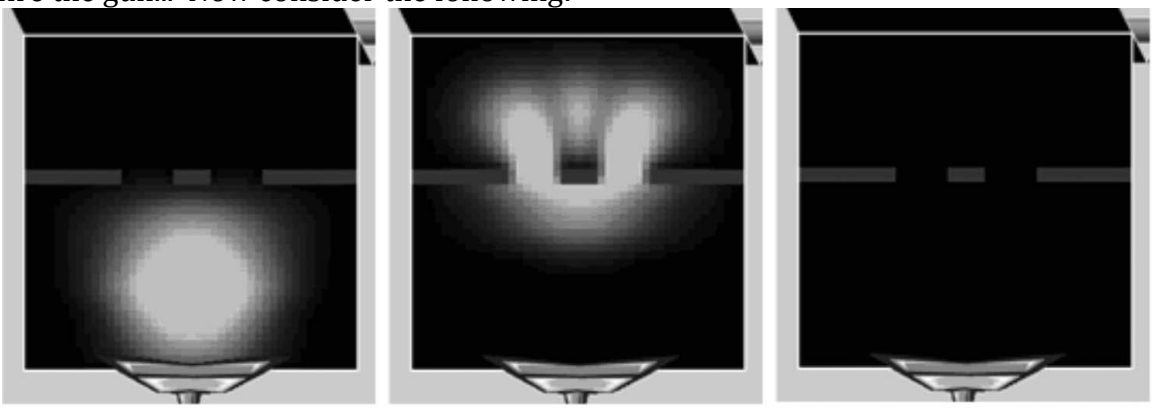
4. I think quantum mechanics is an interesting subject. **(FA08 – FA10)**

5. I have heard about quantum mechanics through popular venues (books, films, websites, etc...) (**FA08 – FA10)**

DOUBLE-SLIT ESSAY QUESTION:

PLEASE NOTE: As before, there are no "right" or "wrong" answers to the following question. We are interested in what you actually believe. Play with the Quantum Wave Interference simulation, at:
http://phet.colorado.edu/new/simulations/sims.php?sim=QWI

In particular, select the "Single Particles" tab at the top of the screen, and then click on the "Double Slits" button at the right of the display. Select "Electrons", and then fire the gun... Now consider the following:



(A) (B) (C)

A bright spot (representing the probability density for a single electron) emerges from an electron gun (A), passes through both slits (B), and a single electron is detected on the far screen (C). After many electrons, a fringe pattern develops (not shown). Three students discuss this Quantum Wave Interference simulation:

Student 1:

That blob represents the probability density, so it tells you the probability of where the electron could have been before it hit the screen. We don't know where it was in that blob, but it must have actually been a tiny particle that was traveling in the direction it ended up, somewhere within that blob. **(SP08)**

The probability density is so large because we don't know the true position of the electron. Since only a single dot at a time appears on the detecting screen, the electron must have been a tiny particle, traveling somewhere inside that blob, so that the electron went through one slit or the other on its way to the point where it was detected. **(FA08, SP09, FA09, SP10, FA10)**

Student 2:

No, the electron isn't inside the blob, the blob represents the electron! It's not just that we don't know where it is, but that it isn't in any one place. It's really spread out over that large area up until it hits the screen. **(SP08)**

The blob represents the electron itself, since an electron is described by a wave packet that will spread out over time. The electron acts as a wave and will go through both slits and interfere with itself. That's why a distinct interference pattern will show up on the screen after shooting many electrons. **(FA08, SP09, SP10, FA10)**

I think the blob represents the electron itself, since a free electron is properly described by a wave packet. The electron acts as a wave and will go through both slits and interfere with itself. That's why a distinct interference pattern will show up on the screen after shooting many electrons. **(FA09)**

Student 3:

Quantum mechanics says we'll never know for certain, so you can't ever say anything at all about where the electron is before it hits the screen. **(SP08)**

Quantum mechanics is only about predicting the outcomes of measurements, so we really can't know anything about what the electron is doing between being emitted from the gun and being detected on the screen. **(FA08, SP09)**

All we can really know is the probability for where the electron will be detected. Quantum mechanics may predict the likelihood for a measurement outcome, but it really doesn't tell us what the electron is doing between being emitted from the gun and being detected at the screen. **(FA09, FA10)**

Quantum mechanics lets us predict the interference pattern, but I think we really can't know or say anything about what each electron was doing between being emitted by the gun and being detected on the screen. **(SP10)**