Title: Using Physlets and Just-in-Time Teaching in Quantum Mechanics

Applicants: Mario Belloni (MB)[1], Larry Cain (LC)[2], and Wolfgang Christian (WC)[3]
Physics Department, Davidson College

Summary Report

"There was a time when the newspapers said that only 12 men understood the theory of relativity. I do not believe there was ever such a time. On the other hand I believe I can safely say that nobody understands quantum mechanics."

---Richard Feynman [The Character of Physical Law]

Abstract: We have developed curricular material in support of a one-semester, intermediate course in quantum mechanics. This curricular material uses the Just-in-Time Teaching (JiTT) technique and, where applicable, Physlets to actively engage students outside of the classroom to enhance their in-class experience. Forty-five such JiTT exercises have been developed to stress the visualization of quantum mechanical concepts with the goal of achieving better student understanding of these concepts. *We originally proposed to develop twenty.*

Student Learning of Quantum Mechanics

Learning quantum mechanics is difficult for many students. There are three reasons for this:

- Quantum mechanics is not like classical mechanics (uncertainty versus determinism).
- Quantum mechanics is one level (at least) divorced from the world we live in.
- Quantum mechanics is inherently mathematical.

The exercises we have developed are geared to address these difficulties. Daily JiTT exercises (WarmUps) help students prepare for class. Students prepared for class by doing these targeted exercises are more motivated to understand the material presented and actively participate in class. Given how difficult quantum mechanics is to comprehend, this preparation and motivation is crucial. In addition, the visual nature of the Physlet-based exercises will aid students in understanding both the concepts and the mathematics behind quantum theory.

Integration into the Curriculum

MB is currently teaching the intermediate-level course in quantum mechanics and will continue to do so next year. He is using the materials developed from this grant in his quantum mechanics course during fall 2001 and will use again use the materials spring 2002 (his advanced quantum mechanics course) and fall 2002. Several colleagues from colleges and universities across the country will also be using these materials in the fall 2001. In addition, some of these materials have "trickled down" to the sophomore-level modern physics course at Davidson.

Evaluation and Dissemination

We are evaluating our materials by administering the Quantum Mechanics Visualization Instrument (QMVI) developed by Richard W. Robinett of Pennsylvania State University, University Park. This test consists of 25 qualitative, multiple-choice questions in the areas where students have difficulties (such as matching wave functions with quantum wells and barriers). We administered the test the first day of class (the pre-test) and will re-administer the test on the last day of class (the post-test). We will calculate the normalized gain from the pre- and post-test

[1]e-mail address: mabelloni@davidson.edu
[2]e-mail address: lacain@davidson.edu
[3]e-mail: wochristain@davidson.edu

results (See Eric Mazur, *Peer Instruction: A Users Manual*, Prentice-Hall Upper Saddle River, NJ, 1996) to evaluate the effectiveness of our materials. Preliminary results will be available December 2001. *We originally proposed to evaluate our materials by administering single- topic pre- and post-tests developed by E. Redish, R. Steinberg, and M. Wittmann and, where necessary, create our own pre- and post-tests. The QMVI is a more comprehensive and established evaluation instrument.*

We have e-mailed the Physics department chairs of the ACS and the members of the ACS-PHYSICS e-mail list with the web address: http://webphysics.davidson.edu/qmbook/qm_acs where they may access our materials (We are currently working with the ACS to master our materials onto a CD, which we will send to chairs.). Chairs have been asked to distribute the materials to their colleagues. In addition, MB, LC, and WC have already widely publicized these materials outside of the ACS. Specifically:

- February 16, 2001: Syllabus column in the Chronicle of Higher Education. Profiled teaching methods (Physlets and Just-in-Time Teaching) and the (then) future work on quantum mechanics. This article is available at the web address: http://webphysics.davidson.edu/mjb/syllabus_02_16_01.html.

- March 17, 2001: Contributed talk, Enhancing Student Learning with Interactive Curricular Material. Mario Belloni reported several preliminary quantum mechanics exercises at the North Carolina Section of the American Association of Physics Teachers (AAPT) at their spring meeting. The talk is available at the address: http://webphysics.davidson.edu/mjb/ncssm_aapt_talk.

- July 22, 2001: Handed out 30 CDs containing the preliminary exercises to our (WC and MB) workshop (Physlets: Teaching with Interactive Curricular Material, W33) participants at the national American Association of Physics Teachers (AAPT) summer meeting in Rochester, NY.

- July 24, 2001: Invited talk, "Using Physlets and Just-in-Time Teaching in Quantum Mechanics." We reported preliminary exercises to the national American Association of Physics Teachers (AAPT) at their summer meeting in Rochester, NY. The talk is available on the web at the address: http://webphysics.davidson.edu/mjb/rochester2001.

- September 5, 2001: Web site, http://webphysics.davidson.edu/qmbook/qm_acs, officially on-line with the quantum mechanics exercises. We e-mailed a letter to each physics department chair in the ACS and the members of the ACS-PHYSICS e-mail list to inform them of our work. We are currently working with the ACS to master our materials onto a CD, which we will send to chairs.

- November 3, 2001: Contributed talk, "Using Just-in-Time Teaching and Physlets in Undergraduate Quantum Mechanics." We will report on these exercises to the Southeastern Section of the American Physical Society, Charlottesville, Virginia.