

Grant Title: Using Physlets and Just-in-Time Teaching in Quantum Mechanics I and II
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Summary Report for Summer 2001 and Summer 2002 Mellon Fellowships

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-six such JiTT exercises and in-class interactive demonstrations have been developed to stress the visualization of quantum mechanical concepts with the goal of achieving better student understanding of these concepts. In addition, a 69-page Instructor's Guide has been produced and disseminated on a CD with the interactive materials.

Student Learning of Quantum Mechanics

Learning quantum mechanics is difficult for many students. There are three main 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 aids students in understanding both the concepts and the mathematics behind quantum theory.

Integration into the Curriculum

MB and WC are currently teaching the intermediate-level course in quantum mechanics and will continue to do so this year and next. MB used the materials developed from this grant in his intermediate quantum mechanics course during fall 2001 and his advanced quantum mechanics course during spring 2002. WC is using the materials in his intermediate quantum mechanics course during fall 2002. Several colleagues from colleges and universities across the country are using these materials. In addition, some of these materials have "trickled down" to the sophomore-level modern physics course at Davidson and "laterally moved" to the junior-level physical chemistry 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. This test is available upon request. Students performed better on the QMVI than graduate students after a graduate course in quantum mechanics. Our data from the fall 2001 course is also available upon request.

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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> where they may access our materials. We have mastered our materials---both the Instructor's Guide and the interactive materials---onto a CD which we sent to the chairs. (Last year we sent the preliminary materials to the chairs as well.) Chairs have been asked to distribute the materials to their colleagues.

In addition, MB, LC, and WC have widely publicized these materials outside of the ACS. Specifically:

- February, 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: http://webphysics.davidson.edu/mjb/syllabus_02_16_01.html.
- March, 2001: *Contributed Talk*, "Enhancing Student Learning with Interactive Curricular Material," North Carolina Section of the American Association of Physics Teachers. The talk is available at the address: http://webphysics.davidson.edu/mjb/ncssm_aapt_talk.
- July, 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 meeting in Rochester, NY.
- July, 2001: *Invited Talk*, "Using Physlets and Just-in-Time Teaching in Quantum Mechanics," national American Association of Physics Teachers meeting, Rochester, NY. The talk is available at: <http://webphysics.davidson.edu/mjb/rochester2001>.
- September, 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 sent our materials on a CD to ACS physics chairs.
- November 3, 2001: *Contributed Talk*, "Using Just-in-Time Teaching and Physlets in Undergraduate Quantum Mechanics," Southeastern Section of the American Physical Society, Charlottesville, Virginia.
- December, 2002: QMVI results tallied. Students performed better on the QMVI than graduate students after a graduate course in quantum mechanics. This data is available upon request.
- January, 2002: *Workshop*, "Using Interactive Java-based Pedagogies in the Classroom" winter meeting of the American Association of Physics Teachers Philadelphia, PA. 50 CDs were distributed to workshop participants and other interested faculty from around the country.
- February, 2002: CDs sent to the 15 ACS Chairs and also GLCA Chairs.
- February, 2002: *Invited Talk*, "Enhancing Student Learning with Physlet-based Just-in-Time Teaching," Invitational Conference on K-12 Outreach from University Science Departments: Using Technology to Link the Classroom to the Laboratory (and Murphy to Manteo), Raleigh, North Carolina.
- March 2002, *Contributed Talk*, "Using a Computer-Rich Curriculum to Teach Quantum Mechanics," North Carolina Section of the American Association of Physics Teachers, Winston Salem, North Carolina.

- April 2002: *Invited Talk*, “Using Physlet-Based Interactive Exercises to Enhance Student Learning,” Spring Meeting of the Southern Atlantic Coast Section of the American Association of Physics Teachers, Gainesville, GA.
- April 2002: *Invited Colloquium*, “Making Quantum Mechanics Interactive with Physlets and Just-in-Time Teaching,” Physics Department, Indiana University-Purdue University, Indianapolis, Indianapolis, IN.
- June 2002: *Contributed Poster*, “Time-Dependent Superpositions in Symmetric Potentials: How the Parity of the Wave Function Affects Expectation Values,” Gordon Research Conference on Physics Research and Education: Quantum Mechanics, South Hadley, MA.
- June 2002: *Invited Special Curriculum Session*, “Physlet-Based Media-Focused Education: Making Quantum Mechanics Visual and Interactive,” Gordon Research Conference on Physics Research and Education: Quantum Mechanics, South Hadley, MA.
- August, 2002: Handed out 30 CDs containing the QM exercises to our (WC and MB) workshop (Physlets: Developing Interactive Curricular Material, W32) participants at the national American Association of Physics Teachers meeting in Boise, ID.
- August 2002: *Invited Talk*, “The Development and Assessment of Interactive Exercises for Quantum Mechanics,” Summer Meeting of the American Association of Physics Teachers, Boise, ID.
- August, 2002: CDs sent to the 15 ACS Chairs.
- August, 2002: Material posted on the MERLOT (Multimedia Educational Resource for Learning and Online Teaching) Digital Library.
- September, 2002: *Opening Plenary Talk*, “Using Physlets to Teach Quantum Mechanics,” 7th Workshop on Multimedia in Physics Teaching and Learning, Parma, Italy.

This work is referenced in:

- “Physlets: Web-based Java Applets for Physics Education,” Wolfgang Christian, Mario Belloni, and Melissa Dancy, *Fall 2001 Newsletter of the American Physical Society Forum on Education*. Web Address: <http://www.aps.org/units/fed/fall2001/index.html>.
- “Enhancing Student Learning with Physlet-based Just-in-Time Teaching,” Mario Belloni, Wolfgang Christian and Aaron Titus, *Proceeding of the Invitational Conference on K-12 Outreach from University Science Departments: Using Technology to Link the Classroom to the Laboratory (and Murphy to Manteo)*. Submitted March 2002.
- “Teaching with Physlets®: Examples from Optics,” Melissa Dancy, Wolfgang Christian, and Mario Belloni, *The Physics Teacher*, November 2002.