

Grant Title: Developing Open Source Physics Curricular Material and Programs
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Summary Report for Summer 2003 Mellon Fellowships

We have developed approximately 5 new programs (applications and applets) and supporting curricular material for intermediate and advanced courses in quantum mechanics. The programs and exercises will stress visualization of advanced quantum mechanical concepts (such as two- and three-dimensional quantum mechanics) with the goal of achieving better student understanding of these concepts. The programs and curricular material will be distributed under the GNU open source model. They can be found on the Open Source Physics Web site at the following URL: <http://www.opensourcephysics.org/applets/ospqm/default.html>.

A list of simulations is described below:

- Two-dimensional Quantum Mechanics Simulations: these programs will show the wave function of a particle confined to a ring and the wave function of a 2D infinite square well.
- Three-dimensional Quantum Mechanics Simulation: these programs will show three-dimensional representations of various wave functions such as the particle confined to a spherical surface and the spherical harmonics.

As part of a pair of previous grants we have already created curricular material in support of a one-semester, intermediate course in quantum mechanics (available on the web at <http://webphysics.davidson.edu/qmbook/>). The interactive curricular material uses Physlets and the Just-in-Time Teaching approach. In addition, a 69-page Instructor's Guide has been produced and disseminated on a CD with the interactive materials.

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 2003 and will use them in his intermediate astrophysics course during spring 2004.

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, fall 2002, and fall 2003 courses are also available upon request.

In addition, MB and WC have widely publicized the materials from this and previous ACS Technology Fellowships outside of the ACS. Specifically:

- January, 2004: Mario Belloni, Wolfgang Christian, and Anne J. Cox, "Physlet-Based Ranking Tasks: From Introductory Physics to Quantum Mechanics," *Contributed Talk*, Winter Meeting of the American Association of Physics Teachers, Miami, Florida.

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- November, 2003: Mario Belloni and Wolfgang Christian, “Physlet-Based Ranking Tasks: From Introductory Physics to Quantum Mechanics,” *Contributed Talk*, Joint Fall Meeting of the North Carolina and Southern Atlantic Coast Sections of the American Association of Physics Teachers, Wilmington, North Carolina.
- November 2003: Wolfgang Christian and Mario Belloni, Curriculum Development and Open Source Physics Workshops,” *Contributed Talk*, Joint Fall Meeting of the North Carolina and Southern Atlantic Coast Sections of the American Association of Physics Teachers, Wilmington, North Carolina.
- August, 2003: Mario Belloni, Adam Abele*, and Wolfgang Christian, “One-, Two-, and Three-dimensional Quantum Mechanics Using Java3D,” *Contributed Talk*, Summer Meeting of the American Association of Physics Teachers, Madison, Wisconsin.
- April, 2003: Adam Abele*, “Using Java 3D to Visualize Problems in Classical and Quantum Mechanics,” *Invited Poster*, Sigma Xi Undergraduate Research Awards, Charlotte, North Carolina.
- April, 2003: Mario Belloni, “Making Quantum Mechanics Visual and Interactive with Physlet-Based Curricular Material,” *Invited Talk*, Joint Meeting of the American Physical Society and the Division of Particles and Fields, Philadelphia, Pennsylvania.
- September, 2002: *Opening Plenary Talk*, “Using Physlets to Teach Quantum Mechanics,” 7th Workshop on Multimedia in Physics Teaching and Learning, Parma, Italy.
- August, 2002: Material posted on the MERLOT (Multimedia Educational Resource for Learning and Online Teaching) Digital Library.
- 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.

This work is referenced in:

- *Physlet Quantum Mechanics*, Mario Belloni and Wolfgang Christian, Prentice Hall, June 2004. ISBN 0-13-101970-8.
- “Developing Open Source Programs for Upper Level Science and Mathematics,” Wolfgang Christian and Mario Belloni, Proceedings of the 7th Workshop on Multimedia in Physics Teaching and Learning of the European Physical Society. October 2003.
- “Teaching Thermodynamics with Physlet® in Introductory Physics,” Anne J. Cox, Mario Belloni, Wolfgang Christian, and Melissa H. Dancy, *Physics Education*, **38**, 433 (2003).
- “Physlets® for Quantum Mechanics,” Mario Belloni and Wolfgang Christian, *Computing in Science and Engineering* 5, 90-97 (2003).
- “Teaching with Physlets®: Examples from Optics,” Melissa Dancy, Wolfgang Christian, and Mario Belloni, *The Physics Teacher*, November 2002.
- “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>.