FY2008 Learning Technologies Grants Proposal

(COVER PAGE)

Project Information

Enhancing the Introductory Physics Laboratory Curriculum Through Computer-Based Measurement

Project Title

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Chad Fertig, Assistant Professor

Project Director

Department of Physics and Astronomy

Requesting Department

$12,315	$12,085
Amount Requested Year 1	Amount Requested Year 2

Project Director's Signature

Proposal Endorsement Signatures

William M. Dennis

Department Head

Dean

Proposal Abstract (100-word maximum)

We propose to overhaul and modernize the laboratory component of the undergraduate introductory physics curriculum through the use of a computer-based data acquisition system. Laboratory instruction utilizing computers in this way permits students to have direct contact with many phenomena that simply are not measurable without the speed and precision of electronic sensors. Another major benefit is the flexibility of the system for designing and implementing new experiments. This program is a first step towards implementing a fully inquiry-based laboratory curriculum, which will ensure that UGA students receive physics instruction based on the most current physics pedagogy research.

Enhancing the Introductory Physics Laboratory Curriculum
Through Computer-Based Measurement

Section I. Project Description

We propose to make broad changes to the instructional laboratory curricula of our service-teaching undergraduate introductory physics courses (viz., PHYS 1111, 1112, 1211, and 1212), through the comprehensive introduction of computer-based data acquisition hardware and software. Over the two-year span of the project. we plan to purchase instrumentation from Vernier Software and Technology, and to deploy this equipment in the laboratories. These new digital tools will enable us both to update current laboratory experiments, and to create wholly new experiments.

The first year of the project will fund the purchase of a variety of electronic sensors and probes for PHYS 1111 and 1211, our introductory Newtonian mechanics labs. Also in this first year, we propose to increase the absolute number of computer-based lab stations, so as to accommodate expected increases in course enrollment in the coming years. We emphasize that we are **not** requesting a routine upgrade to a newer version of existing equipment; rather, the proposed equipment is qualitatively different from what students currently use in the labs. At this stage, curriculum development efforts will concentrate on adapting current lab experiments to the new sensors, in the context of inquiry-based instruction.

In the project's second year of funding, we will obtain additional equipment necessary to develop completely new lab exercises. Also, we propose some computer-based instrumentation for the PHYS 1112 and 1212 lab sections (introduction to electromagnetism and optics). This is in anticipation of acquiring "hand-me-down" computers from the PHYS 1111 and 1211 labs, subsequent to upgrades made possible using FY'08 Student Technology Fees. The iMac computer upgrades to the 1111/1211 labs will enable us to begin implementing innovative digital video "motion capture and analysis" experiments.

Furthermore we propose to train and support, on a trial basis, undergraduate "technology facilitators," to help lab students make the best use of the new equipment. These students are expected to have previously successfully completed the laboratory component of the course, and will receive additional training on the new apparatus to prepare them to act as teaching assistants. The attention of the graduate student lab section leader is always in high demand; the presence of an undergraduate student, familiar with the equipment and the lab exercises, will be an invaluable asset.

Need/rationale

Currently, many instructional laboratory exercises in the introductory physics sequences are conducted with simple and "traditional" instruments—beam balances, spring scales, stopwatches, even compasses. While there is some merit to gaining experience with traditional instruments, the range of experiments one can perform is limited. The equipment often lacks sufficient precision for students to make the detailed measurements they need in the time allotted. Some of the instruments are difficult to keep calibrated under constant heavy student use, resulting in poor accuracy. The students' understandable resulting frustration compromises

their ability to learn from the lab exercises.

Laboratory instruction using computer-based data acquisition equipment permits direct measurement of a large array of physical systems, with precision and reproducibility. Many conceptually challenging phenomena (e.g., free-fall acceleration, action-reaction forces, electric potential, magnetic field lines), previously difficult to measure or visualize with any fidelity, will become accessible to investigation with electronic sensors. The solid-state detectors are less likely to lose calibration, and also easier to recalibrate if needed. The software interface lets students acquire, plot, and analyze their data in real time. This will dramatically cut down on "busy work" and improve the quality of students' results as compared to traditional apparatus. The use of modern digital sensors and analysis software will also provide students with a better idea of how experimental science is conducted today, rather than how experiments were performed a century (or longer) ago.

Acquiring the suite of computer-based laboratory equipment proposed here will enable our department to do more than just modernize its existing lab courses; it will be a significant step towards implementing a fully inquiry-based laboratory curriculum.[1] The University of Georgia finds itself among a minority of top-ranked state universities that do not include some form of inquiry-based instruction in their introductory physics curriculum. The modifications and innovations to our lab courses made possible by this grant will help to ensure that UGA students receive a high-quality physics education, benefiting from the latest research in physics pedagogy.

Our department has made progress toward this goal by procuring a personal computer, sensor interface, and motion detector for every current lab station of the PHYS 1111/1211 labs, funded in part from Student Technology Fee allocations. However, considering the wide variety of available digital sensors, these computers are currently quite under-utilized. This is the situation we propose to remedy.

Another major benefit to computer-based laboratory apparatus is its flexibility for the implementation of novel experiments. Indeed, introductory lab courses tend to grow stale due to the inflexibility of traditional equipment, and students eventually learn through the grapevine of past attendees how to get through the "cookbook" labs with a minimum of effort and thought. By contrast, computer-based instrumentation is highly reconfigurable, allowing instructors to make changes to experimental protocols each semester. Combined with a lab curriculum based on learning through inquiry, this ensures that students continue to be presented with challenging experiences in the lab.

A laboratory curriculum centered around computer-based data acquisition using a similar system (MeasureNet) was successfully implemented in the Department of Chemistry with the help of Learning Technologies Grants. (The Vernier system suits our needs better, in that data is transfered to the computer and plotted in real time, rather than after the experiment is completed.) This encourages us that our plan is viable and scalable. We anticipate that consultation with the Chemistry Department will facilitate a smooth transition of our labs to this new model.

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[1] 2004 Physics Education Research Conference, Scott Franklin, Paula Heron, Jeffrey Marx (editors), American Association of Physics Teachers, Springer (2004).

Relevance of the project to unit and University priorities

As mentioned above, this reinvention and rejuvenation of our introductory physics laboratory sequence is seen as part of a fundamental shift in physics instruction to inquiry-based learning, where students are provided the resources (such as computer-based data acquisition hardware and software) to investigate physical phenomena on their *own* terms, not simply following a recipe prescribed by a lab manual. Many studies support the efficacy of this approach.*

The mission statement of UGA expresses the University's "...commitment to excellence in a teaching/learning environment dedicated to serve a diverse and well-prepared study body, [and] to promote high levels of student achievement." In proposing this new direction for our introductory physics laboratory sequence, the Department of Physics and Astronomy seeks to achieve exactly these goals. It is also hoped that an improved undergraduate laboratory experience will induce more students to consider physics for their major field of study.

This project has the strong support of our department, as demonstrated by the contributions listed in the proposal budget. Specifically, the department has placed the introductory instructional labs at the head of the queue for equipment updates. The department's purchase of 20 new Apple iMac computers in FY'08 will be a key factor in the plans for the project's second year. Also, one of us (Dr. Wiegert), as a faculty member budgeted for scholarship in teaching and learning, has been charged with the task of orchestrating the complete overhaul of the undergraduate laboratory curriculum, and has been provided with significant, non-equipment-related departmental resources to achieve this end. These already-committed resources include startup money for graduate student support extending over both years of the project, and a first-year reduced teaching load for Spring 2008 (represented in the budget below as a course release provided by external sources).

Specific courses benefiting from the project

The courses benefiting from the proposed project are the laboratory components of PHYS 1111, PHYS 1112, PHYS 1211, and PHYS 1212. These are the two-semester, non-calculus and calculus based introductory physics sequences, respectively. The number of students served by these courses, per year, were most recently as follows:

PHYS 1111	866	PHYS 1211	273
PHYS 1112	726	PHYS 1212	163

It bears repeating that these enrollments are projected to grow significantly over the next several years.

Section II. Budget

FY 2007-2008 (Year 1)

Item	Qty	Total Cost	Requested from LTG	External Sources
Vernier Motion Detector	7	$541	$541	$0
Vernier Motion Detector Clamp	6	$38	$38	$0
Vernier LabPro Interface	5	$1133	$1133	$0
Vernier Temperature Probe	7	$210	$210	$0
Vernier Force Sensor	48	$5389	$5389	$0
Vernier Photogate	48	$2225	$2225	$0
Vernier Sensor Air Track Adapter	24	$1162	$1162	$0
Vernier Microphone	24	$915	$915	$0
Vernier Force Plate	2	$410	$410	$0
Vernier Wireless Digital Sensor System	1	$257	$257	$0
Vernier WDSS Accessories	1	$9	$9	$0
Bluetooth USB Adapter	1	$26	$26	$0
Faculty course release	1	$5000	$0	$5000
GRA Support 1/9 th	2	$3750	$0	$3750
Vernier LoggerPro Software (site license)	1	$175	$0	$175
Totals		$21240	$12315	$8925

FY 2008-2009 (Year 2)

Item	Qty	Total Cost	Requested from LTG	External Sources
Vernier Magnetic Field Sensor	24	$1385	$1385	$0
Vernier LabPro Interface	22	$4986	$4986	$0
Vernier Force Sensor	24	$2695	$2695	$0
Sony MiniDV Digital Camcorder	2	$1339	$1339	$0
Undergraduate Facilitators	4	$1680	$1680	$0
GRA Support 1/9 th	4	$7500	$0	$7500
Apple iMac Computer	20	$26000	$0	$26000
Totals		$45585	$12085	$33500

Budget Justification:

Vernier Equipment: Our PHYS 1111/1211 labs currently use Vernier data-acquisition hardware and software, along with (a limited number of) Vernier sensors. This equipment is both reliable and flexible, and the Vernier company has a long history of excellence in service and support of science education. In the first year of the project, the first four budget items will augment our current complement of LabPro computer interfaces and sensors to match the scheduled increase in enrollment per lab section. In the second year, we request additional LabPro interfaces for the computers that we anticipate will be installed in the 1112/1212 laboratory.

Furthermore, successful implementation of this project, particularly the development of new lab experiments, necessitates the purchase of additional types of sensors beyond what we currently have in the labs. Thus, we request a full complement of sensors to measure forces and torques, periods, sound, and (in the second year) magnetic fields.

Digital Camcorders: We request the purchase of two camcorders for use in pilot testing of digital video-based motion capture and analysis. We anticipate that two camcorders at minimum are required to allow all student groups in a lab section to acquire video data in a timely fashion, although ideally we would prefer a lower ratio of students to camcorders in the lab.

Undergraduate Facilitators: Trained facilitators, assisting the regular graduate lab assistants, will be invaluable to help smooth the transition to the new technology. Because most of our graduate lab instructors teach multiple lab sections per week, we can hopefully attain some economy of scale by deploying facilitators in fewer sections.

Departmental and external support:

Graduate Assistants: Dr. Wiegert has been provided with graduate assistant support as part of his startup funding. These assistants will observe students in the labs to assess both their current understanding and their own ideas for lab improvements. The graduate assistants will also work with Dr. Wiegert to modify existing labs and to assess the effectiveness of the new curriculum.

iMac Computers: The Department will be requesting funds from the Student Technology Fee to upgrade the computers currently in use in the 1111/1211 labs. These new computers will be able to support video-based motion capture and analysis labs. Additionally, the computers they replace will be installed in the 1112/1212 labs, to permit the use of digital instrumentation there.

Project Timeline:

Date	Objective	Person(s) Responsible
09/07-05/08	Ongoing assessment of current lab curriculum	Wiegert, GRA
01/08-02/08	Equipment purchase, installation, troubleshooting	Wiegert, Barnello
01/08-05/08	Modifications to current labs, testing modifications	Wiegert, GRA
06/08-08/08	Begin deploying modified labs in summer session; evaluate and modify lab procedures as necessary	Wiegert, Barnello
09/08-12/08	Further deploy modified labs, with undergrad facilitators. Assess student learning and attitudes.	Wiegert, Fertig, Barnello, GRA
12/08-01/09	Evaluation of first year	Wiegert, Fertig
01/09-05/09	Additional equipment purchase, development of new lab experiments; ongoing assessment of student learning outcomes.	Wiegert, Fertig, Barnello, GRA
06/09-08/09	Deploy and test new labs in summer session; evaluate and modify procedures as necessary.	Wiegert, Barnello
09/09-12/09	Further deployment of new labs, and assessment of student attitudes and learning.	Wiegert, Fertig, Barnello
12/09-01/10	Final report to CAIT.	Wiegert, Fertig

Section III. Learning Outcomes

We expect two primary learning outcomes as a result of this project. First, students working with these new technologies, in an environment of inquiry, should achieve a better overall understanding of the process of modern experimental science. Secondly, they should demonstrate a solid grasp of the fundamental physical concepts explored in the labs and how they relate to the lecture component of the course.

To assess the impact made on undergraduate instruction by the proposed project, we will take advantage of a newly implemented laboratory final exam, administered for the first time in Summer 2007, as a benchmark of student performance. A similar exam, administered after the first semester for which the computer-based laboratory is in place (anticipated Fall 2008), will allow for a direct quantitative comparison of the old and new curricula. Furthermore, a differential comparison will be made between final exam scores in sections with and without the presence of an undergraduate technology facilitator.

Attitudinal surveys will also be conducted each semester, to gauge the students' reactions to the computer-based lab equipment and the inquiry-based curriculum as a whole. Follow-up interviews with selected students will help to elicit specific difficulties and concerns, and will provide suggestions for curriculum modifications.

Section IV. Support Plan

Several staff members in the Department of Physics and Astronomy will provide ongoing support for this project in the regular course of their jobs. Mike Caplinger and Jeff Deroshia, our systems administrators, already contribute hardware and software support (installation, troubleshooting, and repair) for the computers used in the instructional labs. Our Laboratory Coordinator, Tom Barnello, has many years of experience with all the lab apparatus, including the Vernier equipment. He supports the instructional labs through maintenance of the lab equipment, apparatus design and construction, and lab setup. Funding for routine maintenance and repair of lab equipment is provided by the department.

One of Dr. Wiegert's long-term goals is an ongoing reform of the introductory lab curriculum, supported in part by the equipment requested in this proposal. Because each type of sensor can be used in several different ways, it should be expected that new and innovative uses will continue to be developed long after the LTG funding period.

The project directors will also actively seek external funding to continue enhancing the lab curriculum. One promising funding source is the National Science Foundation's program in Course, Curriculum, and Laboratory Improvements. These further efforts will likely target the PHYS 1112/1212 labs; these labs have necessarily received less attention in this proposal due to the current absence of computers, a situation which, as previously explained, is scheduled to be remedied within the year.