Pages 165-207 are a compilation of data provided by the various groups. When possible, the data is presented as: An introductory page about the group, a transcript of the discussion presented in the Research and Development Projects We Are Now Doing session at PERC, a short history of the group, and a list of Ph.D.s earned by students in the group.

Arizona State University
Physics Education Graduate Program
Senior Faculty: David Hestenes

Program Description:

The graduate Physics Education R&D program at ASU is primarily concerned with

- developing a coherent instructional theory,
- applying it to the design and conduct of instruction,
- developing validated instruments to assess the outcomes.

Research on instructional theory is grounded on the thesis that scientific activity is centered on modeling: the construction, validation and application of conceptual models to understand and organize the physical world. Accordingly, instructional design is centered on models, as units of coherently structured scientific knowledge, and modeling, as the core of scientific method. Full implementation of modeling theory in science instruction is a huge task, because it requires a thorough analysis and reconstruction of the curriculum. The instructional theory has continued to evolve along with its implementations in teaching practice. Extensive implementation and evaluation is currently underway in high school physics and University (calculus-based) Physics. Details of the high school program are available at the Modeling Workshop Web site: *http://modeling.la.asu.edu*. Research papers of more general interest can also be accessed or traced from this site.

Graduate degrees:

Ph.D. degrees in PER are offered in the physics program and in the Curriculum and Instruction (C&I) program in the College of Education. Course requirements differ in the two programs, but the doctoral research for both is supervised by a physics professor. Masters of Science in Physics and Masters of Natural Science degrees can also be awarded for work in physics education.

Funding: Federal funding for the program has been continuous since 1989.

Ph.D.s granted

Halloun, Ibrahim, 1984, The Use of Models in Teaching Mechanics, Arizona State University, Hestenes. Now at Lebanese University.

Wells, Malcolm, 1987, Modeling Instruction in High School Physics, Arizona State University, Hestenes. Now deceased.

Boise State University

Dewey Dykstra

I probably represent the smallest group listed here, and I am at least tied as the smallest group of any of the groups represented here at the meeting. Most of the work that I’ve been doing in the last two years has been teaching people who are extremely unlikely ever to be physics majors, and in the context of having them look at the phenomena surrounding image formation with lenses. Some of you are aware of the workshop that I’ve done at AAPT meetings and that sort of thing. It occurred to me a couple years ago that people seem to be expressing ideas about how images come to be, initially in the activities, and ways that you could probably represent with three diagrams. So I began to incorporate these three diagrams very early on, and to ask them, "Do any of these make sense to you?" This led to a fairly substantial change, at least conceptually, in the way the activities have worked out, and to substantial change, I think, in the way students have ended up the unit describing their final ideas about the way images come to be. The details are described in the sheet.

Physics Education Research
at the Center for Innovation in Learning
Carnegie Mellon University, Pittsburgh PA

The members of the Center for Innovation in Learning (CIL) work on projects in variety of areas including mathematics, statistics, modern languages, English, and physics. Our efforts in physics are concentrated in two main areas.

Using Computers to Teach Thinking Skills
F. Reif, L. Hsu, L. A. Scott, E. Zeisloft, J. Harvey
http://cil.andrew.cmu.edu/projects/pal

We are working on a set of computer tutorials called PALs (Personal Assistants for Learning) designed to help students learn to apply various physics principles by making the required cognitive processes more explicit.

In a previous study, students using PALs were found to make significantly fewer mistakes on a subsequent exam and also perceived PALs as useful. We are currently expanding the topics covered by the set of existing PALs to include both qualitative and quantitative aspects of applying Newton's laws of motion, as well as applying the concept of acceleration.

Redesigning the Introductory Physics Curriculum
Ruth Chabay, Bruce Sherwood, Tom Foster, Matt Kohlmeyer
http://cil.andrew.cmu.edu/mi.html

We have been developing a new curriculum for the introductory physics sequence which will depart from the canonical physics curriculum by embracing an atomic viewpoint and incorporating some twentieth century physics. These two ideas are already embodied in Chabay and Sherwood's *Electric & Magnetic Interactions.* The new textbook, entitled *Matter & Interactions,* will extend our earlier efforts while incorporating the use of computer tools to model dynamical processes central to an introductory exploration of mechanics and thermal physics.

Formative evaluation efforts have just begun on *Matter & Interactions*. Two small pilot classes succeeded in achieving many of the course goals while suggesting areas for improvement. *Electric & Magnetic Interactions* continues to be refined in an effort to seamlessly merge the two curriculums.

CIL members involved in Physics Education Research 1998-99

Faculty
Ruth Chabay
rchabay@andrew.cmu.edu
Frederick Reif
freif@andrew.cmu.edu
Bruce Sherwood
bas@andrew.cmu.edu

Postdoctoral Researchers
Tom Foster
tfoster@andrew.cmu.edu
Leon Hsu
lhsu@andrew.cmu.edu

Graduate Students
Matt Kohlmeyer
Lisa Ann Scott

Educational Programmers
David Andersen
James Harvey
Eric Zeisloft

Contact us at:

Center for Innovation in Learning
Carnegie Mellon University
5000 Forbes Avenue
Pittsburgh, PA 15213

(412) 268-7675 (voice)
(412) 268-5646 (fax)

Visit our website at:
http://cil.andrew.cmu.edu

Leon Hsu—Carnegie Mellon University

Many students complete their introductory physics courses unable to apply the knowledge that they ostensibly learned. One reason for this is that important scientific thought processes are often inadequately identified or taught.

We have designed a set of computer tutorials, called PALs (Personal Assistants for Learning) to teach such thinking skills more explicitly. These tutorials are based on the following:

- **Systematic methods and basic cognitive processes**. The thought processes necessary to perform scientific tasks must be clearly identified and made explicit to students. Systematic thinking, which involves making decisions, implementing them, and assessing the results is also required. PALs attempt to teach these skills explicitly.
- **Instructional strategy.** PALs use a modified form of “reciprocal teaching” in which PAL and the student alternately coach each other. In some cases, the computer gives instructions to the student and corrects the student’s actions while in others, the roles are reversed, with the student deciding what to do and assessing the correctness of PAL’s actions (which may be deliberately faulty). Throughout, the student is encouraged to learn from examples which he or she has previously worked.
- **Role of computers—individual guidance and feedback.** PALs can provide much better individual guidance and feedback than ordinarily received by most students.

PAL tutorials were constructed to teach the application of Newton’s laws and were tested on a subset of the students in an introductory physics class at Carnegie Mellon University. On a subsequent regular class test on Newton’s law problems, virtually all students who had worked with PALs received scores above 65% (while only half of the students who did not work with PALs received scores above this amount). They also made far fewer errors in describing motion or forces. All of the students using PALs rated them as useful, emphasizing that the tutorials had been particularly valuable in helping them learn a systematic problem-solving method.

Ruth Chabay — Carnegie Mellon University.

Bruce Sherwood, Tom Foster and myself are working on a project to re-conceptualize what students in the introductory course ought to be doing and learning. At Carnegie Mellon University, we have a number of our students who come in having taken some kind of mechanics in high school, and it doesn’t seem particularly profitable for many of them to repeat exactly what they did in high school with about the same results, so we’ve been looking at developing a new curriculum that actually looks very different to the students and engages them in different kinds of activities.

This is a brand new curriculum and it didn't seem plausible that we could use standard materials for it, so a new textbook needed to be written. The goals of the new textbook and curriculum are:

- **Integrating mechanics and thermal physics.** We're taking an atomic viewpoint to integrate these topics that otherwise seem disparate.
- **Modeling the real world.** We want to involve students in doing what physicists really do, namely modeling the real world, so we involve students in building models of the real world.
- **Programming computer models.** To put some teeth into these models, we have the students write computer programs of those models. These programs typically involve numerically integrating non-constant forces, simulating the motion, and producing graphical representations.

This kind of development effort raises a lot of issues. One of the issues involved is that students aren't usually involved in actually trying to construct, manipulate, and extend models of physical systems. A related issue is the effect of having students do computer modeling, by which we mean having the students write computer programs to numerically integrate Newton's Laws of motion and observing the time evolution of the system. Another issue would be the feasibility of teaching twentieth century physics to freshmen. So, we've sort of taken a big jump into a new area and we are trying to explore all these issues at once.

Carnegie Mellon University

CIL History - 1998

The Center for Innovation in Learning (CIL) at Carnegie Mellon University was established in 1994 with the mission to do serious research and development in undergraduate college education. While there are many such R&D centers dedicated to precollege education, such a center is rare at the college level. Due to accidents of history, several of the CIL senior staff happen to have backgrounds in physics or chemistry: Ruth Chabay, Jill Larkin, Fred Reif, and Bruce Sherwood. Several CIL projects have addressed problems in the learning of introductory physics. Chabay, Reif, and Sherwood have joint appointments in physics; Larkin and Reif have joint appointments in psychology. Other CIL senior members are working in the areas of writing and statistics. CIL members collaborate with faculty in other areas, including history, engineering, and mathematics.

In Fall 1997 CIL accepted its first (two) graduate students into a Ph.D. program in Instructional Science. CIL graduate students must have sufficiently strong disciplinary backgrounds to be acceptable as TAs in a university department, and must have an interest in one of the areas of expertise of a senior CIL member. Graduate students take core graduate courses in psychology and statistics, as well as special courses taught by CIL itself. The CIL Ph.D. program could produce a student whose disciplinary focus is physics, but this is by no means a specifically physics program.

Grand Valley State University

Beth Thacker

You're looking at my group. The main research I've been doing for the past few years is on student's understanding of modern physics and quantum mechanics in the context of common experiments that demonstrate fundamental processes of microscopic particles. For example, the photoelectric effect, electron diffraction, Rutherford scattering, Stern Gerlach—typical experiments that you would do in a modern physics class or possibly a quantum mechanics class. The goal of this is to probe the development of students mental models of microscopic processes based on macroscopic observations that they make. That's been the focus of my research. I also do some curriculum development. I've been collaborating with a science educator and two high school teachers in an inner city high school and we've been working on developing materials for ninth grade physical science and eleventh grade physics that are consistent with the Michigan Essential Goals and Objectives for Science Education and consistent with the new proficiency test that we have in the state of Michigan.

Indiana University-Purdue University Fort Wayne

David P. Maloney, Physics Department

I'm going to talk about the three main physics education research projects at IPFW. I'm also one of the small groups—I am the group.

Physics Education Research Projects at IPFW:

- Development of conceptual assessments for the domain of electricity and magnetism. This project is being carried out in collaboration with Curtis Hieggelke of Joliet Junior College, Thomas O'Kuma of Lee College and Alan Van Heuvelen of The Ohio State University. We are working on the development of three conceptual surveys, one for electricity, without DC circuits, one for magnetism and a joint instrument for electricity and magnetism both. The current versions of the instruments have been through several stages of development and we are currently analyzing data on the latest versions.
- Investigation of students' understanding of volume in several contexts, but especially with regard to the particle model of matter. This research is a collaboration between myself and Dr. Arthur Friedel of the Chemistry Department at IPFW. We have carried out several paper and pencil studies of students' ideas about volume, area, mass, and space with two groups of students. One group of students is enrolled in college general chemistry courses and the other group is non-science majors enrolled in a college physical science course.
- Development of an interactive engagement style one-semester physical science course using the particle model of matter as the unifying theme. This course attempts to treat some fundamental ideas from both chemistry and physics with equal attention to each discipline. This course enrolls primarily elementary education majors. The materials under development basically use an elicit-confront-resolve format and the students work in groups throughout the semester.

Iowa State University Physics Education Research Group

Department of Physics and Astronomy
Iowa State University
Ames, Iowa

A new physics education research group has been formed at Iowa State University, which will carry out an integrated program to (1) develop new methods of instruction, particularly for large-enrollment classes; (2) develop improved curricula to support the new instructional methods; (3) carry out basic research in the teaching and learning of physics. The physics education group will work in close collaboration with the well-established chemistry education research group at Iowa State, led by Tom Greenbowe.

Main Themes of Our Work

(1) **Develop and assess new instructional methods for large-enrollment classes**. These methods are aimed at increasing the degree of student-faculty interactivity and of active student participation in the classroom learning environment. We use the "Flash Card" response system to obtain instantaneous feedback on multiple-choice questions from all students simultaneously. In addition, students spend a large fraction of class time working in collaborative groups on carefully structured work sheets.

(2) **Curriculum development to support the new instructional methods.** To ensure that the "active learning" environment is fully effective, appropriate curricular materials must be employed. We are continuing development of a *"Workbook for Introductory Physics"* which comprises two main parts: (a) multiple-choice questions, emphasizing common conceptual difficulties, for use with "flash-card" or other instantaneous student response systems; (b) closely linked sequences of free-response questions for in-class use by students working in small groups. These questions make heavy use of proportional reasoning, qualitative analysis, and multiple representations, and guide students to deepen conceptual understanding in widely varied contexts. The curricular materials undergo continuous testing and redesign through day-to-day class use, combined with careful assessment of student leaning.

(3) **Basic research to support curriculum development.** We have two main projects: (a) Investigation into comparative effectiveness of different representational modes, i.e., the relationship between the form of representation of physics concepts, and efficiency of student learning; (b) Investigation of factors underlying individual differences in student learning of physics: why do some students apparently start (conceptually) at the same point, yet finish at different points? How can curriculum and instruction more effectively target these different groups of students to maximize learning of physics concepts?

Iowa State University
Physics Education Research
1999-2000

Faculty
David Meltzer (Asst. Prof.)

Collaborating Faculty
Thomas Greenbowe (Prof., Chem.)
Laurent Hodges (Prof.)
William Kelly (Prof.)
Francis Peterson (Prof.)

Graduate Student
Jack Dostal

For more information contact:

Prof. David E. Meltzer
Department of Physics and Astronomy
Iowa State University
Ames, IA
50011

dem@iastate.edu
515-294-9358 (voice)
515-294-6027 (fax)

David Meltzer—Iowa State University

At Iowa State we're starting a new physics education group. We're going to be focusing on three separate areas, although they're very closely interlinked: (1) new instructional methods, (2) development of curriculum to support the new instructional methods, and (3) basic research to support both of those efforts. One of the advantages we have is that at Iowa State there has been for several years a very active chemistry education research group led by Tom Greenbowe. It is one of the very few in the country and we expect to have very close collaboration with them. We should obviously be able to promote some connections between physics and chemistry.

The instructional methods we are focusing on are related to large-enrollment classes where you have 100 or 200 people in the classroom. This is something that a number of others have already touched on. We're trying to find ways to make instruction in that kind of very difficult setting more effective, and we want to develop curriculum to support those instructional methods. We want to develop curriculum that is appropriate for use in that kind of environment and yet promote active learning, active participation by the students. We also want to carry out basic research in physics teaching and learning that will support both of those efforts of curriculum and instruction for large enrollment classes.

The main theme of the work on instructional methods is finding ways to increase student-faculty inter-activity in the classroom, and to increase interaction among the students themselves in the large-enrollment classrooms. One of the methods we use is the "El-Cheapo" response system [flash cards]. You're probably familiar with these flashcards. Every student in the classroom has a set of these cards and it's not as fancy as Classtalk, but it's very cheap and it's very easy to implement. We can ask very frequent questions during these lectures. A lot of questions, a lot of answers for multiple-choice forms of questions – and we get instantaneous response from all of the students in the class simultaneously. Of course when one is fortunate to enough to have the expensive response systems it's quite effective to use those, but one needs a lot curricular materials to implement this.

You need lots of questions that are appropriate for showing to students in these large lecture classes, and you may be familiar with Eric Mazur's book. Kandiah Mannivannan and I have been working on something called a "Workbook for Introductory Physics." Each topic starts out with many of these multiple choice questions which we pose in large lecture settings. But it also has sections of free-response exercises, which students actually work on at their desks, working in groups or pairs, and they spend a lot of time during class working through these materials. This is very similar to things that you're probably familiar with from Alan Van Heuvelen, and also some of Randy Knight's work. So we spend a large amount of time in these "Large-room Meetings," as Alan calls them, having students work through these curricular materials.

The basic research we're focusing on is in a couple of separate areas. One is to look more carefully at the difficulty students have with different forms of representation of physics concepts. What I mean by that is the different ways one can pose a physics concept or a physics problem. You can pose it just using words, or you can use mathematical symbols. You can use a pictorial diagram or vector diagrams. You can use graphical ways of transmitting information. Especially now that these multiple forms of representation are coming into much wider use in physics education, it may be very useful to look more carefully at whether the difficulties students have relates simply to the form of the representation, and whether or not one form of representation or another is more effective in teaching certain concepts. This is actually related to something Arnold Arons discussed about the linguistic difficulties that we may be introducing in the learning of physics concepts. There are similar types of difficulties that we may be inadvertently introducing simply by using representations that the students find particularly difficult or with which they're unfamiliar.

Another research problem we're working on is to look at the factors that underlie the variability in students' success in learning physics. In other words, in a large class you'll have students, many of whom will be starting at apparently the same position. Their scores on pretests may be exactly the same. Everything about them, as far as you can tell, is the same and yet at the end of the course some of them have learned a whole lot and some of them have learned practically nothing. Why is that? What are the factors that lie behind that? How can we get a grip on that and how can we hopefully intervene to become more effective instructors for all of the students in the course?

Physics Education Research Group

Kansas State University
116 Cardwell Hall
Manhattan KS 66506-2601
http://www.phys.ksu.edu/perg

Faculty: Professor Dean Zollman
Postdoctoral Research Associates: Sanjay Rebello, Michael Thoresen
Graduate Students: Alice Churukian, Kastro Hamed, Seunghee Lee, Gabi Mihalcea

Projects

Research and Development: Learning Quantum Mechanics

Quantum Mechanics is probably the most important development of physics in the twentieth century. Yet it is inaccessible to most people. Through research and development the Visual Quantum Mechanics Project is exploring new ways for learning quantum physics.

The project staff conducts research on student learning of quantum physics and develops materials based upon research. The instructional units integrate interactive computer programs and digital multimedia with inexpensive materials and written documents in an activity-based environment.

This research and development effort has received widespread recognition, including awards for educational software. It continues with primary emphasis on college science and engineering students so that these students will be able to obtain both a conceptual and mathematical understanding of contemporary physics.

The VQM materials:

Emphasize active learning, utilize visualization techniques as an aid to learning, Are based on recent research in teaching and learning, Have components for non-science and science/engineering students, Include materials for biological science students, Integrate the learning of quantum physics into the physics curriculum, Apply a learning strategy in which students actively construct knowledge, and Illustrate how quantum principles are applied to everyday devices.

Funded by the National Science Foundation with additional funding from the Howard Hughes Medical Institute and the Eisenhower Professional Development program.

Integrating Education and Research

Kansas State University recently received on of 10 awards from the National Science Foundation for having developed programs that integrate university-level scientific research with classroom education. The focus of this program is to help university science faculty integrate state-of-the-art research and technology with K-12 pre-service teacher education and in-service teacher professional development. Courses and materials developed will provide opportunities to improve knowledge of science concepts and assist in developing ideas for extending the latest in hands-on science into classrooms. The development is driven by research on student learning and on student attitudes toward science. Some of this research is completed as part of the project. Included in both the research and development efforts is the use of contemporary instructional technologies. This component builds on the KSU Groups successful work with interactive video, large databases and visualization. By working with teachers and students we will investigate the learning process with a variety of active learning systems including the World Wide Web. This work is interdisciplinary and can include topics from any area of science or engineering. Our primary goal is to continue getting research ideas to in-service and pre-service teachers through hands-on activities and to expand and include similar activities in some of the general education courses

Funded by the National Science Foundation

International Bicycle Project

The international Bicycle Project is a multicultural, interdisciplinary, project involving U.S. universities and European communities. Students from the U.S. spend one semester studying in Europe and European students come to the U.S. to study cultural and scientific aspects of the bicycle.

Funded by Fund for the Improvement of Secondary Education and the European Commission

History of Physics Education Research and Development

Kansas State University has one of the oldest active physics education research programs in the US. The first student to complete a graduate degree in this program was Jacqueline D. Spears. Her Masters degree was awarded in 1972 and her thesis work "Students attitudes toward science and society" appeared in *American Journal of Physics* in 1975.

In 1971 the KSU Physics Department took the pioneering step of advertising for and then hiring an Assistant Professor whose scholarly activities were to be research and development in physics education. Dr. Dean Zollman was selected and was appointed to a tenure-track position in the summer of 1972. Shortly after joining the faculty Dr. Zollman attended the Film Loop Instructional Course (FLIC) which was directed by Dr. Robert Fuller at the University of Nebraska. The participation in that summer course began a long-term collaboration between Dr. Fuller and Dr. Zollman. This collaboration has focused on research and development related to the application of contemporary technology -- from Super 8mm film loops in 1972 to Internet video in 1998 -- in the learning and teaching of physics.

During the early years of the physics education program at K-State the focus was on learning and teaching in the instructional laboratory. In addition to developing and evaluating methods of teaching in the lab, Dr. Zollman and collaborators completed research on student learning. An early paper, which appeared in the *Journal of Research in Science Teaching* in 1977, investigated the influence of the level of structure in lab experiments on the students' understanding of the scientific process. Examples of other early work includes the development and assessment of a Teaching Assistant Orientation Program which was based on research in learning and intellectual development and instructional materials for visually impaired students.

In 1978 efforts were begun to address the needs of teachers. Prof. Zollman developed at physics course that was based on the Learning Cycle and that could accommodate a large number of students in one section. That course, which continues to be offered today, has been the subject of research on student learning.

At about the same time Professors Fuller and Zollman began exploring the use of interactive video, a new technology which was not yet on the commercial market. This collaboration resulted in the first commercially available science videodisc, *the Puzzle of the Tacoma Narrows Bridge*, which remains in print today. The instructional strategy implemented in this videodisc was based on research into students' intellectual development. The disc has also been used in several studies of the value of interactive video in learning physics.

In the mid-1980s the Physics Education group expanded when Tom Manney, Professor of Physics and Biology, became an active member. Dr. Manney's primary interests are to transfer recent research results in genetics and biophysics to the secondary and college classrooms. He has used his own research on genetics as a starting point to introduce teachers to the research and then have them involve their students in similar efforts. The result has been the Genetics Education NEtwork (GENE Project) which has developed interdisciplinary teaching-learning materials and completed research on that teaching and learning.

Dr. Manney has recently retired, but the GENE Project continues to be active through the Web based materials, distribution of instructional materials by Carolina Biological and the efforts of the secondary and college teachers who have been part of the program.

Another effort which expanded in the late 1980s was development and research related to both pre-service and in-service teacher education. Dr. Manney and Dr. Zollman taught a course on modern physics for future teachers which became the basis for the Visual Quantum Mechanics project. They also worked with faculty in the KSU College of Education on a model program of research and development for the education of elementary teachers who would become science specialists.

In recent years the research and development has concentrated on using technology and other instruction materials to bring contemporary ideas into the physics classroom and to make those ideas accessible to students without significant mathematics or physics background. The GENE and the Visual Quantum Mechanics Projects have been the major efforts. These projects both investigate student learning and develop new materials. They were a major factor in KSU receiving, in 1997, an NSF Recognition Award for Integrating Research and Education.

Ph.D.s and Post-docs from KSU

Larry Escalada (Lawrence.Escalada@uni.edu) Ph.D. 1996 now Assistant Prof. of Physics University of Northern Iowa.

Teresa Hein (thein@american.edu) Ph.D. 1996 now Assistant Prof. of Physics, American University

Heidi Gruner (GrunerH.dfp@usafa.af.mil) Ph.D. 1996 now Assistant Prof. of Physics, US Air Force Academy

Sanjay Rebello (srebello@MAIL.CLARION.EDU) post-doc, 1995-98 now Assistant Prof. of Physics Clarion University

Robert Grabhorn, post-doc 1994-95, now in private industry

Jaafar Jantan (jjnita@ksmk.itm.edu.my) Ph.D. 1992 now Prof. of Physics Malaysian Institute of Technology

Raj Chaudhury (schaudhury@vger.nsu.edu) post-doc 1992-94 now Assistant Prof. of Physics Norfolk State University.

MSU ASTRONOMY & PHYSICS EDUCATION

Faculty

- **Jeff Adams:** Collaborative Learning, Gender Equity, Astronomy conceptual Assessment, Project Evaluation
- **Greg Francis:** Physics by Inquiry, FCI Investigations, Teacher-Enhancement, Peer Instruction Training
- **Larry Kirkpatrick:** AAPT Officer, Theory into Practice, Textbook Author, Graduate Student Training
- **Tim Slater:** K-16 Astronomy Curriculum development, NASA EP/O Planning, Student Assessment
- **George Tuthill:** Teacher-Enhancement via Internet-based Distance Learning Strategies (NTEN)

Visiting Faculty

- **Peng Jiehua:** World Bank Scholar, Shaoyong, China
- **Rebecca Lindell-Adrian:** Ph.D. Candidate, University of Nebraska-Lincoln

Graduate Students

- **Larry Watson:** Inquiry-based Computer Based Labs
- **Meredith Wills:** Collaborative Learning Group Dynamics
- **Tom Brown, Jeff Crowder, Melissa Wright:** first year students

Undergraduate Students

- **Elizabeth Noonan:** Longitudinal Study of FCI Gains
- **Chija Skala:** Gender Equity Focus Group Analysis (Visiting from Bethany College, Lindsborg, KS)

http://www.montana.edu/~wwwph/research/phys_ed.html

Greg Francis—Montana State University

It is my privilege to present to you the astronomy and physics education group at Montana State University. This is comprised of five professors, two visiting faculty, five graduate students and two undergraduates. I want to make the point that the state of Montana has more people working on physics education, per capita, than any other state in the union! We are trying to use careful and rigorous assessment to drive curriculum development, curriculum revision. I'm sure that doesn't make us unique in any sense of the word. If there's one phrase that defines what we think is happening at Montana State, it would be, "Theory into practice."

Now let me tell you first about our astronomy education program. It has three prongs. First, activity based collaborative group learning is being investigated. That's not new, but we're looking at it in the large lecture setting—taking a class of 200 and having them pair up into small groups to work on activities instead of listening to a lecture. There's a need within the astronomy education community for valid and reliable assessment instruments based on research—something similar to the FCI. We are part of a national collaboration that is beginning that process. As this process develops it will inform what is going on in collaborative group learning and in large lecture settings. Lastly, our department has a very active research program in astronomy and solar physics and we are involved with a lot of educational outreach projects that are associated with those grants—trying to bring cutting edge research into a K-12 classroom when appropriate and finding a form that is educational.

The group is also involved in teacher preparation and I'd just like to say that we have tried to use an inquiry based teaching strategy modeled after what is happening at the University of Washington. I'm very much influenced by my experience there and feel that what's happening there needs to happen other places, so we've set up and run a lab based course for elementary school teachers that uses Physics by Inquiry. We also use the Tutorials in Introductory Physics in the intro class that services the pre-service high school teachers.

Montana State also has a rich history of experimentation with distance learning. We now have about 80 high school teachers who are taking classes through computer delivery, through the NTEN project and the ... project. As an example of what we mean by theory into practice, let me just briefly mention a project going on. One of our grad students, Larry Watson, is writing a lab manual this summer. That's not the first time that's ever happened. He's writing a lab manual that tries to incorporate inquiry learning and the new computer interfaces that we've just acquired, and certainly that is not the first time that that has ever happened. But, Larry is trying to essentially reinvent the wheel, if I could borrow the phrase, and not a flat tire and he's trying to do this within the constraints that are imposed on him. Namely, the students that we have at Montana State and the constraints that are imposed by our engineering and physics faculty, what they feel the outcome should be to such a lab course.

Physics Education Research and Development Group
North Carolina State University

People

Physics education has long had generous Departmental and University support at NC State. A large group of faculty, staff, and graduate students promote discussion of PER issues and internal review of projects. Faculty and interested associates include:

Assoc. Prof. Robert Beichner (Group Director, SCALE-UP Director)

Prof. John Risley (Editor of Physics Academic Software & WebAssign Director)

Peg Gjertsen (Asst. Editor of Physics Academic Software, Staff Assistant)

Prof. Karen Johnston (past-president of AAPT)

Prof. David Haase (Director of NC Science House Outreach Program)

Assoc. Prof. George Parker (Coordinator of Engineering Physics Courses)

Visiting Prof. Larry Martin (WebAssign author)

Visiting Prof. John Hubisz (Co-founder of NC section of AAPT)

Elizabeth Rieg (Manager of Physics Tutorial Center)

Adjunct Prof. Ray Serway (textbook author)

Adjunct Assoc. Prof. John Park (Liaison with College of Education & Psychology)

Post-doc Scott Bonham (Evaluation of WebAssign project, Physlet design)

Post-doc Jeff Saul (Evaluation of SCALE-UP project)

Two MS degrees had been awarded prior to 1992 when Beichner was hired to establish a full-fledged PER graduate program. By the time he received tenure in 1998, two more MS students and two PhD students had graduated. Current graduate students include Melissa Dancy, Duane Deardorff, David Abbott, Rhett Allain, and Willyetta Brown. Over the years the group has hosted a large number of national and international sabbatical visitors, including Mike Sobko, Binghua Zhang, Al Exton, Bill Wharton, Jay Kopp, Zena Paulli, John Gastineau and Lady Wilkinson.

Projects

- **SCALE-UP**
  Curriculum development and testing
  Classroom design and management
- **WebAssign**
  Deliver / grading of textbook and multimedia focused problems
  In-class questioning
  Research tool
- **Physics for Scientists and Engineers**
  …(Gently) incorporating PER into mainstream textbook
  Active Learning:
  QuickLabs, Quick Quizzes, Technology Support (IP, CD, Web Site)
  Constructivism: Concept first, then name
  Problem Solving: GOAL Protocol

- **Assessment Instruments**
  TUG-K
  DIRECT
  Lab Skills – Measurement and Errors
  Ray Optics
- **Instructional Software**
  Physics Academic Software
  SAS Physics Toolbox: VBL / MBL Input+Math Modeling+Simulator+Graphing
- **CD-ROM Projects**
  Interactive Journey Through Physics (Prentice-Hall)
  Physics: The Core (Saunders)
  World Book Encyclopedia
  Fundamentals of Physics (Wiley)
- **Assistance for Teachers**
  CourseWare Communicator
  Model Classroom Design
  Generic Grant Proposal

Some of the main thrusts of the NCSU PER group are research-based reform of physics instruction, the use of technology in physics instruction, and the development of valid and reliable instruments for assessing student understanding of physics concepts. The Student Centered Activities for Large Enrollment University Physics (SCALE-UP) Project seeks to establish a highly collaborative, hands-on, computer-rich, interactive learning environment in large-enrollment physics courses. This project grew out of a highly successful four-year pilot called the Integrated Math, Physics, Engineering, and Chemistry (IMPEC) project. Several classrooms have been remodeled as we explore the impact of differing layouts. A new room is being built and will be ready for use in the fall of 1999. We are also providing input to the designers of a new Physical Sciences Instructional Building.

We are working closely with publishers in several other reform-oriented efforts. Serway and Beichner are incorporating PER findings into the fifth edition of a popular engineering physics text. Beichner also co-authored two books for pre-service elementary teachers, one on teaching science and another on technology use. Risley and Beichner co-authored two CD-ROMs that take advantage of the multimedia capabilities of today's computers to present physics content. Beichner also created *VideoGraph* and established the educational efficacy of the now-widespread video-based lab pedagogical technique.

The popular WebAssign system originated with the group and in addition to delivering homework problems to thousands of students around the country, provides a platform for educational research, both for general student use and in the use of multimedia problems. Many publishers are collaborating with us to provide a means of delivering their textbook problems to students over the Internet. Besides materials for use with WebAssign, group members have also developed two web-based physics courses.

Close interaction with Physics Academic Software has led to many opportunities for consulting with software authors. Teacher usage of instructional technology has long been a focus, both as a topic of investigation, and as an outreach through many different workshops and summer institutes offered by the Science House and at AAPT meetings. The *CourseWare Communicator*, published by the Physics Courseware Evaluation Project, continues to be a valued resource for high school and college teachers.

Members of the group have produced the Test of Understanding Graphs-Kinematics (TUG-K) and the DIRECT electrical circuits test. Tests of ray optics concepts and student understanding of measurement and errors are currently under development.

Invitation

Through the combination of educational research with the development of new curricula, “mainstream” texts, and CDs, along with the creation of tools for assessing learning, we hope that the efforts of the NC State Physics Education Research and Development Group further the reform of physics instruction. If you would like to learn more about the work we do, please visit our website at *www.ncsu.edu/PER* or arrange for a “non-virtual” visit by e-mailing us at *Beichner@NCSU.edu*.

Ph.D.s awarded

Paula V. Engelhardt, under advisement 1993-97, defended dissertation May 1997, "Examining students' understanding of direct current electrical circuits through multiple choice testing and interviews." Now in Japan.

Aaron P. Titus, under advisement 1994-1998, defended dissertation July 1998, "Effectiveness of web-based delivery of animations and videos." Now Assistant Professor of Physics, North Carolina Agricultural and Technical University

Projects We Are Now Doing presentation:

Bob Beichner—North Carolina State University

A bunch of different projects are going on. The major time spent, I think, is on the SCALE-UP project—student centered activities for large enrollment university physics—and the idea is to take all these things we know work well and try to find ways to make them work well in a large classroom setting. Classroom management issues are important. Classroom design issues are important. You were in a prototype of the SCALE-UP classroom downstairs, only the table would be six feet in diameter instead of five, and we’ll have nine students sitting around a table, but the basic idea is to promote interactions in a setting like that.

The WebAssign project. We are able to use the web to deliver all kinds of different problems. We’ve got I think three quarters of the problems from Halliday, Resnick and Walker in there; multi-media focused problems that Aaron Titus just finished working up, where java applets or perhaps a video or something like that can be delivered, and the problems can be randomized. The nice thing about all this is you can collect all this data and you end up with mounds and mounds of data. Scott Bonham is in the process of trying to figure out what sense we can make of all that. One of the advantages is that you have the entire class, and this is part of their regular work. You're not taking them out of class, so some of those issues of real world settings are addressed nicely with WebAssign as a research tool.

I've been working with Ray Serway to try to modify the next edition of his textbook, which is eating up a ton of my time. The key word here is gently. Publishers are very reticent to make changes in a textbook that has sold as well as his book has, so I'm trying to find ways to do that without upsetting the applecart. I'm trying to incorporate active learning, as much as one can in a textbook, which is a tricky thing to do. One of the things that I like, that I had to argue about just recently to get incorporated, is what I call the "GOAL protocol". It's based on standard ways of solving problems but just put in a mnemonic form. "G" is Gather information that you will use, gather is where you read the problem for key phrases and try to apply your own understanding of the situation. Guess an answer. "O" is Organize free body diagram sketches, that sort of thing. "A" is Analyze, which is where students always want to start, and then "L" is learn from your efforts. Go back and see if your original estimates were correct. Are there interesting dependencies on an angle or something like that? Why was this problem even assigned? We assume students think of that, but they never do unless we sort of coerce them into it.

We're working on assessment instruments. We've done a couple. We are working on more, and the most recent one is the one on lab skills that Duane Deardorff is working on in terms of student understanding in measurement and error.

We're probably best known for some of the things that John Risley has been doing with instruction software, with Physics Academic Software. We are negotiating with the SAS Institute, which is a NC state offshoot, to see if we can come up with a piece of software that's a sort of universal tool for physics. Video based labs or microcomputer based lab equipment at one end, graphical output at the other end and in between our mathematical and modeling tools and simulations that all tie together in some unified fashion.

We've been working on lots of CD-ROM projects for different publishers and have tried to influence those in some way.

We've been trying to help teachers as much as we can by publishing reviews of software and hardware. We've got a model classroom design for the high school level that quite a few people have taken a look at, and—sort of a spur of the moment thing that turned out to be very useful—the Generic Grant Proposal that we made for high schools. It is a Word document. It is basically an outline of what research has shown works, and they can then plug their specific details into the outline and give the result to the school board or to the administration or whoever it happens to be. It turns out to be fairly successful at facilitating finding funds. I think one of the key features of all this is there are lots of different things going on, but they all interrelate. The research and the development connect all these different projects together. That's one of the things we'll probably be talking about more as our discussion goes on later.

The Ohio State University Physics Education Research Group
Research and Curriculum development Projects 8/98

Qualitative Research: In these projects, we attempt to understand student thinking using think-aloud verbal reports as they complete a task. This leads to the development of interactive demonstrations and simulations to help students build images and intuitive visual models of the concepts involved. Project topics include students' conceptions of:

- Work-energy processes with internal energy changes
- Electromagnetic induction
- Quantization and photons

Problem Solving Research and Development: The objectives of these studies are to develop students' abilities to use the symbolic language of physics with understanding and to develop the workplace skills needed to more effectively analyze complex problems of the real world. Project topics include:

- Use of multiple representations in solving problems related to work-energy processes and magnetic induction
- Development of more complex experiment problems that involve planning and design
- Role of math in the analysis of complex problems
- Use of Maple in problem solving

Research and Curriculum Development for Student Laboratories: How can we use the laboratories to help students learn to learn, learn to use the concepts of physics to model and make predictions about the real world, and develop the skills needed for the twenty-first century workplace? Projects include:

- Toys in Motion labs that involve student design of experiments and problem solutions
- Development of Experiment Problems, including research about student thinking when solving experiments involving internal energy and electromagnetic induction
- Concept construction guided inquiry labs

Large Reform Efforts: The above activities are helping to produce more effective learning systems in several courses:

- The introductory calculus-based physics course for engineers (honors and regular)
- The second-year course for physics majors
- A general education course called *The World of Energy*

Evaluation: Several new evaluation tools are being developed, including:

- A web-based Outcome Driven Assessment tool
- Tests that assess students' knowledge and skills with: multipart problems, work-energy processes, electromagnetic induction, and electricity and magnetism (CSEM)

Ph.D.: Cheng-Chih Chien, June 1997 (Ph.D. in Education), "The Effectiveness of Interactive Computer Simulations on College Engineering Student Conceptual Understanding and Problem Solving Ability Related to Circular Motion", presently an assistant professor in the Department of Educational Technology, Tamkang University, Tamsui, Taiwan.

Physics Education
Research and Development at Rensselaer

Department of Physics
Rensselaer Polytechnic Institute
Troy, New York 12115

Interactive learning and effective use of technology in the classroom are the focal points of most of the Physics Education research and development projects currently underway at Rensselaer. The "studio" model of physics instruction used for our introductory courses is at the center of many of the projects currently underway.

Current research:

- Identification of critical aspects of effective interactive curricular materials.
- Effective use of Multi-media simulations in introductory physics classrooms.
- Impact of web-based assessment system use in large classes.
- Comparisons between, and evaluation of, conceptual learning assessment tools.
- Rigorous assessment of all aspects of the Studio Physics course currently in place at Rensselaer.
- Effective use of distance learning methodologies in dissemination of physics education research based curricular materials.

Current curriculum development projects:

- Development of short courses in contemporary physics topics for use in professional development of K-12 teachers.
- New materials for use in the Studio Physics courses. These materials are soundly based on the findings of physics education research and incorporate techniques shown to be effective elsewhere.
- Multi-media simulations and supporting curricular materials for use in introductory physics, engineering and mathematics courses.

Rensselaer's strong educational physics program is enriched by the participation of all the faculty through the teaching program. Many of the faculty involved in other research areas participate in specific projects, often in collaboration with the educational physics group. Below is a list of those who presently play an active role in educational developments.

- Karen Cummings, Edward G Hamilton Clinical Assistant Professor of Physics. 518-276-8077. E-mail: Karen@rpi.edu
- Philip Casabella, Assoc. Chair and Professor of Physics. 518-276-6455
- Michael Malak, Post-Doctoral Research Associate, Mathematical Sciences and Anderson Center for Innovation in Undergraduate Education
- Kongki Min, Professor of Physics, 518-276-6520
- James Napolitano, Asst. Chair, Professor of Physics, 518-276-8019
- Wayne Roberge, Professor of Physics, 518-276-6454
- Jack Wilson, Acting Provost, Professor of Physics, 518-276-4853

Karen Cummings—Rensselaer Polytechnic Institute

Rensselaer Polytechnic Institute is a medium-sized engineering school in upstate New York. We have a program underway for introductory physics instruction which is called “Studio Physics”. Through this course we have taken our large lecture-based class, broken it into smaller classes, and integrated lecture and laboratory into two two-hour class periods per week. We are fortunate enough to have computers in our classrooms, at which students work together in groups of two or three. However, while it is good that we have the students work together in groups, I want to point out that students have traditionally worked together on laboratory activities. It doesn’t seem that this alone is enough to improve the course. The lecture component has also been minimized. So I like the way the course is organized. I have a graduate student in the classroom with me. All of the professors have both a graduate T.A. and an undergraduate T.A. to assist them in the classroom.

However, if you look carefully at this picture of students at work in a Studio Physics course, you may spot something strange. See what these students are doing? They’re doing a totally traditional lab in a technology-rich classroom. This lab exercise is not interfaced to the computer at all. We have the students take the data and then type it into an Excel spreadsheet and analyze it. Many of our activities are very traditional and to borrow a phrase, I think we may have reinvented the flat tire to some extent. I want to point out though that this course is still a wheel, it’s simply a wheel with a flat tire. It’s not like it is a square wheel or anything.

So, in comparison to many people in this room who have research driving their curriculum development efforts, the situation we are in is more like our curriculum development needs are driving our research interests. I feel that the need to make modifications to the curriculum in the Studio Physics program currently in place at Rensselaer is so great that I must look to the physics education community for advice about where to head. Really, most of the work that we do at RPI right now is curriculum development, but sometimes in the course of doing this curriculum development we do actually end up getting some research done. The projects we have worked on during this past year are related to validating the effectiveness of curricular materials developed elsewhere and investigating the feasibility of integrating them into the Studio Physics course at Rensselaer. We have also been working on making comparisons between different diagnostic tools. So, we’ll have poster on a comparison between the Force Concept Inventory and the Force and Motion Conceptual Evaluation. I’ll also give a talk on our attempts to implement interactive lecture demonstrations and cooperative group problem solving in a couple of our Studio Physics sections. The implementation of both of these techniques was quite successful.

Projects and History

Rensselaer Polytechnic Institute has a long history of contribution to the field of physics education. For example, an enormous number of students have received training in introductory physics courses using Robert Resnick's textbook (with Halliday and now Walker), "Fundamentals of Physics". More recently, Jack Wilson pioneered the use of the "Studio" model of Physics instruction at Rensselaer. Studio courses are an attempt to incorporate the findings of modern physics education research into a student-centered course that is not only effective, but also efficient enough to allow sustainable use with a large student population at a research oriented institution. The Studio Physics courses at Rensselaer are the focus of our current physics education research and curriculum development efforts. We are in the process of doing a careful assessment of the strengths and weaknesses of the studio program and are investigating the feasibility of integrating research-based activities, which have been proven to be effective elsewhere, into Studio Physics at Rensselaer. Conceptual learning gains have been measured using both the Force Concept Inventory (FCI) and the Force and Motion Conceptual Evaluation (FMCE). Having assessed the same student population (with N>800 students) with both of these tests has allowed us to begin to study exactly what each of these instruments measures, and to investigate their similarities and differences.

Currently all Rensselaer students (approximately 1000 students per year) take Physics I and Physics II in the studio format. Use of CUPLE software, which was a fundamental part of the early Studio Physics courses at Rensselaer, is being phased out. However, many characteristics of Jack Wilson's original studio model persist. Presently, the defining characteristics of Studio Physics at Rensselaer are integrated lecture/laboratory sessions, small classes of 30 to 45 students, extensive use of computers in the classroom, collaborative group work, a high level of faculty-student interaction and a significantly reduced emphasis on lecturing. Studio classes meet twice a week for sessions lasting 110 minutes each. Hence, we have reduced the number of contact hours-from 6.4 hours per week to less than 4 hours- without significantly reducing course content. Initial measurements of conceptual learning gains in Studio Physics were disappointing. In 1995, Marie Cooper used the FCI to assess learning in the course and found $\langle g \rangle$* to be 0.22. In the spring 1998 semester, we found $\langle g \rangle = 0.19 \pm 0.11$. This indicates that Studio Physics has been no more effective than traditionally structured courses at teaching basic Newtonian concepts. Additionally, costs associated with Studio Physics seem to be higher than expected (up to 50% higher than traditional instruction). The additional expense appears to be predominately the result of average class sizes that are substantially smaller than anticipated. We are currently working toward correcting both of these shortcomings.

The goal of our current investigations is to determine if incorporation of researched-based student activities into studio physics will have a significant effect on conceptual learning gains. In the process of pursing this goal, we have verified the effectiveness of Interactive Lecture Demonstrations ($\langle g_{FCI} \rangle = 0.35 \pm 0.06$ and $\langle g_{FMCE} \rangle = 0.46 \pm 0.05$) and Cooperative Group Problem Solving ($\langle g_{FCI} \rangle = 0.36$ and $\langle g_{FMCE} \rangle = 0.35$). The data we have collected on the two diagnostic exams used indicates a high degree of correlation between FCI and FMCE scores (correlation coefficient = 0.80). This correlation was the same in pre-instruction testing data and post-instruction testing data. Furthermore, the correlation in FCI and FMCE scores is maintained across several different instructional strategies investigated. However, the average gain (and average normalized gain) on the two exams were often quite different from one another, even when measured for a given student population and instructional technique. As expected, the gains on these exams vary significantly with pedagogical approach.

*$\langle g \rangle$ = (Post-test % Correct – Pre-test % Correct) / (100 – Pre-test % Correct)

Ph.D.s Awarded

Jeffry D. Marx, Ph.D. 1998, current address: Dept of Physics, University of Oregon, Eugene, Oregon

Michael Mallack, Ph.D. 1998, current address: Anderson Center of Innovation in Undergraduate Education, Rensselaer Polytechnic Institute, Troy, New York 12180

San Diego State University/University of California at San Diego

Areas of interest:

- Studying learning from multiple perspectives in a computer-rich collaborative learning environment
- Development of innovative computer software to promote physics learning
- Development of innovative physics courses for middle school and high school.

Senior Professor: Fred Goldberg

Graduate Students: Andy Johnson, Valerie Otero

Contact: fgoldberg@sciences.sdsu.edu
CRMSE
6475 Alvarado Road, Suite 206
San Diego, CA 92120
619-594-5090
http://public.sdsu.edu/CRMSE/jointdoctoral.html

University of California, Berkeley
Graduate Group in Science and Mathematics Education (SESAME)

(description from http://www-gse.berkeley.edu/program/SESAME/sesame.html)

The Graduate Group in Science and Mathematics Education is an interdisciplinary academic unit dedicated to advancing the understanding and practice of learning and teaching in science and mathematics. It acts in most respects like a regular department, carrying out research, teaching courses, and offering a graduate program leading to a Ph.D. degree in science or mathematics education. The faculty of the group consists of professors from several of the Berkeley science and engineering departments and the School of Education, and instructors associated with other units on campus such as the Lawrence Hall of Science. The group operates under the auspices of the Graduate Division.

SESAME is closely related to the EMST program and shares many courses with EMST. A major difference in the programs is that SESAME students are expected to obtain at least master's-level competency in their mathematical or scientific disciplines. SESAME Ph.D.'s have frequently taken positions in college science departments, teaching courses in the discipline but serving as the "education person" in the department and doing research on the teaching and learning of the subject matter. Through the years SESAME students have also focused on learning in informal settings and have gone on to careers in institutions such as museums and science centers.

Faculty: M. Alice Agogino, Marian Diamond, Andrea diSessa, Rogers Hall, Marcia Linn, Carolyn Merchant, Michael Ranney, Kenneth Sauer, Alan Schoenfeld, Glenn Seaborg, Angelica M. Stacy, Glenys Thomson, Barbara White

Affiliated Members: Michael Clancy, Herbert Thier.

SESAME Ph.D.s with Physics Education Dissertations

Brunschwig, Fernand, 1972, Experiments that walk: four self-study units with portable kits for introductory physics, Univ. of California, Berkeley, Karplus, SESAME

Theil, Edward Hiram, 1972, Structure and strategy: the development of a course in mathematical physics, Univ. of California, Berkeley, Karplus, SESAME.

Larkin, Jill Huston, 1975, Understanding relations in physics : a model and teaching materials for the development of a learning skill, Univ. of California, Berkeley, Reif, SESAME. Now at Carnegie Mellon University.

Kurtz, Barry Lloyd, 1976, A study of teaching for proportional reasoning, Univ. of California, Berkeley, Karplus, SESAME.

St. John, Harry Mark, 1978, Thinking like a physicist : new goals and methods for the introductory laboratory, Univ. of California, Berkeley, Reif, SESAME. Now at Inverness Research Associates.

Eylon, Bat-Sheva, 1979, Effects of knowledge organization on task performance , Univ. of California, Berkeley, Reif, SESAME.

Harvey, Wayne, 1981, Sucess and failure in problem solving : an investigation of mental processing , Univ. of California, Berkeley, Reif, SESAME.

Tourniaire, Françoise, 1984, Proportional reasoning in grades three, four, and five, Univ. of California, Berkeley, Karplus(?), SESAME.

Erickson, Timothy Eric, 1987, Sex differences in student attitudes towards computers , Univ. of California, Berkeley, Stage, SESAME.

Songer, Nancy Butler, 1989, Promoting integration of instructed and natural world knowledge in thermodynamics, Univ. of California, Berkeley, Reif, SESAME.

Hammer, David Morris, 1991, Defying common sense : epistemological beliefs in an introductory physics course, Univ. of California, Berkeley, DiSessa, SESAME. Now at the University of Maryland.

Lewis, Eileen Lob, 1991, The process of scientific knowledge acquisition among middle school students learning thermodynamics, Univ. of California, Berkeley, Reif, SESAME.

Allen, Sue, 1994, Transparent detector models : promoting conceptual change in geometrical optics, Univ. of California, Berkeley, DiSessa, SESAME.

Sherin, Bruce Lawrence, 1996, The symbolic basis of physical intuition : a study of two symbol systems in physics , Univ. of California, Berkeley, DiSessa, SESAME.

LABORATORY FOR RESEARCH IN PHYSICS EDUCATION (L.R.P.E.)

University of Maine
Department of Physics and Astronomy

Brief History:

The Laboratory for Research in Physics Education was established in January of 1995 at the University of Maine to support research on the teaching and learning of physics and physical science. The research currently being conducted by members of LRPE is motivated by the need to develop more effective instructional strategies for teaching physics and physical science. Although certain aspects of these strategies must be informed by general theories of learning, we strongly believe that physicists must use their expertise to conduct research that focuses on the details of applying those theories to the teaching of specific topics. The results of this research can then be used by teachers, education researchers and curriculum developers to improve instruction.

Integration of Instruction, Curriculum Development and Research:

Instructional goals for the materials under development are motivated, and continually revised, based on three important considerations: (1) the underlying conceptual framework of the target concepts or topic ("content"), (2) students conceptual and reasoning difficulties specific to their understanding of these concepts, and (3) the results from systematic classroom-based research where instructional strategies[1] are developed to assist students in developing a more sophisticated and rigorous understanding of the ideas being taught. As a result, a key component of this research must be performed in classroom environments where student responses and interactions are recorded and analyzed.

To achieve these instructional goals, members of LRPE are engaged in several long-term research projects. Our current work is focused on helping students to develop an understanding of the underlying structure of matter through macroscopic observations. Students involved in these studies come from a wide range of backgrounds and grade levels including graduate students, undergraduate physics majors, college students (both science and non-science majors), pre-service and in-service teachers, and K-12 students. Aspects of this work include research on student understanding of electric charge, magnetism, atoms, radiation and radioactivity. Our primary instructional strategy is *directed inquiry* and we make extensive use of the tutorial approach to teaching first developed at the University of Washington.[2]

<u>*L.R.P.E. (University of Maine)*</u>
1995-1999

<u>*Faculty*</u>
Randal Harrington (Assistant Professor)
David Clark (Lecturer)

<u>*Graduate Students*</u>
Edward Prather
Gregory Kremer
Marilyn Funk
Steve Kaback

<u>*Undergraduate Students*</u>
Dave De Isles
Alison Manowski
Matthew Bennage

<u>*In-Service Teachers*</u>
Andrew Paradis
Pam Keef
Stephanie Wheaton

<u>*For more information contact:*</u>
Dr. Randal Harrington
Department of Physics and Astronomy
5709 Bennett Hall
Orono, ME 04469

207-581-1237 (voice)
207-581-3410 (fax)
randal@maine.edu
http://LRPE.umephy.maine.edu

Current Courses:

Members of LRPE are currently involved in teaching and reforming a descriptive physics course for non-science majors, the algebra-based introductory physics course and a special course for pre-service elementary and middle school teachers based on Physics by Inquiry.[3] We also teach a weekly seminar to prepare teaching assistants and a physics education seminar for pre-service high school physics teachers who work as peer instructors during tutorial and laboratory sessions. In addition we have developed and tested several middle school science units in cooperation with local teachers.

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[1] By 'instructional strategies' we mean all aspects of instruction including course structure, tutorials, laboratory experiments, computer programs, homework, student designed projects, etc.
[2] L.C. McDermott, P.S. Shaffer, and the Physics Education Group at the University of Washington, *Tutorials in Introductory Physics*, Prentice Hall, Upper Saddle River, NJ, 1998.
[3] L.C. McDermott, and the Physics Education Group at the University of Washington, *Physics by Inquiry*, Vols. I and II, John Wiley & Sons, Inc., New York, N.Y., 1996.

Rand Harrington—University of Maine

Rather than telling specifics about some of our projects, I wanted to give you an overall framework for how we conduct our research and what sort of things we do or how we go about it. Three over-riding things motivated our instructional goals for the materials we develop. The first thing is the historical and sort of intellectual underpinnings of the topic—looking really carefully at the deep conceptual issues of the topic at hand before we get involved in our work. Some of those things, or many of those things, we didn't learn in our undergraduate or even graduate education so it takes really going back and thinking carefully about the topic. We're also motivated by what we find from student pre-existing ideas, through interviews and written surveys, and we're informed by general theories of learning. All of these things inform our initial instructional approach, our initial set of materials that we try to develop, and then we go into the classroom and test these materials. It's both formative and summative assessment looking at post-instruction as well as what's going on with classroom observations. We do lots of video taping in the classroom and examining what students actually do with the set of materials that we've designed. We then take that information and feed it back, in iterations, hopefully converging on a reasonably effective instructional strategy after several iterations. To achieve these goals we do have several long-term projects we're involved in. Our current work is focused primarily on helping students to develop an understanding of the underlying structure of matter through macroscopic observations. The topics related to this include work we're doing on student understanding of electric charge, magnets and magnetism, radiation and radioactivity, and of course their understanding of the atom and atomic models. A lot of our work is being done in a descriptive physics course for non-science major as well as K-12, and we're involved in pre-service teacher training. We use the Physics by Inquiry materials for that course.

Physics Education Research Group (PERG)

Department of Physics
University of Maryland, College Park

The Physics Education Research Group (PERG) at the University of Maryland does research on how students understand physics. This research offers new insights into what makes physics instruction work (and not work) and provides paths for developing innovative and effective physics curricula. Physics education research helps to develop transferable teaching methods that are demonstrably effective for a much larger fraction of physics students.

Our work considers physics teaching and learning from the high school to the graduate level. Our main themes are:

- Understanding student difficulties with specific areas of physics
- Understanding student attitudes about physics learning
- Developing effective curricula to help students improve both their understanding of specific areas and of the ways they approach physics learning
- Finding ways to help teachers understand and evaluate their students more effectively.

Our current research includes the following topics:

- Student understanding of wave physics
- Student understanding of models of conductivity and semiconductor devices
- Student understanding of quantum mechanics
- Student ability to connect conceptual and mathematical knowledge
- Effectiveness of computer-based technology for concept building
- Gender and culture specificity of student attitudes about physics.

In all of these areas, we take a strong cognitive viewpoint focusing not only on what students know or do not know, but on the structure and process of how they know it.

We are currently engaged in three curriculum development projects:

- Group-learning, active engagement tutorials in introductory physics using microcomputer-based laboratories and simulations
- Materials for a new practical, device-oriented course in quantum physics
- Materials for a new course, "How to learn physics", that helps non-science students develop a better understanding of how to think about physics problems effectively.

The Maryland PERG
1998-99

Faculty
E. F. (Joe) Redish (Prof.)
David Hammer (Assoc. Prof.)
John Layman (Prof. Emeritus)

Postdoctoral Associates
Richard Steinberg
Michael Wittmann
Apriel Hodari*
Beth Hufnagel*
Andrew Elby*
(* PFSMETE)

Graduate Students
Bao Lei
Mel Sabella
Aziza Baccouche
Hadley Lawler
Rebecca Lippman

Undergraduate Students
Heather Dobbins

For more information contact

Prof. E. F. Redish
Department of Physics
University of Maryland
College Park, MD
20742-4111

redish@physics.umd.edu
301-405-6120 (voice)
301-314-9525 (fax)

Check out our web site at:
http://www.physics.umd.edu/rgroups/ripe/perg

Michael Wittmann—University of Maryland

The University of Maryland Physics Education Research Group is a relatively large group. The names on the list here are slightly different from what some of you may recognize. David Hammer has just joined our group from Tufts, while John Layman is now retired.

We are involved in a variety of projects. The basic goal of Joe Redish's part of the group is to understand student misconceptions in a variety of different areas: wave physics, mathematics and problem solving, and quantum mechanics. All of those are in some sense related to each other because some of the difficulties in waves crop up in quantum mechanics, and problem solving is a constant theme. We are involved in designing a quantum mechanics course for engineers, a project that involves activities beyond studying the student misconceptions of quantum mechanics. The work includes trying to develop curriculum materials, evaluating the curriculum materials, and developing investigative probes to see how students are approaching the material. Finally, under David Hammer, we are evaluating and understanding student expectations and attitudes of physics and how students make sense of physics. In a sense, this continues a project that Jeff Saul worked on until his recent departure as a post doc to NC State.

Let me describe some of the research areas in more detail. In general, we are trying to move beyond cataloguing the student difficulties we see. We're trying to organize these difficulties and try to come up with a theoretical framework that lets us explain student difficulties in more detail. We use the ideas of mental models, which comes out of cognitive studies, and try to describe difficulties in terms of the patterns and analogies that students make as they have difficulties with certain ideas. So we find that students use naive mental models, but at the same time there are correct models we would like them to use. We're trying to see when and how students use multiple models at the same time. The poster describing my research begins to address this topic. In addition, we have a study going on by Mel Sabella, comparing qualitative and quantitative use of mental models and possible different mental models used in different types of reasoning. Lei Bao's poster is on building useful mental models for quantum mechanics and conductivity. Finally, as we uncover and describe some of the expectations and attitudes that students have, we are trying to see how we can affect teacher's classroom behaviors based on our understanding of the expectations and attitudes that both they and students have.

Our research helps us come to an understanding of what is needed in the classroom, which naturally leads to curriculum development. We are in the process of developing a variety of materials, mainly University of Washington-style tutorials. The ABP tutorials (Activity Based Physics) include computer based and problem solving tutorials developed in a large, multi-university project. Our new course in quantum mechanics includes tutorials and other materials. In addition, we are developing advanced homework problems that are semi-lab oriented and possibly incorporate web based tools. Finally, for the expectations and attitudes investigation, we are incorporating a new course that focuses on how to learn physics and is geared toward what one might call physics phobes. It is physics for people who have a hard time coming to an understanding of physics or don't really feel comfortable learning physics.

That's a quick overview of our research group. If you're interested in more, we have a strong web presence and would love to give out more information as needed.

History of the University of Maryland Physics Education Research Group

Physics education has been a core activity in the University of Maryland Physics Department since the early days of the Department's growth in the mid '60s. In that decade, the Department was an active participant in the Commission on College Physics. In the last half of the '70s, John Layman, a joint appointment between Physics and Education (and a former high school physics teacher), served as president of the AAPT and through AAPT workshops, introduced thousands of physics instructors to microcomputer-based laboratories with the Apple II.

In 1983, Layman and Joe Redish (who was then serving as Department Chair) put together a proposal that helped bring the AAPT to College Park. The deal included a part-time teaching appointment for Jack Wilson, the AAPT Executive Officer. The interaction between the Department and the AAPT helped further many AAPT activities including the development of an electronic database of articles from AJP and TPT and the US participation in the Physics Olympics.

A significant effect of the collaboration was the focusing of the activity of many of the Department's faculty members who were interested in using the computer in physics education into a single project - M.U.P.P.E.T. The Maryland University Project in Physics and Educational Technology involved Redish, Wilson, and 3 other members of the Physics Department's faculty, Jordan Goodman, Bill MacDonald, and Charles Misner. The project was funded at the $400 K level by FIPSE (Dept. of Education). This project led to the production of a variety of software products, many of which won awards from Computers in Physics. The most notable were The M.U.P.P.E.T. Utilities (Redish, Wilson, and Johnston, Physics Academic Software, 1994) and Spreadsheet Physics (Misner and Cooney, Addison-Wesley, 1991).

After the publication of The M.U.P.P.E.T. Utilities, Bill MacDonald and his collaborators at George Mason University, created the CUPS Project. This project brought together two dozen faculty software designers from around the world and created nine volumes of upper division physics materials and associated software published by John Wiley and Sons. The code is open and utility based - an extension of the M.U.P.P.E.T. code and philosophy. The CUPS Utilities is published by Physics Academic Software. A second project that grew out of M.U.P.P.E.T. was CUPLE (The Comprehensive Unified Physics Learning Environment, Physics Academic Software, 1995), developed by Joe Redish and Jack Wilson. This project brought together a wide variety of multi-media tools in an open environment and has since evolved into The Physics Studio at Rensselaer under Wilson's guidance.

The philosophy of the M.U.P.P.E.T. project was focused around bringing together three elements - powerful technology (including programming by students), contemporary topics in physics, and insightful pedagogy, based on what was being learned from research in cognitive science and education. These themes were summarized as "the three C's" - computer, contemporary, and cognitive. Over the period of the M.U.P.P.E.T. and CUPLE development, Redish became increasingly convinced that the intellectual heart of the education reform effort lay in understanding the pedagogy. In 1991 he began devoting his full research effort to physics education. Taking his '92-'93 sabbatical year at the University of Washington with Lillian McDermott's physics education group, he returned to Maryland in the Fall of '93 determined to build a physics education research group within the Maryland Physics Department.

In the fall of 1993, Redish was awarded an NSF grant to carry out research in student attitudes and expectations. Jeff Saul was hired as the group's first graduate student. Richard Steinberg was hired as a postdoc in 1995 and together, the three completed development of the Maryland Physics Expectations Survey (MPEX). In 1997, Redish and Steinberg won grants to study and develop materials in a junior level course in quantum mechanics for engineers. In addition, members of the group participated in the Activity Based Physics Project with Cooney, Laws, Sokoloff, Thornton, and have been involved with evaluating research-based curricula. The group's first Ph.D. degrees were granted in 1998 to Jeff Saul and Michael Wittmann. In 1999, David Hammer was hired to replace the retiring John Layman as the joint Physics/Education faculty member.

Ph.D.s Awarded

J. M. Saul, Beyond Problem Solving, Evaluating Introductory Physics Courses Through the Hidden Curriculum, Ph.D. Dissertation, University of Maryland, January 1998

Michael Wittmann, Making sense of how students come to an understanding of physics: An example from mechanical waves, Ph.D. Dissertation, University of Maryland, December 1998

Physics Education Research Group (PERG)

Department of Physics & Astronomy
University of Massachusetts–Amherst
Amherst, MA 01003–4525

Four thrusts comprise the primary focus of the University of Massachusetts Physics Education Research Group (UMPERG):

Assessing To Learn (A2L)*

This project addresses the mismatch between the goals of physics instruction and the way we assess student progress toward those goals: 1) Periodic cumulative exams that test for information and low level problem-solving skill do not directly promote a deep understanding of physics concepts, the ability to apply physics knowledge to solve problems, and an appreciation that physics is a process of inquiry; 2) Cumulative exams cannot be used by teachers to shape instruction dynamically and lead to rote learning on the part of students.

Goals of A2L Project

- To develop and evaluate innovative materials that integrate formative assessment and instruction.
- To use assessment to help students evaluate their own learning, and to help teachers tailor instruction to meet students' needs.
- To explore the use of classroom communication technologies to deploy formative assessments in the classroom so that both teachers and students can get immediate feedback and make teaching and assessment seamless.

Minds•On Physics (MOP)* (Published by Kendall/Hunt)

- MOP is a full year high school curriculum that stresses both conceptual understanding and problem solving through collaborative learning activities.
- MOP is designed to be consonant with findings from different strands of educational and cognitive research.
- MOP activities are designed to help students learn to use physics concepts to analyze and solve problems, and to curb students' proclivity toward rote learning and formula manipulation.
- MOP helps students organize their physics knowledge in ways that are efficient for recall and application.
- Teachers play role of coach in MOP.

Effective Use of Classroom Communication Systems (CCS)*

- Research on effective uses of interactive instructional approaches in large introductory courses.
- Research on the relationship between active learning strategies and students' attitudes toward learning physics.

Fundamental Research on Learning and Assessment

- Research on developing tools to model the knowledge store of physics students and experts.
- Research on the use of multiple-choice questions for probing students' knowledge, for formative assessments of conceptual understanding.

* Work supported by the National Science Foundation.

University of Massachusetts PERG
1998-1999

Faculty
William J. Gerace (Prof.)
Jose P. Mestre (Prof.)

Research Faculty
Robert J. Dufresne
Wiilliam J. Leonard

Graduate Students
Ian Beatty
Daniel Miller

Undergraduate Students
Trevor Thompson

For more information contact
Prof. Jose P. Mestre
Department of Physics & Astronomy
University of Massachusetts
Lederle Graduate Research Tower
Amherst, MA 01003-4525

mestre@phast.umass.edu

413-545-2040 (voice)
413-545-4884 (fax)

Check out our web site at http://www-perg.phast.umass.edu

Jose Mestre—University of Massachusetts

There are four of us at the University of Massachusetts. Two are tenured professors, two are research faculty, and we have two graduate students: Ian Beatty and Dan Miller. Let me tell you about four projects that are on our poster. I'll go through them quickly.

Our newest is Assessing to Learn Physics, which is a high school development and research project. We're trying to use formative assessment combined with an efficient delivery system to see if we can shape physic instruction to be more responsive to students needs. As you know, the goals of physics education—to have students learn concepts and to apply their knowledge to solve problems efficiently and so on, are not well served with the end of semester one shot test where all the student can do is get a grade. We're trying to use assessment to inform instruction as it happens. So by using a classroom communication system, I hope with some very nice items we could have the teachers, as they are teaching, assess student knowledge and use that assessment. The assessment happens immediately because they can display the results right in front of the class to everybody. They can shape their own instruction. The research issues here are, "Do teachers adapt to this? Can they use the information they got from students or do they need a lot of support? What are the things they need to make this happen?" That's our newest and we just got that funded, so it will be a four-year project.

Minds-On Physics is a curriculum development project that is three quarters of the way done. We have books already published by Kendall Hunt. This is a high school curriculum that is intended to be used in a collaborative learning setting. It is very different because the student is supposed to be learning physics by doing it in small groups. There is no textbook per se. There's just an activity book. There is a reader but the reader is supposed to be used at the end of the activity, so the students do the activity and then read a little summary at the end to kind of make everything cohesive. We've tried taking into account research on learning and misconceptions research. We're incorporating the expert-novice research that you heard about from Gregg Schraw this morning by having certain assessments and categorization which experts and novices view differently, and so on. We're also looking at knowledge organization. How do we help students organize all this knowledge that they're learning so that they can recall it efficiently and apply it to solve problems efficiently?

We're doing research on the use of classroom communication systems. Many of you know we're using ClassTalk to teach large lecture courses, and part of our past work is thinking about how you develop some questions and how you structure the classroom to make it efficient. We're now looking at what kinds of things happen better in the course taught this way as opposed to a traditional course. Part of the issue there is how you isolate variables. There are many issues such as, "Do students spend more time because they like the course better? Do students become more motivated in a certain kind of course than in another kind of course?" We're trying to tweak out as much as we can to explain the variation.

Finally, we’re looking at research on learning and assessment. In particular we’re concentrating on what multiple-choice questions tell us about students knowledge. If you give the FCI (Force Concept Inventory), how do you interpret what students say on many of these questions? We’re finding that if you phrase those questions in different way you get a lot of different results. You even get inconsistent results. You get results in which you don’t see how the student can answer one way for a question and then another way for the same question phrased in a different way a little bit later. So I’ve even looked at the way we phrase the questions and what that’s telling you.

University of Massachusetts-Amherst History
1998

The Physics Education Research Group at the University of Massachusetts-Amherst began in 1979 when Bill Gerace (a tenured professor) and Jose Mestre (a fresh Ph.D. in nuclear theory) wrote a successful proposal to the National Institute of Education (NIE) to study the role of language proficiency in problem solving among Hispanic engineering majors. From 1979-1987, Mestre was on "soft-money" funded by other successful proposals. In addition to the problem solving work with bilingual students, this period also marks the beginning of a research program investigating expert-novice differences and the nature of expertise in physics. This research focused on investigations of new methods for assessing expertise in physics and studies that demonstrated that novices exhibited expert-like behavior if constrained to solve physics problems in ways similar to those used by experts. In 1987 Mestre was appointed to a tenure-track Associate Professor position in the Department of Physics & Astronomy, and Bob Dufresne joined the group as a post-doctoral associate. The following year, Bill Leonard became a post-doc in the group as well. During the early '90s, the group applied findings from cognitive research to the development of curriculum materials that emphasized active learning. The culmination of this work is the Minds-On Physics high school curriculum, which emphasizes conceptual understanding through collaborative problem solving activities and is currently available through Kendall/Hunt Publishers. The group's most recent interests focus on the use of formative assessments for tailoring instruction to meet students' needs, and on promoting active learning in large introductory physics courses. Both of these projects employ classroom communication technologies. Currently, Gerace and Mestre are tenured Professors, and Dufresne and Leonard are Research Assistant Professors.

Physics Education Group
at the
University of Minnesota

Our main goal is to design effective instruction within the constraints of a traditional physics department. We are working to create curriculum and instruction that is informed by research, and works towards the traditional goals of introductory physics teaching: conceptual learning and problem solving.

This involves several pieces:
- curriculum development at the introductory level, and development for preservice elementary education teachers,
- future faculty preparation
- research into the meaningfulness of assessment tools
- research in students' problem solving difficulties
- research on gender issues
- research in stability of curricular changes
- and dissemination through workshops and publications.

Physics education at the University of Minnesota is a joint effort between the College of Education and the School of Physics & Astronomy:
- graduate students have the options of getting a M.S. in physics, and a Ph.D. in science education, or a M.A. in science education and a Ph.D. in physics
- coursework is taken in graduate-level physics, theories of curriculum and instruction, and qualitative and quantitative research design/analysis procedures

University of Minnesota Physics Education Group
1998-1999

Faculty
Patricia Heller
Kenneth Heller

Graduate Students
Charles Henderson
Paul Knutson
Laura McCullough

For more information, contact:

Ken Heller
148 Tate Lab of Physics
116 Church St. SE
Minneapolis, MN 55455

physed@physics.spa.umn.edu

612-625-9323

Visit our web site at:
http://www.physics.umn.edu/groups/physed

Laura McCullough—University of Minnesota

At Minnesota we're a fairly small group. There are currently four of us: Ken Heller, Pat Heller, Paul Knutson and myself. Our family is expecting. We have a post-doc opening. At Minnesota we're more interested in development than research and our main goal is institutional change to better student learning. We want to change the system so that our students are learning better, and we do a lot of development and research to get to this goal. One of the things we have been working on is curriculum development for introductory physics. We've got a poster outside on putting computers into our introductory problem solving labs, and we also work on problem labs and problem solving discussions sections. We do curriculum development for pre-service teachers. Pat Heller works with Fred Goldberg at San Diego on the CPU project. We do faculty development for our teaching assistants and professors. We have a three week course for TAs which all our incoming TAs are required to take before they can teach, so that's the development side.

In order to get to this development, we have to do a little bit of research. We take from other people and do a little of our own. Some of the research we've been working on lately is the meaningfulness of assessment tools such as problem solving assessment, how best we can test for problem solving abilities, and related to that problem solving difficulties such as the fact that students sometimes tend to lose track of the physics in their drive to get a solution. We all know the problem, they make a physics claim and then on their way to solution say, "Oops! I need an acceleration," and it doesn't matter that they said acceleration equals zero three steps ago. Now they'll say acceleration equals *g*. We're interested in gender issues. We see some gender differences in our class on the FCI, on other tests, and on grades. We're interested in why these differences exist. What can we do to help work those out? We're also interested in longitudinal stability. Are these changes that we're making stable? Can we actually make the system change or is this just kind of a Hawthorne effect, in which it's different this year so we get good grades this year but is it going to hold? Underlying this is of course assessment. We're assessing everything we do. It's a big part of what we do and it helps both with the research and development and of course institutional change.

Research in Physics Education Group

University of Nebraska-Lincoln

The work of the University of Nebraska-Lincoln Research in Physics Education Group has two main thrusts. One is to examine student reasoning and the other is to use multiple forms of media to improve the teaching and learning of physics. Multiple projects are underway in the summer of 1998 which are related to these interests.

Computer Intensive Physics Class: This is an outgrowth of a "paperless" physics class. It is an experiment in the effectiveness of a "workshop physics"-style class in which the use of paper for transferring information (homework, tests, etc.) between student and teacher is minimized and the use of computers is maximized for all phases of learning.

Introductory Physics Laboratories: Since 1993, the group has worked on incorporating interactive multimedia learning activities into UNL's introductory physics laboratories.

Color Images of Physical Phenomena CD-ROM: A slide collection of 360 images produced by Japanese physics educators in the late 1960s has been digitized and re-released as a CD-ROM by the UNL RPEG. New uses for the images are facilitated by their digital format and their organization in a database. This follows several other instructional materials development projects.

International Bicycle Exchange Project: This is an exchange program in which U.S. and European students exchange travel across the Atlantic Ocean to study the scientific and cultural aspects of the bicycle and develop multimedia materials about the bicycle.

Graduate Research Traineeship: Using Hypermedia for Knowing Physics. The current RPEG graduate students are supported by this NSF funded fellowship.

University of Nebraska-Lincoln RPEG
1998-1999

Faculty
Robert G. Fuller

Research Associate
Vicki L. Plano Clark

Graduate Students
Rebecca Lindell Adrian
Thomas C. Koch

Staff
Marilyn T. McDowell

Recent Collaborators
V. S. Rao
Steven R. Dunbar
Amy N. Spiegel

For more information, contact:

Robert G. Fuller
Department of Physics and Astronomy
314 Ferguson Hall
University of Nebraska-Lincoln
Lincoln, NE 68588-0109

rfuller@unlserve.unl.edu
(402) 472-2790

Visit our web site at:
http://physics.unl.edu/research/rpeg/rpeg.html

Robert Fuller—University of Nebraska-Lincoln

The Nebraska group benefited from the existence of Ph.D. programs in other physics departments, such as the one at the University of Washington. In 1989 the physics department voted to offer Ph.D.s in research in physics education here. We got interested in this really from two different directions. ADAPT was a Piagetian-based program for college freshmen that we had here for 22 years. So we were encouraged in this direction by Robert Karplus and his work on student reasoning. At about the same time, we got interested in single concept films in the early 1970s and then we discovered videodiscs. Dean Zollman and I made the Tacoma Narrows Bridge Collapse videodisc, and then we got interested in digital databases. These two themes have been an essential part of the program at Nebraska—media, which is now called multimedia or hypermedia, and student reasoning. The projects we do at Nebraska involve both media and student reasoning. The Ph.D. theses that have been done here are really mixed methods research in the jargon of John Creswell from this morning. We're now involved in a Bicycle Student Exchange Project. Based on a class I called Computer Intensive Physics, I have a paper in draft form called "Paperless Physics? Not Yet," which I hope to submit to the *American Journal of Physics*

University of Nebraska-Lincoln History

Summer 1998

The Research in Physics Education group (RPEG) at the University of Nebraska – Lincoln has its roots in the Film Loop Instruction Course (FLIC) of the early seventies. In 1972, tenured associate professor Robert Fuller led the first FLIC to teach physics faculty about using single concepts films to teach physics. In 1973 after the visit of Robert Karplus to the UNL campus, an interdisciplinary group of UNL faculty was formed to study the work of Jean Piaget. This group developed the ADAPT program, a multidisciplinary Piagetian-based program for college freshmen, directed by Fuller from 1975 until 1997.

During this time, Robert Fuller formed RPEG to study how to enhance college students' understanding of physics through the use of various media. Marilyn T. McDowell was hired as the RPEG and ADAPT project associate. The first two physics education graduate students (Thomas C. Campbell, 1977, and Scott M. Stevens, 1984) at UNL completed their degrees in science education with a physics emphasis. In the 1970s and 1980s, the work of the group was enhanced by a number of faculty who spent their sabbaticals at UNL.

During these years there was a strong emphasis in the group on faculty development workshops and on instructional materials development. During this time, Robert Fuller began collaborating with Dean Zollman of Kansas State University. Their collaboration resulted in many successful projects including, the 1979 production of ***The Puzzle of the Tacoma Narrows Bridge Collapse,*** videodisc, the Annenberg videodisc projects of the 1980s, the ***Physics: Cinema Classics*** project and the ***Physics InfoMall*** CD-ROM product completed in 1995. Because of his innovations, the American Association of Physics Teachers awarded Professor Robert Fuller the 1992 Milliken Award.

During the next ten years the group continued to grow. In 1988, Christopher J. Moore joined the group as a research associate. After staying a decade as project support person, Christopher recently left the group for a position in Madison, WI. In 1989 the UNL physics department voted to permit physics dissertations with research in physics education. The first two students to complete such degrees were Weijia Zhang, 1996, , and Brian Adrian, 1997. In 1993, Vicki Plano Clark joined the physics department as a part-time laboratory manager and a part-time member of the RPEG. In 1994 the RPEG received NSF support for a graduate research traineeship (GRT) Ph.D. program in physics: ***Using Hypermedia for Knowing Physics***. This fellowship allowed funding for five doctoral students to complete their dissertations in physics education research at UNL. To date, the following students have received GRT fellowships: Brian Adrian (1994-1997), Rebecca Lindell Adrian (1996-present) Cecilia Hernàndez (1996-1998) and Thomas Koch (1997-present).

Currently RPEG is involved in many curriculum and development projects. Since 1993, the group has worked on incorporating interactive multimedia learning activities into UNL's introductory physics laboratories. In 1995, in cooperation with Steve Dunbar, UNL mathematics professor, the Multimedia Mathematics Across the Curriculum (MMATC) project was started. As part of MMATC, the group taught an experimental "paperless" physics course using the ***Physics InfoMall*** as an electronic textbook with multimedia and Maple learning activities. This project is continuing. The work of the UNL RPEG continues to combine an interest in the intellectual development of college students and the use of various media for teaching physics.

Ph.D.s Awarded

Campbell, Thomas C., 1977, An Evaluation of a Learning Cycle Intervention Strategy for Enhancing the Use of Formal Operational Thought by Beginning College Physics Students, University of Nebraska-Lincoln, Fuller, Education. Now at Illinois Central College.

Stevens, Scott Michael, 1984, Surrogate Laboratory Experiments: Interactive Computer/Videodisc Lessons and their Effect on Students' Understanding of Science, University of Nebraska-Lincoln, Fuller, Education. Now at Carnegie Mellon University.

Zhang, Weijia, 1996, Using Multimedia to Teach Optics to College Students, University of Nebraska-Lincoln, Fuller, Physics. Now at Flomeries, Austin, Texas.

Adrian, Brian W., 1997, Using Multimedia to Teach College Students the Concepts of Electricity and Magnetism, University of Nebraska-Lincoln, Fuller, Physics. Now at Bethany College, Lindsborg, Kansas.

The Physics Education Group at the University of Washington is engaged in a coordinated program of research, curriculum development, and instruction. Under the leadership of Lillian C. McDermott, members of the group conduct in-depth investigations of student understanding in order to identify serious difficulties commonly encountered in the study of physics. The results are used to guide the design of instructional strategies to address specific conceptual and reasoning difficulties. Ongoing assessment is an integral part of this process.

Graduate students in the group select physics education as their field of research for the Ph.D. in physics. As of Summer 1998, nine had received their Ph.D.'s. Three had completed their research with plans to defend their dissertations during the 1998–1999 academic year. Several Master's degrees have been awarded for work with the group.

The research of the group focuses on the learning and teaching of physics and physical science from the elementary grades through the graduate level. The main emphasis is on introductory university courses. However, the group also conducts investigations of student understanding of more advanced material (e.g., special relativity, thermal physics, and quantum mechanics). Some studies are directed toward examining student ability to transfer knowledge from introductory physics to other physics courses and to courses in related disciplines, such as engineering. The computer is incorporated both as an investigatory tool and as an instructional medium.

The group is currently engaged in two research-based curriculum development projects: *Tutorials in Introductory Physics* (Prentice Hall, 1998), which is intended to supplement the lectures, textbooks, and laboratories through which introductory physics is traditionally taught, and *Physics by Inquiry* (Wiley, 1996), a laboratory-based curriculum designed to prepare K-12 teachers in physics and physical science. For more than 25 years, the group has been conducting special physics courses for preservice teachers and annual Summer Institutes for inservice teachers. The research, curriculum development, and Summer Institutes have been supported in part by a series of grants from the National Science Foundation.

Physics Education Group

(1998-1999)

Faculty

Lillian C. McDermott
Peter S. Shaffer
Paula R.L. Heron
Stamatis Vokos

Postdoctoral Associates and Lecturers

Bradley S. Ambrose
Elain S. Fu
Lezlie S. DeWater
John R. Thompson

Emeritus Faculty: Arnold B. Arons

Graduate Students

Leslie J. Atkins
Christopher T. Border
Andrew Boudreaux
Christian H. Kautz
Michael E. Loverude
Luanna Gomez Ortiz
Rachel E. Scherr

Dept. of Physics ❖ Box 351560 ❖ University of Washington
Seattle, WA 98195-1560
(206) 685-2046 ❖ (206) 543-9702 (fax)
peg@phys.washington.edu ❖ www.phys.washington.edu/groups/peg/

Ph.D.s in physics awarded to graduate students with the Physics Education Group at the University of Washington, Lillian C. McDermott, Chair of Supervisory Committee

David Trowbridge, "An investigation of understanding of kinematical concepts among introductory physics students" (1979). Microsoft Corp., Redmond, WA (Retired)

Mark Rosenquist, "Improving preparation for college physics of minority students aspiring to science-related careers" (1982). Shell E & P Technology Co., Houston

James Evans, "History and practice of ancient astronomy" (1983). Dept. of Physics, University of Puget Sound, Tacoma, WA

Ronald Lawson, "Student understanding of single particle dynamics" (1984). Shell E & P Technology Co., Houston

Diane Grayson, "Use of the computer for research on instruction and student understanding in physics" (1990). MASTEC, Pietersburg, S. Africa

Peter Shaffer, "The use of research as a guide for instruction in physics" (1993). Dept. of Physics, University of Washington

Randal Harrington, "An investigation of student understanding of electric concepts in the introductory university physics course" (1995). Dept. of Physics, University of Maine, Orono

Karen Wosilait, "Research as a guide for the development of tutorials to improve student understanding of geometrical and physical optics" (1996). University Preparatory School, Seattle

Pamela Kraus, "Promoting active learning in lecture-based courses: Demonstrations, tutorials, and interactive tutorial lectures" (1997). Pacific Science Center, Seattle

Tara O'Brien Pride, "Investigating student difficulties with reference frames and multibody systems in introductory mechanics" (1997). Self-employed

Bradley S. Ambrose, "Investigation of student understanding of the wave properties of light and matter," (1999). Dept. of Physics, University of Washington

Stephen E. Kanim, "Investigation of student difficulties in relating qualitative understanding of electrical phenomena to quantitative problem-solving in physics" (1999). Dept. of Physics, New Mexico State University, Las Cruces

Michael E. Loverude, "Investigation of student understanding of hydrostatics and thermal physics and of the underlying concepts from mechanics," (1999). Department of Physics, University of Washington

Selected Publications of the Physics Education Group at the University of Washington

L.C. McDermott and E.F. Redish, “Resource letter on Physics Education Research,” to be published in *Am. J. Phys*. (1999).

L.C. McDermott and L.S. DeWater, “The need for special science courses for teachers: Two perspectives,” an invited chapter in *Inquiring into Inquiry in Science Learning and Teaching,* J. Minstrell and E.H. van Zee, eds., to be published by the AAAS (1999).

K. Wosilait, P.R.L. Heron, P.S. Shaffer, and L.C. McDermott, “Addressing student difficulties in applying a wave model to the interference and diffraction of light,” to be published in Physics Education Research: A Supplement to the *American Journal of Physics* (1999).

B.S. Ambrose, P.R.L. Heron, S. Vokos, and L.C. McDermott, “Student understanding of light as an electromagnetic wave: Relating the formalism to physical phenomena,” to be published in *Am. J. Phys.* (1999).

B.S. Ambrose, P.S. Shaffer, R.N. Steinberg, and L.C. McDermott, “An investigation of student understanding of single-slit diffraction and double-slit interference,” *Am. J. Phys.* **67** (2) 146 (1999).

P.R.L. Heron and L.C. McDermott, “Bridging the gap between teaching and learning in geometrical optics: The role of research,” *Opt. & Phot. News* **9** (9) 30 (1998).

K. Wosilait, P.R.L. Heron, P.S. Shaffer, and L.C. McDermott, “Development and assessment of a research-based tutorial on light and shadow,” *Am. J. Phys*. **66** (10) 906 (1998).

T. O’Brien Pride, S. Vokos, and L.C. McDermott, “The challenge of matching learning assessments to teaching goals: An example from the work-energy and impulse-momentum theorems,” *Am. J. Phys.* **66**, (2) 147 (1998).

R.N. Steinberg, G.E. Oberem, and L.C. McDermott, “Development of a computer-based tutorial on the photoelectric effect,” *Am. J. Phys*. **64**, (11) 1370 (1996).

D. J. Grayson and L.C. McDermott, “Use of the computer for research on student thinking in physics,” *Am. J. Phys.* **64** (5) 557 (1996).

L.C. McDermott, P. S. Shaffer, and M.D. Somers, “Research as a guide for teaching introductory mechanics: An illustration in the context of the Atwood’s machine,” *Am. J. Phys.* **62** (1) 46 (1994).

L.C. McDermott, Guest Comment: “How we teach and how students learn—A mismatch?” *Am. J. Phys* **61** (4) 295 (1993).

L.C. McDermott and P.S. Shaffer, “Research as a guide for curriculum development: An example from introductory electricity, Part I: Investigation of student understanding,” *Am. J. Phys.* **60** (11) 994; Part II: Design of instructional strategies,” Am. J. Phys. **60** (11) 1003 (1992).

L.C. McDermott, “What we teach and what is learned: Closing the gap,” *Am. J. Phys.* **59** (4) 301 (1991).

L.C. McDermott, “A perspective on teacher preparation in physics and other sciences: The need for special courses for teachers,” *Am. J. Phys.* **58** (8) 734 (1990).

L.C. McDermott, “Research and computer-based instruction: Opportunity for interaction,” *Am. J. Phys.* **58** (5) 452 (1990).

R.A. Lawson and L.C. McDermott, “Student understanding of the work-energy and impulse-momentum theorems,” *Am. J. Phys.* **55** (9) 811 (1987).

L.C. McDermott, M.L. Rosenquist, and E.H. van Zee, “Student difficulties in connecting graphs and physics: Examples from kinematics,” *Am. J. Phys.* **55** (5) 503 (1987).

M.L. Rosenquist and L.C. McDermott, “A conceptual approach to teaching kinematics,” *Am. J. Phys.* **55** (5) 407 (1987).

F.M. Goldberg and L.C. McDermott, “An investigation of student understanding of the real image formed by a converging lens or concave mirror,” *Am. J. Phys.* **55** (2) 108 (1987).

F.M. Goldberg and L.C. McDermott, “Student difficulties in understanding image formation by a plane mirror,” *The Phys. Teach.* **24**, 472 (1986).

L.C. McDermott, “Research on conceptual understanding in mechanics,” *Phys. Today* **37**, 24 (July 1984).

D.E. Trowbridge and L.C. McDermott, “Investigation of student understanding of the concept of acceleration in one dimension,” *Am. J. Phys*. **49** (3) 242 (1981).

D.E. Trowbridge and L.C. McDermott, “Investigation of student understanding of the concept of velocity in one dimension,” *Am. J. Phys*. **48** (12) 1020 (1980).