ACTIVITIES of the Modeling Workshop Project (1994-2000)
and
CONTRIBUTIONS & SIGNIFICANCE OF THE MODELING WORKSHOP PROJECT

These are two sections in the Final Report submitted to the National Science Foundation in fall 2000 for the Teacher Enhancement grant entitled *Modeling Instruction in High School Physics*. David Hestenes, Professor of Physics at Arizona State University, was Principal Investigator. Extensive information about the Project is at http://modeling.asu.edu.

ACTIVITIES of the Modeling Workshop Project (1994-2000)

Goals.

The primary goals of our project were threefold:

(1) To make the Modeling Method available to interested teachers through the United States, because of its proven effectiveness in increasing student understanding and problem-solving ability,

(2) To contribute to the formation of institutional mechanisms for lifelong professional growth of high school physics teachers, because teachers are more valuable to their students when their personal knowledge is enhanced, and

(3) To facilitate technology infusion into the high school physics classroom, because computers and electronic networking are indispensable tools in science and in educational reform of physics as we enter the 21st century.

We found that many graduates of our Leadership Modeling Workshops were in great demand in their schools to assist in technology infusion, so it became apparent that we needed to add another goal:

(4) To cultivate physics teachers as school leaders in teaching science effectively with technology.

Our progress in realizing these goals during the six years of this project is substantial. Recent evidence for this is: On Sept. 12, 2000, the U.S. Department of Education announced that Modeling Instruction in High School Physics is one of seven programs designated as exemplary or promising out of a total of 134 educational technology programs submitted to the U.S. Department of Education's Educational Technology Expert Panel. The Panel summarizes our project on its web site as follows:

> Modeling Instruction in High School Physics uses computer models and modeling as a focal point to develop the content and pedagogical knowledge of physics teachers who then serve as local experts in the use of technology in teaching and learning science. In eight weeks of modeling workshops over two summers, teachers revamp their current

high school physics course to incorporate technology and insights of educational research. In the revamped course, instruction is organized into modeling cycles that engage students in all phases of model development, evaluation, and application. Students collaborate in planning and conducting experiments, use software to organize and analyze data, and present to the class a summary of their group's experimental procedure, interpretation, and findings.

Setting objectives.

Because of delay in funding the project, we had to shift the starting time for our first Leadership Modeling Workshops from summer 1994 to 1995. This turned out to be a boon, because the additional time for planning and preparation enabled us to enhance the quality and extend the scope of the Project.

During the first six months of the Project, David Hestenes (DH) consulted with many leaders in physics education across the country about possibilities for maximizing the impact of the Project by coordination with other programs at local, regional and national levels. From all quarters, DH received strong encouragement to use the Project as an *instrument for the reform of high school physics*, and he concluded that such an ambitious expansion of the original goals of the project is feasible.

To formulate precise objectives for high school physics reform and a definite plan for promoting it with teacher training in our Modeling Workshops, DH prepared a set of three *Project Policy Documents.* These documents established a common understanding of Project goals among the staff, participating teachers, and other concerned parties. They identify key issues in educational reform which must be addressed by the physics community. Consequently, the documents are also being used to promote a broader consensus on reform goals.

(A) Teacher support. To optimize the benefits from training in our Modeling Workshops, we actively promote the formation and maintenance of teacher support systems along three lines: (1) Local teacher alliances, (2) electronic networking, (3) University - High School partnerships.

(B) Technology infusion. To produce a highly credible document on technology infusion which can command instant respect and broad support, DH formed an advisory committee of nine leading experts on the use of computers in physics teaching. All the committee members acknowledged agreement with the resulting policy document. We used this document to support our solicitations for funds in the high school physics classrooms. It has been well received by administrators and business people.

(C) Leadership training. Although the Modeling Workshops are designed for teachers with weak backgrounds as well as strong, a special effort was made to recruit and train leaders in Phase I (1995-97) who could assist in expanding the program in Phase II (1997-98) and III (1998-99). This was highly successful.

Teacher Recruitment.

Teacher recruitment was a complex process because of the ambitious Project goals. The selection of participants for the Leadership Modeling Workshops was competitive. To ensure serious commitment from the teachers and schools, each applicant was required to submit a plan for local implementation, and each school submitted a cost-sharing agreement. We gave advice and feedback on how to do this.

Throughout the three phases of Leadership Workshops, the Modeling Workshop program was advertised by announcements in AAPT and NSTA publications and posted on Internet physics teachers' lists and PHYSLAB BBS, as well as by many talks and several workshops at national and regional AAPT meetings by staff and earlier workshop participants, mailings to local physics alliances (LPAs) and AAPT section officers, SECME (Southeast Consortium for Minorities in Engineering) coordinators, college and university professors who work with high school physics teachers, representatives of USIs, SSIs, and RSIs, and dozens of school/business partnership coordinators in cities across the nation. A special effort was made to phone minority, female, and rural teachers, and teachers in regions that are traditionally underserved in science.

Teams of participants were selected when we thought it would enhance the reform, in accordance with the suggestion of the NSF Program Director. In line with an NSF suggestion, 5% of participants were post-secondary physics teachers.

Every attempt was made to provide housing for families at one or more sites each summer. Many participants (1/4 to 1/3 at each such site) gladly took advantage of it. Family housing allowed a whole new category of teachers to participate: those with preschool and school age children - not just those whose children had grown up or who had no children.

All school boards or comparable authorities were given the required information to assist them in arriving at a decision on participation. Cost sharing agreements were from principals and constituted the required written approval for participation in the project activities. The total cost sharing was well over 30% of the grant award.

We encouraged participants to collaborate with local universities and teacher alliances to conduct local workshops, and many of them made such arrangements. We are pleased at the number of partnerships that applicants made with universities for future local dissemination of the modeling method to in-service and/or pre-service teachers

Training in the Leadership Workshops was thorough and extensive: from 8 to 12 weeks of full day training over 2 or 3 years. Despite this tremendous demand of time and effort on participants, the net attrition rate was nearly zero (because there were waiting lists of eager teachers to fill the few slots of teachers who withdrew)**!** We reached our projected number of 200 teachers to be trained in the three workshop phases.

IV. Leadership Modeling Workshops and teacher support

Eighteen Leadership Modeling Workshops provided professional development for 200 experienced in-service teachers with exceptional qualifications and motivation from 44 states. Of these teachers, 15% taught at urban schools and 15% at rural. 25% of the teachers were women, and 5% were disadvantaged minorities. 20% served low income populations and 50% served middle class populations.

Phase 1 Modeling Workshops (1995-97) served 50 teachers for 12 weeks at ASU and the University of Illinois at Chicago (UIC; Gloria Hoff, faculty liaison). The first workshop focused on teaching the Modeling Method in mechanics. In the second and third workshops, the emphasis was on analyzing materials and activities from diverse sources and integrating them into instructional units. To introduce the best new materials that we could secure, we enlisted cooperation of several NSF PI's, including Melvin Steinberg, John Clement, Bruce Sherwood, Fred Goldberg, Richard Olenick, Robert Beichner, and John King.

The Phase 2 and 3 Workshop series served 150 teachers for 4 weeks in each of two successive summers. Finding universities eager to serve as workshop sites was no problem, so we were able to apply strict criteria in our selection. Chief among these were strong support from a cooperating physics professor, a Phase I leader who lived nearby, and strong links with a local physics alliance. Phase 2 sites (1996-97) were ASU, the University of Akron in Ohio (Frank Griffin), and the University of Wisconsin at River Falls (Neal Prochnow). Phase 3 sites (1998-99) were at the University of California at Davis (Wendell Potter), the University of Central Florida in Orlando (Madi Dogariu), and the University of Maryland (Edward “Joe” Redish). It was moved to Bob Morse’s classroom at St. Albans School in Washington D.C. for the second summer because of better technology and lab equipment. Each site had two workshop leaders chosen from Phase I participants. Because of the rigorous selection procedure for Phase I, the majority of the 48 participants turned out to be exceptionally well qualified and motivated. Eighteen agreed to assume the responsibility and time commitment to serve as Phase II and III Workshop Leaders, and 12 of these were selected to co-lead workshops. We see this as the strongest possible evidence for the success of our whole Modeling approach, for these teachers were so impressed that they offered to commit the better part of two more years of their life to promulgating it.

To determine the optimal length for the summer workshops we surveyed the opinions of many teachers, including all our Phase I participants, and we came to the following conclusions: Our objectives could not be achieved in workshops of less than 4 weeks. Most teachers regard six weeks as too long for out of state workshops, mainly because it disrupts their families. 5 weeks is probably best, and we adopted it for our Phase I workshops because we were training our Phase II Leaders there. However, 4 weeks is logistically more practical, so we adopted that for the Phase II and III workshops. Besides, that put less strain on the neophyte workshop leaders.

C3P PI Richard Olenick proposed that a special modeling workshop be scheduled in summer 1998 for C3P mentors who wished to learn the modeling method in mechanics. Enough mentors responded affirmatively to make this a reality, so it was held at their Colorado Western College site in conjunction with their final meeting. Some C3P mentors joined Phase 3 participants in 1999 for the second Modeling Workshop.

In Phase 1, Internet training was provided to participants so they could effectively make use of Project listserv support after the summer workshops. Phase 2 and 3 teachers were more adept at the Internet. A Modeling listserve was initiated to provide electronic support year-round. It has grown to 600 teacher subscribers, and they report that it has been a valuable resource, as illustrated by these recent quotes: "The list serve is a great source of professional conversations and ideas." "I've found the listserve very informative..." "Thanks, Jane, for maintaining this list-serve. I have learned much from the discourse." "I must add my thanks as well. It is constant 'professional development'."

Many Phase I teachers needed massive technology infusion, and their school districts provided it with an average cost share of about $18,000. Phase 2 and 3 teachers had readier access to computers before they started the workshops, and this was reflected in their lessened school cost share. Still, many teachers have needed technology upgrading. Project involvement has helped them, as illustrated by these quotes from academic year 1999-00. "I was called into the Principal's office and was informed that a parent had been impressed enough by what was occurring in physics that they wished to anonymously donate the full $26,000 dollars to the program." "Using modeling theory, I have convinced board members and administrators that I already know how increased technology will be applied in my teaching and therefore have moved to the front of the funding line. My department chair relies on me to be able to articulate how technology can be utilized in science education."

V. Educational research, development and evaluation.

The Project maintained continuous efforts to upgrade all aspects of the program, both by in-house research and by importing new ideas and materials.

In 1995 David Hestenes and Gregg Swackhamer published "A Modeling Method for High School Physics," describing the Modeling Method to be taught in the Workshops and documenting its effectiveness in the hands of a well-trained teacher. Since that time, several other papers on aspects of our project have been published, and more is to come.

Hestenes brought Dr. Ibrahim Halloun into the project to collaborate on developing an instrument (as promised in our proposal) to assess the effectiveness of science instruction in changing beliefs about knowing and learning science. We had anecdotal evidence that Modeling Instruction is especially effective in this domain, and we suspected that this is a secret of its success. We needed this instrument to replace our suspicions by objective evidence. To make the broadest comparisons we needed an instrument that can be applied to any science course. The instrument, called *Views about Sciences Survey* (VASS), focuses on learning styles and epistemological beliefs about science. Different versions have been developed for physics, astronomy, chemistry, and biology. VASS has been administered to thousands of high school and college students in many states. Preliminary analysis of the data indicates that the instrument is highly valid and reliable. IH presented several papers on Modeling theory and evaluation at national meetings, and he participated in national workshops related to his project work.

With input from other workshop leaders and I. Halloun, Larry Dukerich and Gregg Swackhamer refined and edited curriculum materials for the workshops. This effort included providing a much more explicit description of the steps in the construction and deployment of scientific models. The mechanics portion, addressed in the first summer, though well developed, was refined based on LD's experiences with the teachers in the PHY 480 course. In developing new materials for the second summer, LD concentrated on waves and optics, while GS concentrated on electricity and magnetism. They selected models and organized activities around student difficulties as well as the features of the models. Later on, outstanding participants contributed to their work. The second semester model-based materials are now ready for full use; they are on the web site and CD-ROM.
Dr. Frances P. Lawrenz, Dept. of Curriculum and Instruction, University of Minnesota, was the required external evaluator. Her evaluation commenced during the first workshops and continued during Phase 2.

VI. Institutionalizing Modeling Workshops in Artizona

We have followed our own advice on establishing a HS–University Partnership. First, we institutionalized our Modeling Workshops in a series of two courses at ASU (PHY480 and 481: Methods of Teaching Physics I and II) taught by an experienced high school teacher who is thoroughly trained in the Modeling Method. Second, we organized teachers into a statewide network of local physics alliances for mutual support and collaboration in learning. Third, we convinced the Phoenix Urban Systemic Initiative (USI) to accept our program as one of their "academies" for teacher training. The USI paid inner city high school teachers to attend the courses.

We established these courses and an associated teacher support system as a worthy model for other colleges and universities to improve physics teaching in nearby high schools. We also intended it as a model for how USIs can be made more effective. It is clear that the Phoenix USI would have done nothing for physics teaching without our intervention. Even so, it was not easy to convince the USI administrators to take advantage of our program. We explored similar collaboration with other USIs and SSIs throughout the country but found no takers.

The considerable developments described in this section were mere spin-offs of our Project. None of them were contemplated in our original proposal, and they consumed only a tiny portion of Project funds. Yet they could not have been achieved without the organization, personnel and vision of the Project. They formed the foundation and inspiration for a statewide partnership for sustained professional development and support of high school physics teachers. We received supplemental funds to assist this partnership in organizing and conducting Modeling Workshops, and for similar activities in Wisconsin, which also had the beginnings of a statewide University - High School partnership.

Stimulated by the NSF supplemental funds, ASU, Northern Arizona University (NAU), and the University of Arizona were each awarded a series of $50,000 grants for Eisenhower-funded 4-week summer modeling workshops for school technology infusion. Ten modeling workshops were held at in 3 summers. Over half of the 230 high school physics teachers in Arizona have participated; 20% teach in urban schools and 20% are rural (chiefly low income). 30% are women. Almost all physics teachers in the (now ended) Phoenix Urban Systemic Initiative (USI) use the Modeling Method.

Last spring, expert Arizona physics teachers extended the Modeling Method to ninth grade physical science; a team of a dozen developed a two-week Modeling Workshop for middle school and ninth grade science and math teachers. The workshop design was piloted in inner city Phoenix and in rural southern Arizona. It was so successful that it will be repeated next spring and summer in a partnership with Phoenix high school district's NSF Pilot grant.

ASU has approved $50K/year funding for 2 years starting this summer, and an endowment program for sustained support has been started for its umbrella organization at ASU.

VII. Wisconsin Activities.

Outside of Arizona, Wisconsin was the most promising prospect for a statewide University-HS partnership, so half of our supplemental funds were devoted to Modeling Workshops in Wisconsin to stimulate that.

Neal Prochnow, Wisconsin Project Manager, reports that the University of Wisconsin - River Falls (UWRF) offered seven workshops throughout Wisconsin in 1998-2000. They were as follows:

Workshop	Location	Number of Teachers
Mechanics	Madison West H.S.	9
E & M	Madison West H.S.	11
Mechanics	Brookfield H.S.	12
E & M	Brookfield H.S.	10
Mechanics	Neenah H.S.	23
Mechanics	UW-River Falls	18
Modeling Prep	UW-River Falls	16
TOTAL		99

All modeling workshops were 13 full days with two follow-up days. Participants earned 3 semester hours of graduate credit with tuition waiver. The modeling technology preparation course was 10 full days, for two semester hours of tuition-waiver graduate credit. Twelve participants were from other states. Recruitment was statewide through direct mail to the physics teacher, the WISPHYS newsletter, and one-on-one contacts.

Jay and Anna Zimmerman describe their Milwaukee area Modeling Workshop:

> “A first-year physics modeling workshop was held at Brookfield Central High School in August 1998. The course of 90 hours of instruction was taught by high school physics teachers Jay and Anna Zimmerman and was held over a two and a half week period with three days of follow-up training during the fall semester. The ten high school science teachers took the role of students and performed and wrote up nine lab experiments, worked with technology that was new to them, solved worksheet problems, and presented their labs and problems through the use of "whiteboarding." The participants, guided by the instructors, became responsible for the learning, thus utilizing "constructivist" principles.
>
> Most of the ten participants reported using at least some of the techniques in their classes, and several followed the curriculum completely. All agreed the workshop had revolutionized their teaching because they had become more of a guide and lab facilitator and less of a lecturer. Many have become active in our local physics sharing group. Two have joined the UW-River Falls summer physics programs.
>
> In August of 1999, the modeling course was repeated at Brookfield Central, again taught by the Zimmermans. Eleven new high school science teachers enrolled in the course and five of the 1998 participants came back for a second-year session (Modeling II) that involved an evaluation of how the use of modeling in their classrooms had succeeded, a thorough review of second-year modeling topics, and time to develop their own modeling topics. Two of the new participants became involved with the UWRF summer physics adaptation program. All of the participants, first and second-year, have had the opportunity to be subscribed to the modeling listserv, where they can interact with other teachers who use the modeling approach.
>
> Jay Zimmerman is a summer staff member at UWRF, where he helps teach the physics adaptation program to equip novice science teachers with the ability to teach high school physics. Zimmerman always includes at least one lab experiment that utilizes the modeling approach. In addition, Zimmerman teaches a physics methods course to undergrads who are preparing to student teach in physics. These students always get a healthy dose of the modeling experience in their coursework.”

Wisconsin has 450 public and private school districts. The average number of physics classes per district is about 1.5. The impact on teaching and learning in Wisconsin is that about 20% of the physics classes taught in Wisconsin in 2000-2001 are taught by a teacher who has been through a physics modeling workshop. The increased use of communication skills by students is the most positive attribute cited by parents.

Mark Lattery, a physics professor at UW-Oshkosh, attended part of the Neenah workshop. One master teacher involved in the project, Jay Zimmerman, continues to expand the modeling approach to physics through professional meetings and networks. Over the past three summers, about 120 in-service teachers and 12 undergraduates have been exposed to the modeling methodology. It is difficult to estimate the impact of this.

CONTRIBUTIONS & SIGNIFICANCE OF THE MODELING WORKSHOP PROJECT:

A. Within physics education.
This project has validated a new approach to teaching physics called the "Modeling Method." It has completely revamped the standard high school physics course, incorporating the insights of Physics Education Research in a student-centered pedagogy in full accord with the National Science Education Standards. The considerable success of project is thoroughly documented with objective test data on student learning and profound changes in teaching practices. One teacher described it as "The next step after PSSC & Harvard Physics Project."

Project reforms have been institutionalized in courses on "methods of physics teaching" at Arizona State University that can serve as a model for courses at other universities, incorporating 21st century curriculum design.

B. To other disciplines in science education:
In accord with the National Science Education Standards, which identifies "modeling" (i.e. making and using scientific models) as a unifying theme for all the sciences, this project has started to extend the Modeling Method beyond physics. Physics teachers have been involved in developing model-based curriculum materials for 9th grade physical science and high school chemistry. Workshops (for graduate credit) have been developed for 9th grade & junior high science & math teachers. A mathematical modeling course to help integrate high school math and science is under development.

C. To education & human resources:
This project has stimulated the creation of University-High School Partnerships to cultivate inservice physics teachers as leaders of K-12 science education reform (currently being continued under another grant). This is a mechanism for institutionalizing and expanding reforms started with NSF funding. Unfortunately, most NSF-supported reforms disappear when the initial funding runs out.

D. To resources for science & technology
This project has thoroughly integrated computer technology into high school physics. In particular, the computer is used as a scientific tool, not merely as a word processor or Internet link. Moreover, physics teachers are cultivated as experts in science teaching with technology who are prepared to pass this on to other teachers.

E. Beyond science & engineering:
A GENERAL CAPABILITY FOR DAILY LIFE: The Modeling Method is aimed at engaging students in scientific discourse – teaching them to talk about things in a scientific way! An important task for everyone in society is to formulate and evaluate scientific claims. How do you formulate a scientific claim clearly? How do you evaluate it? This, of course, is something we want students to be able to do in daily LIFE! They need a general ability to evaluate people's claims in life situations. But before you can evaluate a claim, you must express it clearly! From the modeling point of view, we use MODELS to evaluate claims. Accordingly, students are taught about

1) models, to formulate and evaluate scientific claims,
2) methods to investigate the applicability of these models,
3) data, to evaluate the models and hence the claims.

All of this is aimed at justified belief! We want students to take responsibility for their own knowledge. That means, instead of asking the teacher, that they must be able to come up with their OWN arguments.

Students and teachers should be talking about this explicitly in class. If they want to protect themselves from the unjustified claims that pervade our society; if they want to function as intelligent, responsible members of the society, they need the capacity to make judgments on their own; they need an ability to evaluate evidence. That includes understanding STANDARDS of evidence. That will help them ascertain whether someone who claims he's an expert really IS an expert.