History of the Physics Resources and Instructional Strategies for Motivating Students (PRISMS) Project

Initiation of a Physics Project

Jack Gerlovich, state science consultant, contacted Roy Unruh in October, 1981 and asked him to help form a Physics Task Force to address the issue of assisting marginally prepared teachers of physics to improve the quality of instruction. Teachers assigned to teach physics in low enrollment schools were often teachers with a marginal background in physics. Members of this task force were Tim Cooney (co-director of the PRISMS Project), Rollie Freel, Marshalltown; Ken Schaefer, Mason City; Bob Wilson, Belmond; Ken Hartman, Ames; Dan McGrail, Carlisle; and Vince Lunetta, University of Iowa.

An awareness session was organized by George Magrane, science consultant with Southern Prairie Educational Association, for March 2, 1982 with teachers of physics and their school superintendents to meet with Jack Gerlovich, Roy Unruh, Tim Cooney, Dan McGrail, and Vince Lunetta. The purpose of this meeting was to assess how best to improve the quality of physics teaching, especially in schools where physics was taught by teachers with a marginal background in physics. An approach was presented for teaching the concept of conservation of energy that involved a learning cycle consisting of exploration, concept development, and application activities with inexpensive, easily obtained equipment.

The Learning Cycle

The PRISMS materials were developed utilizing the learning cycle as described and advocated in the *Science Teaching and the Development of Reasoning-Physics* (1981) workshop materials developed at the Lawrence Hall of Science, Berkeley, California under the direction of Robert Karplus. The learning cycle contains the basic processes characteristic of scientific reasoning and guides students to an effective understanding of major concepts in physics.

Just as scientists start with making informal observations, so also PRISMS contains exploration activities in which students are given the opportunity to make their own observations and find their own patterns. Students don't need to "get it right" during this phase of the learning cycle. The important thing is to have the students express their logic in making their observations and finding their patterns. If you want students to understand the nature of science you must give them the opportunity to participate in the same mental functions that a scientist does when he/she creates understandings in science.

The concept development activity is used to test students' tentative understandings of the concept and to guide them toward an acceptable scientific explanation or interpretation of a physical phenomenon. Teachers may have different laboratory groups share their explanations and ask students which explanations are the most encompassing or that make the most sense or are the most easily understood. Concept development was left largely to the teacher with the idea that this phase of the learning cycle somewhat emulated what the teacher would normally do to create conceptual understanding.

It is said that science starts with an experiment and ends with an experiment. In other words, after a theory has been formulated, scientists then conduct an additional experiment to see whether the theory can be verified in another phenomena. In a similar manner, the test for student understanding is for them to be able to apply the newly learned concept to another phenomenon. The application activity provides an opportunity for the students to generalize the concept instead of seeing an explanation applied to only a specific phenomenon.

Pilot Program

Teachers indicated they did not have time available during the summer to take university level physics classes to supplement their backgrounds in physics. They were, however, very receptive to the activities presented, especially since they could be taught with readily available materials.

In October, 1982, a pilot program began in Southern Prairie Area Education Agency (AEA) with six schools from the Empire Conference. The program was designed to upgrade the quality of physics instruction with teachers who had a marginal background in physics and was designed to educate teachers on their school site, during the school day.

A teachers' guide was developed by the State Task Force, designed specifically to improve physics teachers' content preparation and confidence to teach the subject. Plans included the production of videotapes to simulate activities which would be difficult to replicate in small communities. Student activities were developed which emphasized application of physics knowledge to everyday student events. Computer software was to be researched and developed to provide simulation activities relevant to physics.

The six participating schools were provided with a telephone line into the classroom where physics was taught and a telephone with amplifier to free the teachers' hands so that they could conduct laboratory activities being narrated to them by Tim Cooney and Roy Unruh from the University of Northern Iowa. These telephone conference calls continued through the teaching of the entire unit on conservation of energy. The reaction of the pilot school teachers was very positive.

Program Expanded

Through efforts of the Governor's Science Advisory Council, the Iowa Academy of Science, and the Iowa Department of Public Instruction (DPI) a report was prepared which detailed the problems and potential solutions to the issues of securing and retaining qualified science teachers in Iowa. The report entitled "The Crisis in Science Education in Iowa: The Problem and Recommendations" was delivered to Governor Ray's Office and to the DPI in November 1982. The most prominent need identified in that report was to upgrade biology teachers, who, due to retirement of physical science teachers, were being forced to teach physics and chemistry; and to do so in a cost effective manner.

The State Legislature provided direct support in the amount of $40,000 to expand the support to 45 schools, three from each AEA for the 1983-84 academic year. The AEA science consultants were asked to make the selection of these teachers based on commitments to implement the teaching strategies of the materials, a desire to strengthen physics enrollments, and acquire necessary computers and video playback units.

Summer 1983

During the summer of 1983 the Physics Task Force developed activities for four units in physics, Force and Motion; Work and Energy; Waves and Optics; and Electricity, Magnetism, and Modern Physics. Materials were written for student distribution and teacher's notes to assist teachers in presenting and evaluating the learning experiences. The University of Northern Iowa provided support by providing released time from teaching for Roy Unruh to direct the project for the fall semester. An anonymous donor provided $18,800 which, in part, was used to provide Roy Unruh released time for the project for the second semester.

1983-84 Academic Year

Four in-service workshops were conducted in Cedar Falls, Storm Lake, Red Oak, Des Moines, and Mount Pleasant during the 1983 - 84 academic year. Administrators and teachers attended these workshops in which the teaching strategies of the learning cycle of exploration, concept development, and application were presented. Teachers were treated as students in working through representative activities in some of the learning cycles. Methods of introducing the activities, with appropriate questioning techniques, were modeled and discussed.

Between workshops teachers were divided into groups to participate in the teleconference calls. Teachers were given opportunity to provide reflections on how they experienced the teaching of these learning cycles. Instructions and demonstrations of teaching techniques on future activities were also modeled and discussed during the teleconferences. Teachers were required to have video tapes made of them teaching activities of the learning cycle to their students. These were sent to the Project staff, evaluated, and returned with comments to the teachers. Personal visits by the directors of the project were also made to the schools in the project to give personal feedback to the teachers on the techniques used in their teaching.

Evaluation of the project, which included the teleconferences, and student and teacher materials, was conducted throughout the 1983 - 84 academic year. The teleconference calls were very favorably received. A survey administered to the teachers was designed to determine the extent they used the PRISMS philosophy in teaching their course. The results showed a substantial implementation of the learning cycle teaching strategies, but with some reluctance to abandon a lecture style of teaching.

A proposal submitted to the U. S. Department of Education, Secretary, Applying Technology to Provide Resources and Instructional Strategies for Secondary Physics Teachers, was funded through the Iowa Academy of Science for $132,000 for the period January 1, 1984 - December 31, 1984. This grant allowed for the completion of the development of the PRISMS resource guide and to field test activities that applied the use of the computers to science classrooms.

Summer 1984

During the summer of 1984 the Task Force conducted a rewrite of the activities based on feedback from the teachers and students of the pilot project during the previous year. The focus on teachers for the 1984-85 academic year was expanded to incorporate teachers with adequate backgrounds in physics and teaching in larger school systems. Two one-week summer workshops were taught, one at the University of Northern Iowa and the other in Storm Lake located in western Iowa.

Academic year 1984-85

Four in-service workshops were again conducted in Cedar Falls, Storm Lake, Red Oak, Des Moines, and Mount Pleasant during the 1984 - 85 academic year. Teleconference calls were again conducted with groups of teachers with from five to eight teachers in a group. One teleconference call incorporated students in physics classrooms. The lesson focused on energy conservation with a set of slides disseminated to the schools describing an earth sheltered home with soil and air temperatures for the various seasons. Students were allowed to ask questions during this teleconference call. Teachers created one video tape of them teaching a learning cycle in their physics class. These tapes were evaluated by the Task Force and returned to the teachers. The co-directors visited each classroom once each semester.

The PRISMS Project received funding from the US Department of Education for a continuation grant from January 1, 1985 - June 30, 1986 for $83,000, again administered through the Iowa Academy of Science. The grant assisted in the implementation of technology into the PRISMS activities. This included such devices as photogates for timing events, thermistors for measuring changes in temperature, and sensors to measure light intensity.

Summer 1985

Two videotapes were created for use in a learning cycle. “Collage of Motion” was a collection of common scenes of carnival rides at the state fair, a football game, car races, a dance group, etc. The video tape was used as an exploratory activity to the introduction to motion in which students were asked to develop their own system of classifying motion. The videotape, “Potential and Kinetic Energy” was introduced by archery and skiing scenes. The purpose of the tape was to make measurements of the potential energy transferred to a rubber band across an air track simulating the archer’s bow and comparing this with the kinetic energy of the glider released by the drawn rubber band.

PRISMS gains national exposure

Presentations describing the nature and content of the PRISMS Project were presented at state educational meetings including Arrowhead Education Agency, Fort Dodge, Iowa; Iowa Council of Science Supervisors, fall meeting, 1983; Iowa Science Teachers Fall Conference, 1983; Iowa Curriculum and Instruction Conference, 1983; and Iowa Section of American Association of Physics Teachers, 1983. We were asked to present an invited paper on PRISMS at the American Association of Physics Teachers/American Physical Society National Convention, 1984. A presentation, “Science Teacher In-service by Teleconference,” was given at the Regional Form on Distance Learning, conducted by Southwest Educational Development Laboratory, Austin, Texas, 1984. Another presentation on PRISMS was given at the National Science Teachers Association National Convention, Boston, Massachusetts, 1984.

The U S Department of Education had created the National Diffusion Network (NDN) to promote exemplary programs in education. These programs and curriculum projects were identified from K-12 based on research studies and documented data. In the spring of 1983 the directors of the PRISMS Project were informed that they were encouraged to conduct such a research study.

Feedback received from teachers and students indicated that concepts in physics were more thoroughly understood and that the teaching strategy encouraged the cultivation of reasoning skills as a result of using the PRISMS materials and teaching strategies. A study was designed to assess these two claims. Since the AEA curriculum coordinators recommended schools to participate in the PRISMS program, they were asked to select control schools which were similar to the experimental schools in their AEA on the basis of school enrollment size, physics teacher experience and hours of physics background of the teacher. Twelve schools were originally selected from the pool of schools using PRISMS. For the PRISMS schools, the sample included students (N=287) in grades 10, 11 and 12 and for the control group the sample consisted of students (N=222) in grades 10, 11 and 12.

Achievement gain in understanding physics concepts was measured using two forms of the New York Regency Physics Exam. Gain in reasoning/science problem solving skills was measured by using two forms of the Test of Integrated Process Skills (TIPS II). It measures science process skills such as hypothesizing, identifying variables, operationally defining, designing investigations, and graphing and interpreting data. The data were collected during the third week of October, 1985 and the first week of May, 1986.

A t-test was used to determine the level of significance in comparing the gain of the experimental and control groups with the .05 probability level selected as the standard to show a significant difference between the two groups. The difference in the gain ($p < .001$) on the physics achievement test supported the claim that the activities and teaching strategies used in the PRISMS program make the understanding of the physics concepts more meaningful than in a more traditionally taught physics course.

The same design, population, sampling procedures, data collecting methods and analysis were used for the evaluation of the second claim. The change in the scores favors the PRISMS group for the gain in reasoning/science problem solving skills at the 0.02 level of probability.

The results of this study were submitted to the NDN for their evaluation. The next cycle of announcements for selection of exemplary curriculum projects would be made in October, 1987.

Based on the feedback from teachers in the PRISMS Project and the enthusiasm shown at national meetings, it was decided to apply for funding from NSF for PRISMS implementation beyond the borders of Iowa. In April 1986 NSF informed the project that it had been awarded a Regional Teacher Enhancement grant for $178,000, which was administered through the College of Natural Science at the University of Northern Iowa.

The grant provided funds to invite 60 teachers from nine upper Mid-West states who had assignments to teach physics during the 1986-87 school year to be part a PRISMS implementation program. These teachers were assigned to one of two three-week workshops during the summer of 1986. The workshops were conducted with the same teaching strategies as done in previous years to implement the philosophy, strategies and activities of the PRISMS program. Support activities during the academic year included monthly teleconference calls as well as on site visits to the teachers’ classroom while teaching their physics classes. A similar grant of $140,000 was received for the summer of 1987 and the 1987-88 academic year for another group of teachers from the upper Mid-West.

In October of 1987 the directors of the PRISMS Project were informed that PRISMS was validated by the NDN as an exemplary curriculum and awarded a grant for $53,000 to begin the dissemination. NDN contains facilitators in each state whose responsibility it is to assist schools in their state to become acquainted with and adopt programs that have been deemed exemplary by research studies. It would be a great asset to implementing PRISMS at the national level if each state had a PRISMS teacher that could work with the state facilitator in spreading the information about PRISMS.

A proposal was submitted to NSF to identify a leader teacher in each state to attend a PRISMS training workshop and commit to implement PRISMS in their school. They could then become resource leaders for helping school systems in their states to become acquainted with PRISMS and assist them in the implementation process. Consequently, a proposal was submitted to NSF for such a National Leadership Development program and was funded for $278,000.

Summer 1988

Sixty teachers were selected to participate in one of two workshops from a national cross section of physics teachers. Concepts traditionally taught at the high school level were modeled utilizing the learning cycle approach. Computer interfacing was relatively new at this time so appropriate ways of utilizing these devices was modeled. A test bank of 2700 questions sorted by objective and Bloom's taxonomy on computer discs were provided for the teachers for student evaluation.

Teachers prepared lesson plans for teaching physics with the PRISMS materials and teaching strategy integrated into their high school physics courses. During the third week of the workshop teachers were assigned to model teach a concept. These lessons were videotaped and feedback was provided by peer teachers and workshop staff. During the academic year telephone conference calls were conducted with these teachers on a regular basis. Experiences, questions, and evaluations were shared between the teachers and staff during these calls.

Summer 1989

These teachers returned to the UNI campus during the summer of 1989 for a one week workshop. Feedback on teaching the activities and learning cycles was shared. Suggestions for improvement were welcomed and incorporated in updates on the PRISMS guide. The focus of this week was to prepare them to give presentations about PRISMS with some demonstration activities for large group presentations, such a state science teachers meetings. They also developed plans for conducting PRISMS training workshops in their states. They were encouraged to work with their state NDN facilitators to help school adopt PRISMS into their curricula. A grant was awarded to the PRISMS Project by the NDN for $514,000 to aid in the PRISMS dissemination through September of 1995.

Dissemination information

Surveys were sent to teachers in the spring during the first year of implementing PRISMS. An attempt was made to determine the effects that PRISMS had on the teaching strategies teachers employed and responses of students to this approach of teaching physics.

Teachers significantly increased the number of laboratory activities in their teaching and especially the use of exploratory activities prior to the introduction of a concept. The teachers perceived that students were being challenged more to cultivate reasoning, science problem-solving skills, critical and independent thinking now that they were teaching with PRISMS compared to before they implemented PRISMS. Students were also doing a better job relating physics to common experiences.

Teachers were asked on the survey to report their physics enrollments prior to PRISMS and the current enrollment. It was not uncommon to see enrollments in physics in some schools double or triple. Teachers reported in a survey that the average increase in student enrollment in physics was a 39%. These schools reported 36% of the graduating class taking a physics course, whereas the national average was 20%.

Some comments from teachers regarding PRISMS: "PRISMS has made physics fun. It has given me more confidence as a teacher and encouraged me to continue to seek out new ideas." "I love this program!" "This has been a boost to my creativity, have gone on to develop my own activities." From a teacher who teaches in an urban girls school: "You have the best physics program for my needs." "We now teach physics every year instead of every other year."

Monitoring Retention of the Project and Key Elements

A telephone survey was designed to assess the retention rate of PRISMS in schools that had adopted the program in the fall terms of 1986 or later. Numbers were assigned to all the teachers that had taken a PRISMS workshop from which 50 teachers were randomly selected for the survey. Of the 50 teachers selected contact was established with 47 of them. All 47 teachers claimed to still be currently using PRISMS or using it during the last year they taught physics. This was a very striking retention, but does not attempt to determine the level of use. A question was asked, "To what degree did you implement the program immediately after taking the workshop?” Forty-three out of 47 (91.5%) of the random sample started with an appropriate implementation of PRISMS. Three out of 47 (6.4%) showed limited implementation and one (2.1%) showed no implementation of PRISMS.

The next question was, "How would you compare your current use of PRISMS to when you first implemented the program?" Now 87.2% showed an appropriate level of implementation, and 12.8% showed limited implementation. The highest level of implementation may be when participants apply the teaching strategy of PRISMS to other courses that they teach. Forty-two percent of the teachers reported that they were applying the learning cycle teaching strategy to other courses that they taught.

One of the needs that PRISMS seeks to address is to make physics more interesting to students with applications to phenomena that are of interest to them. In the telephone survey teachers were asked whether student interest in learning physics had increased, remained the same or decreased from the time they implemented PRISMS. Eighty-seven percent of the teachers indicated that their student interest had increased. To support the observation that student interest in physics has increased, student enrollment increases were reported by 87.2% of the teachers in the survey. One teacher in Alabama reported that his enrollment in physics increased from 32 students to 160 students in just a few years.

Academic year 1992-93 Revalidation study for NDN

Curriculum projects that are incorporated in the NDN must be revalidated to show that they continue to provide positive results in schools where they are implemented. The revalidation process requires additional research on current practices for each project. The population for the PRISMS revalidation study was taken from the group of schools that were part of the national cadre of physics teachers in the 1988 summer PRISMS Project. These teachers then identified a teacher that taught physics in their area in a school as similar to their situation as possible. This included selecting teachers that had a similar background in terms of experience and background preparation. It involved students from 34 matched pairs of schools.

The New York Regents High School Physics Examination and the Test of Integrated Process Skills was administered on a pre-posttest basis in early September, 1992 and early May, 1993. New questions are written for the Regents Examination each year and, hence two consecutive year's tests were used as two separate forms for pre and post testing. The PRISMS students showed significantly greater gain in understanding basic concepts in physics. This confirms that by using an activity based learning cycle approach students gain a deeper understanding of basic concepts in physics.

On the five different integrated process skills, namely, identification and control of variables, stating hypotheses based on collected data, evaluating operational definitions, judging the design of an investigation, and graphing and interpretation of data, the PRISMS students' gain was significantly greater than the non-PRISMS students' score.

Based on this research study PRISMS was revalidated as an exemplary curriculum and recommended for continued adoption by the NDN. The program continued to flourish through the promotion and distribution by the state facilitators and trained PRISMS teachers who conducted workshops for teachers in their area. During the years from 1986 – 93 over 2,000 teachers participated in these workshops through the support of the U S Department of Education by way of the NDN. In this same time period nearly 1200 schools adopted the PRISMS curriculum which affected approximately 64,000 students.

PRISMS Enhancement

The PRISMS Project was funded by NSF from April, 1998 to September, 2002 for enhancing the project. The objectives of the PRISMS enhancement project, were: a) to add activities to show connections of basic ideas in physics to other fields of study, such as: biophysics, astronomy, physics of sports, meteorology, acoustics, and alternative energy sources; b) to add and rewrite activities to give students a deeper understanding of the basic ideas in physics which often cause difficulty for the learners; c) to add and rewrite activities to increase the level of learning by inquiry to include longer term projects; d) to develop additional authentic assessment activities to be aligned with the method of instruction as described in the National Science Education Standards; and finally e) to add and rewrite activities to incorporate technological design and to show the interplay of science and technology such as in the development of computerized sensing devices for displaying and analyzing data.

Some of the enhancements occurred within the learning cycle. Previously concept development was left largely to the discretion of the teacher, thinking that this was the specialty of the teacher. However, it was recognized that often times there was not the logical transition made from the exploratory activity to concept development. Consequently, specific concept development activities were created that should lead the student to construct the desired concept with some guidance. A conceptual enhancer activity followed with additional explanations to enforce the concept. Conceptual practice activities were added to give students added opportunities to utilize the concept to problem situations. The application activities ended with thought questions in "Developing and Using Scientific Ideas." A final part of the application was to "Extend the Activity" to situations outside of the laboratory to explain normal life situations in which the main concept was couched.

In addition to technological advances incorporated into the PRISMS activities, there were other programs that applied current technology. One such program, Constructing Physics Understanding, (CPU) developed at San Diego State University, was a program that simulated many phenomena not possible to conduct in the classroom and allowed students to collect data and graphs from these simulated events. This information was helpful in also developing concepts and was referenced in the PRISMS guide. The original PRISMS test bank was expanded with questions keyed to the concepts in the curriculum. It was also made more user friendly and compatible to both PC and Macintosh users.

Larry Escalada joined the University of Northern Iowa Physics Department in 1997 and joined Tim Cooney and Roy Unruh as codirector of the PRISMS Project. He also contributed to additional learning cycles in the area of modern physics.

The teacher's guide was also enhanced. The concepts in each learning cycle that relate to concepts in the National Science Education Standards (5-8 and 9-12) and Benchmarks for Science Literacy (6-8 and 9-12) were identified. The guide identified science process skills (observing, classifying, inferring, predicting, hypothesizing, or formulating models) that were most likely encountered in each activity. Reasoning indicators (proportional reasoning, combinatorial logic, hypothetical/deducting thinking, controlling variables, and reflective thinking) are also identified that students would encounter.

During the summer of 1998 five master teachers worked with three scientists and the project directors in developing activities and learning cycles to enhance the PRISMS Project to include: Holography, modern physics, meteorology, astronomy, biophysics, physics of sport and technology. The master teachers field tested the enhanced materials and authentic assessments and provided feedback for rewriting during the summer of 1999. Based on feedback and evaluations received from field testing, master teachers revised materials for final adoption.

During the summer of 1999 twenty experienced PRISMS trainers from diverse schools across the country were brought on campus for a workshop to prepare them to conduct PRISMS workshops with the new enhancements. These trainers conducted workshops for teachers across the country.

At one time NSF published projects that it supported, but during this PRISMS funding period NSF encouraged curriculum projects to find publishers that were interested in publishing these funded projects. The directors of the PRISMS Project sought interested publishers and were contacted by Centre Pointe Learning. An agreement was made with Centre Pointe for the publishing of the enhanced project, which was called PRISMS PLUS. Centre Pointe Learning was a small startup publisher and was not able to build up sufficient volume of projects to continue with the publishing of PRISMS PLUS.

Larry Escalada became the principle director after 2001 and continued with conducting PRISMS workshop at UNI. The PRISMS PLUS materials are currently available to be purchased through the UNI Physics Department in computer disc format.

PRISMS gained international exposure by way of presentations and workshops in several countries. The NDN conducted awareness workshops in American Samoa which included PRISMS. Demonstrations in teaching physics with the PRISMS approach were presented at Hebei Teachers University, Hebei Province, Peoples Republic of China. Workshops on PRISMS were presented at the International Conference on Physics Education three different times in an eight year span at Puebla, Mexico. PRISMS was also presented in Mexico at the Autonomous National University of Mexico, Mexico City and at the Mexican Academy of Natural Science Teachers National Conference, Vera Cruz, Mexico. An invited presentation on PRISMS was given at the VI Inter American Physics Education Conference in Argentina, followed by a workshop for high school physics teachers in Argentina on the methods and materials of PRISMS. Two invited presentations on the methods and activities of PRISMS were given in St. Petersburg, Russia. One was at the Herzen Pedagogical University of Russia and another at the International Conference on Physics Education. Science teachers from Taiwan also participated in the activities, methods, and materials of the PRISMS Project.