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Final Report to the Concord Consortium and the National Science Foundation on the Technology-Enhanced Elementary and Middle School Science (TEEMSS) Project

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1. Background for this Final Report.

On June 3, 2001, Ms. Carolyn Staudt of the Concord Consortium sent this reviewer an e-mail regarding the possibility of an outside review of the progress of the Technology-Enhanced Elementary and Middle School Science (TEEMSS) Project. A summary description of the project was also forwarded by e-mail on that date. On June 17, 2001 this reviewer contacted Dr. Gerhard Salinger of the National Science Foundation (NSF) indicating that he had been contacted by the project. Further communication with Dr. Salinger (8-13-01) revealed that NSF was interested in responses to the following questions regarding the progress of the TEEMSS Project.

1. What are the project's goals?
2. What activities has the project taken to meet these goals?
3. What evidence is the project developing to meet these goals?
4. Will the use of probeware help students to learn effectively?
5. Does the project have a good balance between developing and testing instructional materials and developing probes?
6. Will teachers be able to use probeware effectively?

Subsequent to the communications by e-mail with staff at the Concord Consortium and with NSF, a copy of the original proposal (NSF#9986419 - 8/15/99) and a letter modifying the goals and activities of the original proposal (Dr. Robert Tinker to Dr. Gerhard Salinger - May 11, 2000) were sent to this reviewer. A visit was arranged to allow this reviewer to meet with the TEEMSS staff, observe the development of materials with teachers on August 28 and 29, 2001 and to schedule activities to take place during the entire evaluation.

During these dates it was decided that visits would be made to schools in Boston and Maynard, Massachusetts, and in New York City to see how the hardware and software developed by TEEMSS was working in classrooms. These visits were tentatively scheduled for the months of November through January when teachers had scheduled the necessary time to fit the units into their school programs and to give their students sufficient exposure to them. However, delays in the development and receipt of materials pushed these dates back to May of 2002.

After these visits a draft of the reviewer's final report was submitted to TEEMSS project personnel to check it for accuracy. Then the final draft was submitted to Concord and to the National Science Foundation.

On October 11 and 16, 2001 this reviewer received phone calls from Ms. Staudt indicating that an interim report was required by NSF by November 1, 2001. This deadline did not allow for visits to the various classrooms scheduled to try the materials and, thus, did not permit an appropriate evaluation of questions 4 and 6 listed above. Further, the preliminary report was be able to address only partially the goals (listed in Section 3 below) of the project as, again, classroom observation is a necessary activity for such an evaluation. Thus, the preliminary report was confined mainly to addressing NSF questions 1, 2, 3 and 5 as they applied until October 25, 2001. A copy of the preliminary report was then sent to Dr. Salinger on October 25, 2001.

As the project progressed, this reviewer remained in contact with Dr. Robert Tinker, Ms. Carolyn Staudt and other TEEMSS staff members. Materials, both instructional and probeware, were sent to him at the beginning of April, 2002 for his review. A schedule for classroom visitation was determined. The dates were strongly affected by the receipt of the instructional materials in the classrooms. As mentioned above, materials acquisitions were delayed yet arrived in time to allow them to be put into use during May of 2002.

Classroom visitations took place in Maynard, Massachusetts on May 20, 2002 and in Dorcester and Brookline, Massachusetts on May 21, 2002. Further classroom visits took place in two schools in New York City on May 31, 2002. Finally, an online course was initiated in the spring of 2002 for a second cohort of teachers. These teachers also provided instruction in materials developed by the TEEMSS Project. A questionnaire was sent to them by this reviewer to determine their feelings about various aspects of the materials and hardware and specifically about NSF Questions 4 through 6.

2. Organization of the Project and its Timelines

Since the award letter for the Project in October of 1999 some changes and management and schedule have occurred. Robert Tinker remains the Principal Investigator. Carolyn Staudt has moved from the position of Director of Training to Project Director for the TEEMSS Project. Stephen Bannasch is Director of Technology, Melissa Chatfield is Research Assistant, Scott Cytacki is Senior Program Developer, Dima Markman is Program Developer Assistant, Ed Hazzard is Curriculum and Materials Developer Assistant, Shari Metcalf is Research Software Developer, Cynthia McIntyre is Professional Development Specialist.

Discussion with members of the staff proved informative and fruitful. In every instance they were open, forthcoming and cooperative in their responses to questions. This reviewer would like to thank them all for their hospitality, warmth, and considerable help in providing the information for both the preliminary and final reports.

The original proposal to NSF had a start date of April-June 2000 with an initial workshop to be held for three weeks in July-August 2000 at Concord to develop the initial drafts of the investigations. The first tryouts were to be held in September 2000 to June 2001. During this period there were to be revisions of the materials as practice dictated, initial dissemination activities and online workshop development and testing.

Under the original proposal, a one-week meeting with the teacher/developers was scheduled for July-August 2001 to be held in Cleveland. The purpose of this meeting was to coordinate the final revisions of the materials, and to provide professional development for a new cohort of twelve teachers. From September 2001 to March 2002 all 26 sites in the project were to be evaluated. Arrangements were to be made for publication of the materials. Efforts to disseminate information about the materials were to be undertaken including the use of online workshops. From April to June 2002 analysis and reporting of the summative data was to be accomplished along with final dissemination about the project. These dates have been pushed back to July and August of 2002.

The goals, activities, funding, and the timeline of the original proposal were modified as a result of a letter of agreement between the project and NSF (May 11, 2000)[1]. In this letter the number of units to be developed was reduced from five to two. The idea of using software (Pedagogica) to help monitor student direction and performance was introduced. The grade range of materials to be developed was changed from 2 - 8 to a concentration on grades 5 - 8. The evaluation of the project was altered to include the use of the student performance information derived from Pedagogica (Letter of May 11, 2000 p. 5).

The Award letter from NSF listed August 15, 2000 as the official start date for the TEEMSS Project. The Concord Consortium actually started the project on May 16, 2000 with permission from NSF to start 90 days prior to the official starting date. The Project planned to deliver curriculum, probeware, and software by November 30, 2001. However, this timeline slacked a bit because of probe production issues. The materials were delivered in the spring of 2002 with instruction getting underway toward the end of April and the beginning of May. The original 19 teachers who took part in the workshop at Concord from August 25-31, 2001 (See section 4 below) were asked to complete the two learning material modules by February 15, 2002. Again, this date slipped because of delivery issues. The online course for 10 -12 new teachers started on March 2, 2002 and continued until June 18, 2002. The web site remains open as a Backup Course to allow for further comment and discussion by participating teachers. All these dates are before November 30, 2002 which is the end date for the project.

Oversight of the internal evaluation process is under the direction of Dr. Shari Metcalf, a staff member at Concord. She has developed pre- and post-tests and protocols used for classroom observations to address the research questions formulated by the project.

3. Goals of the TEEMSS Project

The purpose of TEEMSS Project is to demonstrate the applicability of probeware and associated instructional materials in middle school (grades 5 - 8) science, mathematics, and technology programs. The project takes a systemic approach to the questions of applicability, costs, professional development, and program design. While the TEEMSS project is focusing on two topic areas, it is supposed to provide data indicating how probeware and instructional materials can be used in other areas of science, mathematics and technology in the middle school.

The use of probeware (probes and associated software) at the high school level is not new. The principal investigator of this project was himself instrumental in introducing them into the schools several decades ago. Since that time commercial vendors such as Vernier and Pasco have entered the field and developed some 40 or 50 different probes, as well as interfaces and associated software. However, for the most part, such materials are not as yet prevalent at the middle school level. Nor do they, at this time, make extensive use of handheld computers.

The goals of the project as articulated in the original proposal from Concord to NSF (August 18, 1999) and modified in a subsequent letter to Dr. Gerhard Salinger from Dr. Robert Tinker (May 11, 2000) are as follows. The project will

A. demonstrate the educational potential of inexpensive probeware and handheld computers,
B. demonstrate how typical teachers can…meet difficult math and science standards using materials that are inexpensive and easy to implement.
C. measure teacher success by observing whether student activities are successfully implemented and students are successful in…achieving the learning goals.
D. utilize Pedagogica to record student actions, control available options, determine application state, and interact directly with the user. This software is an important tool for giving… a practical and low-cost way to monitor, in detail, the performance of students at remote sites. Pedagogica scripts can provide embedded assessment of student performance.

The TEEMSS project introduces several innovations. It makes use of handheld computers. These devices have a power, flexibility and potential greater than calculators used in many currently developed portable packages (calculator-based labs) used with probes. Further, the TEEMSS project was to have a unique feature that might have had considerable meaning for student instruction and assessment. This was the Pedagogica software package. (Goal D) This package supported the other aspects of the project, and provided guidance to students as they progress through their activities. As it turned out, memory limitations of the handheld precluded the use of the Pedagogica package. Therefore, strictly speaking, Goal D was not met. However, curricular materials were written for the handheld that allowed the teacher to monitor student progress as they moved through their science investigations. Student responses to an investigation can be entered into the handheld using either a handwritten format or by use of a built in keyboard. These responses can then be beamed to the teacher. Teacher commentary on such progress can then be returned in a similar manner to each student. In essence this can provide a 'paperless' activity. Still, these activities are not as robust as Pedagogica.

4. The Curriculum and Probeware Development Workshop (Cohort I)

In her initial contact with this reviewer Ms. Staudt indicated that a workshop was to be held for teachers involved in the development of the materials for the project. This workshop, to assist in developing the instructional materials and software for the use of probes and handheld computers, was held in Concord, Massachusetts from August 27 to August 31, 2001. The materials are designed to help students understand the underlying science concepts, as well as to collect and analyze data from the various investigative activities that support such understanding.

A visit by this reviewer was scheduled for August 28 and 29, 2001 to allow him to discuss the organization of the project with the TEEMSS staff, as well as to interact with teachers and staff developing the curricular materials and probeware.

The one-week workshop held at the Concord Consortium form August 27-31, 2001 was attended by nineteen teachers and members of the TEEMSS staff. The teachers were from Israel (3), Australia (4), and the United States (12). Teachers from the United States came from the following towns and cities: New York City, New York (2), Brookline, Massachusetts (8), Boston, Massachusetts (1), and Maynard, Massachusetts (1).

The workshop was well organized and gave participating teachers time to try out the probes and handheld computers for activities involving force, and speed and acceleration. The workshop also featured discussion sessions to allow teachers to exchange ideas as to how to improve the probes and the investigations from both a content and pedagogical point of view.

An interesting, and useful, feature of the sessions was to give teachers the opportunity to comment on the ways in which the software should be changed to meet instructional needs. An adept programmer (Scott Cytacki) was on hand to make the changes almost immediately. This gave teachers the opportunity to see some of their suggestions in action.

The handheld computers (some 470 Palm IIIc handhelds were donated to the project by the Palm Computer Company) offer a power and flexibility that is not available through the use of graphing calculators. They also give students the opportunity to transfer (beam) their results to the teacher and to other students in the classroom.

5. The Unit Outlines

There is one instructional unit for Forces and Motion and one for Transfer of Energy. Each of these units addresses a National Science Education Standard[2] and each contains five investigations.

For the unit on Forces and Motion the investigations are

- Air cart
- Tracker
- Propeller
- Collision I
- Collisions II

For the unit on Transfer of Energy the investigations are

- Heat Flow
- Potential and Kinetic Energy
- Heating with Electricity
- Forms of Energy: Single Transformations
- Forms of Energy: Multiple Transformations

Curricular materials have been written for the investigations. Each of the investigations is structured and includes topics (as shown for the Propeller activity) such as

- Introduction
- Thinking About the Question
- Materials
- Safety
- Trial I: Measuring the force of a propeller
- Trial II: Measuring the force of a propeller in the reverse direction
- Trial III: Measuring the force of a sail on a propeller-driven cart
- Technical Hints
- Analysis
- Further Investigations

The investigation has the student interact with the handheld computer for information, data gathering and analysis, and response purposes. This information is managed by the software in the handheld and can be beamed to other students and to the teacher.

Over the years, the terms 'inquiry' and 'discovery' have often been used interchangeably. The TEEMSS procedure is more akin to Muska Mosston's 'Guided Discovery'[3] approach or Robert Gagne' s concept discovery[4] than to the more open-ended discovery or inquiry approach espoused by J. Richard Suchman in his Inquiry Development Project[5] or that suggested by the National Science for Education Standards[6]. The NSES definition includes having the student design the experiment. Although targeting 'inquiry', each TEEMSS investigation is structured and generally follows the sequence listed above. The students are posed with a question and given an opportunity to discuss it. In the classes observed by this reviewer much of this discussion took place before the activity (pre-lab). The labs themselves are structured with considerable step-by-step instruction and some questioning along the way. This fosters a guided discovery approach rather than strictly adhering to the definition of inquiry as stated in the NSES document. Still, as can be seen from teachers' responses (areas of concern - Section 7) they often view guided discovery and inquiry as the same.

All curricular materials as outlined above are contained in the handheld. Thus the student is led through the concept development, the content needed for this development, instruction in the use of probes, and the data gathering and graph representation used in supporting the understanding of the concept. Updates for any of these are downloaded from TEEMSS headquarters.

6. Classroom Visits - May 2002

Project staff scheduled this reviewer into five classrooms in the towns mentioned above. The Table below provides some salient information.

School	Grades	TEEMSS Offered In Grade	Number of TEEMSS Students Observed
Fowler Middle School, Maynard, MA	4-8	6	24
Jeremiah E. Burke H.S., Dorcester, MA	9-12	9	12
Pierce School, Brookline, MA	K-8	8	16
Mott Hall Middle School, PSIS 223. Manhattan, NY	4-8	6	25
Raphael Cardoso y Molinar School, PSIS 184, Bronx, NY	6-8	8	23

During each visitation Ms. Staudt and various other members of the TEEMSS staff accompanied this reviewer. About a half-hour to an hour was allocated for the reviewer to be alone with the teacher so that his questionnaire protocol might be completed on a one-to-one basis.

Teachers were favorably disposed to the goals of the project and were aware that they were using techniques to enhance the learning of various concepts and skills. (NSF Question 4) While they were positively impressed with the labs and the questioning approach used in the text in the handheld, they took particular note of student learning regarding the analysis of graphs developed by data gathered in 'real time'. This may not be surprising since a significant portion of the lab time is spent on gathering data and seeing it displayed in the form of a graph on the screen of the handheld. Still, analysis of data in a graph format is considered of importance by the national standards in both science and in math.[7]

It must be noted that project TEEMSS staff interaction with the teacher at each location visited was most impressive. The teacher-project staff communication system devised by TEEMSS is particularly worthy of note. Teachers commented that their questions are answered almost immediately and authoritatively by e-mail. Further, they are visited by at least one team 'researcher' at frequent intervals - often weekly. These researchers not only observe what is taking place in class, but also provide technical support. While he has not seen this, the reviewer was told that for teachers in far-off locations such as Israel or Australia, a 'researcher' is also on hand to provide support. Teachers interviewed felt this face-to-face interaction was of considerable help in piloting the units.

Students appeared to have little difficulty relating to and using the handhelds. Teachers indicated that it took about two to three class periods to make them feel at home with these devices. Still, some students did experience difficulty in finding some data gathering sites for the appropriate activity on the handheld. In some instances - a few - they had difficulty with the correct connections of the probe to the handheld. But the teachers, or staff members present, were able to assist them quickly.

The desire of the TEEMSS staff is to move toward a 'paperless' lab with all student activity beamed to a teacher and responses beamed back. Still, some teachers interviewed preferred hard copy. In one instance, a teacher in a school where the students had reading difficulties wanted hard copy with boldface questions to attract their attention. It should be noted that the TEEMSS staff provided these materials quickly. The use of 'paperless' vs. paper provides an area that could be an area for some research - particularly for students with different learning styles and reading backgrounds. The TEEMSS Project has developed an approach in which the source documentation can be formatted for display in several different technologies, through the handheld, desktop, or hard copy generated from pdf files. Again, the use of these various technologies for instructional purposes provides a source for research.

7. The Online Course (Cohort II)

An online course for TEEMSS was developed and administered starting in March of 2002. Access to the course was provided to this reviewer so that he might observe its content, approach and pedagogy. He found the course to be carefully constructed, with its content and pedagogy consistent with what had been offered to those teachers who took the summer institute (Cohort I). The science content is the same as that piloted by the first cohort and is mentioned in Section 4 above.

Eleven teachers took the TEEMSS Online Course. The TEEMSS Project Manager reported a fee of $1000 was required for each teacher taking the course. For this fee the teacher received approximately $8000 worth of course instruction, handhelds and probeware for his/her classes, and online interaction with project staff and other participating teachers.

This reviewer e-mailed a brief questionnaire to all eleven participating teachers asking about their feelings relative to various aspects of the course. Responses were obtained from seven. Most of the questionnaire used a Likert Scale approach. For all questions using that approach the teachers responded with a 4.32 on a 1 through 5 scale - quite good.

Some specific responses were quite favorable with regard to

- Ease of access to the course
- Communication with the online instructor
- Relation of online course content to what is normally being taught in class
- Instruction in use of the handheld computer
- Instruction in the use of probes
- Instruction in the content of the lab activities
- Value of handheld technology in teaching aspects of science content and process
- Assistance in measuring student progress
- Communication with fellow teachers

A few areas that caused some concern were

- Fragility of some probes
- Lack of student use of Website
- Late receipt of probes
- Offering the unit materials late in the year
- Shortness of the timeline for offering the course materials to the students
- Hard sell on inquiry approach rather than content

8. Overall Observations

It is clear that considerable effort has gone into the development of the units offered by TEEMSS. The team is efficient, effective and caring. This reviewer has the following general observations.

- The TEEMSS project is proceeding after what appears to have been a modification of its goals, activities, timelines, and funding. Despite some delays, the project has made considerable headway in meeting its timeline.
- Management and staff are quite competent and well-versed in the content, pedagogical approaches and technology necessary to develop the activities required to meet the project's goals.
- A vendor - Fourier Industries of Israel - is providing probes, thus contributing to the attainment of Goal A of the project.
- The development of the curricular materials has taken into consideration the expertise of practitioners. Nineteen classroom teachers were involved in a critique of the probeware and in the development of the instructional materials. Eleven teachers have taken an online course and have provided their feelings about the course content and pedagogical approaches.
- An online program was offered, to assist a second cohort of eleven teachers taking part in the TEEMSS project. This course - according to a questionnaire e-mailed to them by this reviewer - received high marks with regard to content, communication, and Web-based support. There was concern, voiced by both cohorts of teachers, about the lateness in the year in which the materials arrived.
- A series of research protocols has been developed to assist in the internal evaluation of the project. These range from classroom observations to analysis of data provided from student progress as a result of their investigations - this latter type of

information now supplied mainly by some classroom visitation and pre and post-testing. These data are in the process of being reduced and analyzed.

- In the first cohort, teachers from diverse backgrounds, towns, cities, countries and ethnic backgrounds were involved in the development of the materials.
- The science units are designed to meet the National Science Education Standards for Grades 5-8 of Motions and Forces and Transfer of Energy.[2] Five investigations have been written for each unit. The layout for each investigation is structured in a manner to give guidance to the students as they progress through the investigation. The text for the investigations is contained in the handheld. In some schools students appear to use this 'paperless' approach. However, in at least one school - in which reading poses a problem - hard copy still seems to be the preferred approach. This area should be an interesting one for research.
- Investigations were written to be targeted at the grades 5 through 8. A grade span of 6 through 9 was observed in the schools visited. (See Table)
- Some investigations use materials that require significant construction (e.g. air cart).
- Some teachers report that some materials (Smart Wheel, temp probe) are fragile and require replacement.
- A reasonable amount of time is required to acquaint students with the operation of the hand held computers. However, it must be said that overall, the students observed felt quite comfortable using the handhelds themselves. Some did experience difficulty with probe-interface attachments.

9. Response to National Science Foundation Questions.

Project TEEMSS has made considerable headway since this reviewer's first visit last summer. Based upon teacher reaction the development of the materials and the development of the probes are still being refined. However, they have been distributed and placed into use by members of both the first cohort (summer institute teachers) and second cohort (online course teachers).

NSF Question 1. What are the project's goals?

The project's goals are to:

A. Demonstrate the educational potential of inexpensive probeware and handheld computers

The technologies applied to school instruction have increased dramatically over the past few decades. The uses of handheld computers in the schools have not evolved at this point to the extent as have, for example, the uses of probes with handheld calculators in computer based lab activities (CBLs). The use of handheld computers with probeware offers some interesting possibilities. Not the least of these is the opportunity for the handheld to

- include both the text and graphics of lab investigations,
- allow for downloading new and updated learning activities.
- allow for portability for investigations taking place beyond the lab bench,

- provide the data gathering and data analysis abilities available on larger computers,
- transfer information from student to student or between teacher and student by 'beaming',
- follow a student's progress through an investigation,
- assess the quality and quantity of such progress, and
- hold out the interesting prospect of 'paperless' investigations. (Which will undoubtedly prove to be an interesting area for research.)

The use of management software - reducing the data obtained from the student's moves in the investigation - allowing the teacher to more easily determine student progress made and thus the prescriptions needed to improve it has not as yet been fully implemented.

In the judgment of this reviewer the educational potential of this approach is significant and meets the goal stated above. With regard to the goal statement of 'inexpensive' probeware, this will probably be affected by market pressures as the development of handhelds for lab purposes progresses.

B. Demonstrate how typical teachers can…meet difficult math and science standards using materials that are inexpensive and easy to implement.

The standards for this project were derived from the National Science Education Standards[8] and the National Council of Teachers of Mathematics[9]. These are the standards mentioned in the letter of May 11, 2000. The degree to which they are met is being determined as a part of the research taking placed in the classroom phase of the project.

Dr. Sheri Metcalf is responsible for this aspect of the project. Surveys have been developed to determine teacher teaching style, classroom experiences with the instructional and probeware materials and methods of student assessment. Pre- and post-tests of student achievement have been developed and applied. In addition protocols for classroom observation have been developed and put into use.

What will be needed here are definitions for the words 'typical teachers' and 'inexpensive'. While the teachers taking the August 25-31, 2001 workshop represented diverse situations, they were highly motivated to attend the workshop and to take part in it. For the cohort assembled for the spring, these teachers were self-motivated in that they took the initiative to get the program into their schools. The characteristics (education background, years of experience, geographic location, etc. for middle school teachers - data available from various sources, federal, state, professional associations) of such teachers be 'fit' to those of a 'typical' middle grades teacher are needed. They, understandably, seem to be secondary to attracting teachers into the program.

The term 'inexpensive' can have two interpretations. One is 'inexpensive' as compared to other similar types of materials on the market. Again, this reviewer feels that some of the material developed by this project has a different potential than that provided by materials presently on the market. When, and if, similar types of materials are developed by other projects or by vendors then 'inexpensive' will have greater meaning. The second interpretation could be 'inexpensive' as compared to yearly school expenditures for science. Such information is available. Many school budgets are divided into equipment, supplies, and text account lines. These will vary from year to year. A five-year average is sometimes used to develop such figures since purchases vary from year to year and since the degree of emphasis on a particular subject for a given year may also change.

C. Measure teacher success by observing whether student activities are successfully implemented and students are successful in…achieving the learning goals.

Observations by this reviewer indicate that the students are capable of using the handheld computer and probes. When questioned, a number of students appeared to be able to understand the graph and its trends. An understanding of the science concepts was not as clear. A fuller determination of student understanding of the science concepts remains for the analysis of the data from the pre and post-tests and information gathered from the classroom observation protocols developed by the project. This information will then provide an indication of teacher success.

D. …..utilize Pedagogica to record student actions, control available options, determine application state, and interact directly with the user. This software is an important tool for giving… a practical and low-cost way to monitor, in detail, the performance of students at remote sites. Pedagogica scripts can provide embedded assessment of student performance.

The use of the Pedagogica software was not implemented.

NSF Question 2. What activities has the project taken to meet these goals?

Project Goal

A …demonstrate the educational potential of inexpensive probeware and handheld computers.

The teachers interviewed believe there is considerable educational potential in this approach. They are enthusiastic about the use of technology to help students understand science concepts and to participate in the investigations needed to support an understanding of these concepts.

In order to achieve this potential the Project has taken the following steps

- A competent staff has been organized to work on the project. Some changes in personnel have taken place since the submission of the original proposal, but to this point, the project is meeting its revised timeline.
- The scope of the units, the outline of the investigations in these units, and their content and pedagogical approaches have been prepared.
- A workshop was held in August, 2002 so that practicing teachers could critique the probeware, some of the investigations, and their associated instructional materials
- Probes for the units have been developed
- Certain research protocols have been created to determine the effectiveness of the materials in classroom situations
- Discussions have been, and are, taking place with vendors to determine how to keep the costs of the production and distribution of the probeware to a minimum
- An online professional development program for the instruction of the second cohort of teachers has been developed and is in operation.
- A web site for the project has been configured. This site provides information about the project, an outline of the investigations for each unit, and for the investigations, the step-by-step procedures for accomplishing them.

B. ….demonstrate how typical teachers can…meet difficult math and science standards using materials that are inexpensive and easy to implement.

The test for the attainment of this goal is to see how well students meet these standards. The project has developed a pre and post-test protocols to determine student gains. Classroom observations by this reviewer show that students are interested and excited about the use of technology to help with their science investigations. Many move easily through the sequences provided by the handheld computer. Data from the pre and post-test protocols will provide more definitive information.

C. ….measure teacher success by observing whether student activities are successfully implemented and students are successful in…achieving the learning goals.

Observations by this reviewer indicate that students are receiving experiences in gathering data, and in analyzing those data. The 'trend analysis' of temperature and speed seems to enhance their understanding of these concepts. Once again however, an analysis of the pre and post-test data sent in has not as yet occurred. It is scheduled for July and August of 2002.

D. …utilize Pedagogica to record student actions, control available options, determine application state, and interact directly with the user. This software is an important tool for giving… a practical and low-cost way to monitor, in detail, the performance of students at remote sites. Pedagogica scripts can provide embedded assessment of student performance.

This activity did not take place and thus the goal was not met. Pedagogica required a greater amount of memory than was available on the handhelds presently in use. The internal evaluation is using pre and post-testing, as well as classroom interview and observations, but these do not provide the type of specific monitoring information suggested in the goal statement.

NSF Question 3. What evidence is the project developing to meet these goals?

Project Goal

A. ….demonstrate the educational potential of inexpensive probeware and handheld computers,

This reviewer is of the opinion that the approach taken by the TEEMSS project to use technology for hands-on science investigations has considerable educational potential. The investigations seen thus far are interesting and challenging. The use of the technology makes them exciting and provides students the opportunity to exercise their creativity - albeit in a structured format.

B. ……demonstrate how typical teachers can…meet difficult math and science standards using materials that are inexpensive and easy to implement.

Discussion with selected classroom teachers and a questionnaire to teachers taking the online course indicate that the curriculum materials provided and the supporting technology assists them in moving to meet the science and math standards.

C. …measure teacher success by observing whether student activities are successfully implemented and students are successful in…achieving the learning goals.

As stated for NSF Question 2 Goal C above.

D. utilize Pedagogica to record student actions, control available options, determine application state, and interact directly with the user. This software is an important tool for giving… a practical and low-cost way to monitor, in detail, the performance of students at remote sites. Pedagogica scripts can provide embedded assessment of student performance.

As stated for NSF Question 2 Goal D above.

NSF Question 4. Will the use of probeware help students to learn effectively?

Based upon discussion with classroom teachers and questioning online course teachers there is a favorable feeling about the use of probeware to help students learn. They believe it adds a dimension to their pedagogical approach in the classroom. They liked the collection of data and a graph interpretation in 'real time'. Students seemed to enjoy the 'hands-on' features of the materials. They particularly welcomed seeing the graphs as they developed from the data they were gathering. As was stated above, the analysis of the data from the tests given should provide additional information.

NSF Question 5. Does the project have a good balance between developing and testing instructional materials and developing probes?

The project has emphasized both the development of the probes and the associated software in the context of an instructional situation - namely a science concept and its investigation. The use of probes and instruction in science concepts are intertwined. There is good balance between the development of the instructional materials and the development of the probes. The overall project goals and the specific instructional goals of the two units have dictated this development. Thus, force and motion probes for the dynamics unit have been developed as well as temperature, electrical energy, and light probes for the energy transfer unit.

There has also been work to make the instructional aspects of the project easily available. Student activities (on the TEEMSS web site (http://concord.org/teemss) provide information regarding the student investigations in some detail. Teacher notes provide teachers with the alignment to standards, discussion guides, additional background information, and suggested timelines. Feedback from teachers is used to review the content of the investigations and to make appropriate changes.

NSF Question 6. Will teachers be able to use probeware effectively?

Classroom observation has shown that, for the most part, teachers are able to put probeware into use. While some teachers required assistance on specific details there was good support, either in person, or through e-mail and the WebSite to get them information and instruction in a timely fashion.

10. Summary

Overall, this reviewer believes that the TEEMSS Project has considerable worth. It utilizes a technology (handheld computers and probes) that is, at this time, not found commonly in middle school lab investigations. Further, there is growing evidence that these devices will become more prevalent in schools in the near future[10]. Work done in the TEEMSS Project takes laboratory investigation a step beyond that now available with graphing calculators. Also, the handhelds portability offers possibilities off the lab bench and in the field that are more difficult with larger computers such as notebooks or desktops.

There are several aspects of the project that are worthy of note.

1. The portability of a computer that allows for types of investigation that go beyond those presently available in many middle school science programs.
2. The ability of the handheld to contain lessons, instructions, questions, graphics and other elements that are more often offered in a hard copy textbook or lab manual format.
3. The possibility of moving to a 'paperless' format with information being beamed to teachers and students.
4. The promise of an assessment management system that will help teachers review, score and organize information about student progress.

The TEEMSS project has made good progress on the first three of these aspects. The limitations of the memory in the handheld presently in use have made the fourth a 'promise' at this time. However, this reviewer has seen Pedagogica in development on a desktop, and it is probably a matter of time before this aspect is realized.

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