TEEMSS2: Technology Enhanced Elementary Math and Science - Year 1 Report

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Abstract: Technology Enhanced Elementary Math and Science (TEEMSS2), has the goal of bringing the power of information and communication technology to science education in grades 3—8, by creating and disseminating valuable, proven, and easily implemented technology-based science learning materials and associated teacher professional development. The project has selected age-appropriate, standards-based content for which technology offers real advantages. The learning strategy is based on student investigations of real phenomena using sensors and of virtual environments based on computer models. The new materials take advantage of computers, sensors, handhelds, and electronic networking to more effectively teach students and give them deeper insights into the process of science inquiry. This paper reports on the year 1 formative evaluation of TEEMSS2, which showed both quantitative and qualitative evidence of student learning when teachers implemented the materials in their classrooms.

Background

Technology is an essential part of modern science, but it is rarely used in elementary and middle school science education. Computer and information technologies should be an integral part of elementary and middle school science teaching, in ways that can greatly improve learning. In recognition of the importance of technology, the National Science Education Standards (The National Research Council, 1995), the Benchmarks (AAAS, 1993) and many state standards require the integration of technology into science education to facilitate student inquiry, starting as early as first grade.

Not all uses of technology are equally important for learning science. Multimedia documents, drill and practice, Internet searches, and student-generated reports are increasingly commonplace and do have a role in teaching and learning, but these applications skirt the periphery of science. The core of science is about investigating, exploring, asking questions, analyzing, and thinking. Technology is uniquely able to support inquiry in ways that are largely lacking in elementary science teaching: investigations of real events with probes and investigations using highly interactive models.

A substantial body of research shows that probeware can facilitate student learning of complex relationships (Adams & Shrum, 1990; Beichner, 1990; Friedler, Nachmias, & Linn, 1990; Krajcik & Layman, 1993; Laws, 1997; Linn, Layman, & Nachmias, 1987). Similarly, models and simulations allow students to understand through exploration the behavior of systems that are difficult or impossible to understand by other means (Beichner, 1990; Brassell, 1987; Mokros & Tinker, 1987; Thornton, 1997).

TEEMSS2 (Technology Enhanced Elementary Math and Science) addresses the need for inquiry-based technology for elementary and middle school science teaching through the production of 15 units keyed to the NSES standards that take full advantage of probeware, models and simulations. In support of student activities, the project is producing software, implementation assistance for teachers, and an online course and support for teachers. The project is designed to work with whatever curriculum, computers, and probeware schools adopt.

Project Goals and Objectives

The goal of the TEEMSS2 project is to bring the power of inquiry-based technology to science education in grades 3-8, by creating and disseminating valuable, effective, and easily implemented technology-based science learning materials and associated teacher professional development. The project has selected age-appropriate, standards-based content for which technology offers real advantages. The materials are modular so they can be integrated with existing curricula or used on their own. The learning strategy is based on student investigations of real phenomena using probes and of virtual environments based on mathematical models.

TEEMSS2 is producing 15 units keyed to the National Science Education Standards (NSES) that take full advantage of computers, sensors, and interactive models. Grade levels 3-4, 5-6, and 7-8 will have five units each, targeting the five NSES standards: Inquiry, Physical Science, Life Science, Earth and Space Science, and Technology and Design. Each unit contains two 1-week investigations, each with a discovery question, several trials, analysis, and further investigations. There is also a teacher's version of each investigation, which contains background material and a discussion guide. Table 1 shows the 15 curriculum units, by grade level and NSES standard.

Table 1: TEEMSS2 curriculum units

Standard	Grades 3-4	Grades 5-6	Grades 7-8
Inquiry	**Sound** Explore sound and vibrations with a computer model	**Water and air temperature** Mix fluids and measure temperature changes with a temperature sensor	**Air Pressure** Explore soda bottle, balloons and lungs with a gas pressure sensor
Physical Science	**Electricity** Explore light bulbs, batteries, and wires using a voltage sensor	**Levers and machines** Design and test your own compound machine with a force sensor	**Motion** Graph, describe, and duplicate motion using a motion sensor
Life Science	**Sensing** Compare electronic and human sensing of your environment using temperature and light sensors	**Monitoring a living plant** Monitor a living plant in a plastic bag with relative humidity and light sensors	**Adaptation** Explore population, selection pressure and adaptation with a computer model
Earth & Space Science	**Weather** Observe and measure weather-related changes with temperature and relative humidity sensors	**Sun, Earth, Seasons** Connect planetary motion to day/night cycles and seasons with a light sensor	**Water cycle** Study water phase changes and relate to terrestrial phenomena with temperature and light sensors
Technology/ Engineering	**Design a playground** Study your playground and build models of several pieces of playground equipment using force and motion sensors	**Design a greenhouse** Build a working greenhouse model and monitor temperature, light, and relative humidity sensors	**Design a measurement** Choose something to measure and devise a way to do it using any or all of the sensors

The TEEMSS2 activities are embedded in software (CCPortfolio) that allows students to read the investigation, answer questions, collect data, analyze their results, and save their work within one application. It also allows the collection of formative and summative assessment data, which is readily available through online teacher reports. CCPortfolio is not specific to any manufacturer or platform. It is designed to work with whatever curriculum, computers, handhelds, and sensors schools may adopt. Seven different sensor developers are working with the project to provide sensors to the teachers.

The present TEEMSS2 project rests on a foundation provided by a prior TEEMSS pilot project. The pilot project focused on developing just two units and testing them with three groups of teachers, supporting one group of teachers with a face-to-face workshop and the other groups exclusively with online courses. Units that address the NSES middle school force and motion and energy transfer standards were developed. Because teachers report that these standards are difficult to achieve, they represented a challenging test of our approach. Pretests and posttests aligned to the standards were given to students to measure their learning gains.

The following are the major findings of the TEEMSS pilot project (Metcalf & Tinker, 2003):

- Handhelds and probes are effective in inquiry learning environments. We observed gains in student scores on standards-based tests in classrooms using TEEMSS materials that made extensive use of handhelds and probes.

- Online teacher professional development is effective for preparing teachers to use inquiry-based materials. We measured gains for students of teachers whose only preparation for using these materials was through online teacher professional development.
- Scaffolding is feasible with handhelds. We developed a lab notebook technology for handhelds, CCPortfolio, that provided text support, combining applications, and assessing student work.

Research Design

The research goals for the TEEMSS2 project are to evaluate student learning of the targeted standards, and to evaluate the components of the project: the materials, the teacher training, and the classroom implementation. The TEEMSS2 research evaluation is designed as a two year classroom testing plan. The first year is a formative evaluation of the first 6 units in the classrooms, during the second semester of the 2004-5 academic year. The second year is a summative assessment of all 15 units during the 2005-6 academic year. This paper reports the results from the first year of evaluation.

Fifty-eight teachers were recruited to participate in the evaluation. Participating teachers were assigned to one of two groups, 30 in Group 1 and 28 in Group 2. Group 1 teachers use the TEEMSS2 materials in both year 1 and year 2. Group 2 teachers use the TEEMSS2 materials only in year 2, but cover the content area of the units with their students using their current classroom resources in year 1. Both groups apply pretests and posttests to their students in both years 1 and 2. Analysis of the year 1 data allows comparison of student scores in the untreated vs. treated groups. The year 1 and year 2 data together allows a longitudinal study comparing the effect of the TEEMSS2 materials on similar students taught by group 2 teachers before and after treatment, and for the group 1 teachers, the effects of teacher experience in the second year once they are familiar with using computers, sensors, and interactive models for science education.

The teachers groups were not matched, nor were teachers assigned to groups randomly, Participants were assigned to groups based on the computers available at their schools; Group 1 teachers had desktop computers, and Group 2 had handhelds. The reason for this division was that Group 2 teachers would not use the sensors until year 2, when the sensor interfaces for handhelds would be available for distribution.

The primary purpose of identifying two groups of teachers was to conduct formative testing with a smaller group in year 1, and summative evaluation with all of the teachers in year 2. The year 1 goals for Group 1 were to try out the materials, technology, and software, obtain initial measures of student learning, identify materials that need revision, and prepare for the summative test. The year 1 goals for Group 2 were to collect baseline data by administering pretests and posttests in year 1, as they taught the content of the units using their current practices.

The student pretests and posttests were developed in collaboration with external evaluators at SRI. The tests consist of both multiple-choice and constructed-response questions. The test questions were drawn from existing standardized tests, and supplemented by unit-specific questions developed for TEEMSS2. The questions evaluate student learning of the standards which are targeted by the TEEMSS2 materials. Validity testing of the tests was conducted in November, 2004 for the first nine tests, and a second round of validity testing was conducted in September, 2005, for the remaining three tests. Approximately 60 - 100 students answered each test, and their responses were analyzed in order to select questions that were appropriate for the target grade level, to evaluate inter-rater reliability for scoring, and to compare student performance on matched pre/post variations of questions.

In addition to the pretests and posttests, other data being collected includes teacher surveys, student surveys, embedded assessments within the materials, and classroom observation. The surveys cover background, experiences with the materials, opinions and reflections. The software stores student answers to embedded assessment questions as they use the materials, which will supplement the assessment of student learning. Classroom observations are being conducted by trained observers, using a observation protocol designed with the goals of learning the range of ways in which the materials are used in the classroom, the effectiveness of the experience on a particular day, and typical classroom experiences.

Classroom Implementation in Year 1

The 58 participating teachers in Year 1 were in 17 school districts, at 22 schools, with 1 to 8 participating teachers per school. Teachers were recruited from across the state of Missouri, and 2 additional teachers in Texas. Teachers were expected to use their classroom or school lab computers for the project; the project provided CCPortfolio software and one classroom set of sensors to each school. Each classroom set included seven of each of seven different probes: temperature, light, voltage, relative humidity, force, motion, and gas pressure. All sensors were selected to be compatible with the types of computers available at that school.

The formative assessment for Year 1 started on February 1st with the on-line teacher professional development course. The course began with an introduction and review of inquiry in the classroom, and a discussion of the goals of using sensors for science education. In week 3, teachers were given the CCPortfolio software. During the first week of March, sensor equipment was delivered to all the teachers, and in mid-March teachers were presented with the first units to try out for themselves. Teachers installed the software on their computers, learned how to use the sensors, and, from late March to mid-May, tested out the materials with their students.

Year 1 also served as a formative assessment of the technology. Teachers used the CCPortfolio software on a variety of platforms, and the project was able to identify and fix software problems, improve the functionality of the software and release new versions. There were technical issues with some schools having inadequate computers or less memory than had been required. As the materials were distributed, facilitators spoke with a teacher or administrator at each school to help them get the software and sensors up and running.

The original expectation was for Group 1 teacher to try out two units with their students. However, once delays were accounted for due to spring break, time needed for equipment distribution and technical assistance, and the Missouri Assessment Program (MAP) standardized testing for two weeks in April, most teachers only had time to use one unit with their students. These time constraints also meant that some research teachers were unable to administer posttests to their students at the end of the units.

Quantitative Findings

Twenty-four of the 30 teachers in Group 1 reported using the materials with their students, and spent an average of about 6 hours of classroom time on the units. For Group 1, 19 of the 30 teachers gave at least one pretest and posttest to their students, while in Group 2, 26 of 27 teachers gave the pretests and posttests. This disparity can be attributed to Group 1's time constraints with learning and getting the technology to work, scheduling their school computer lab, and other obstacles to implementing the units. In the following analysis, only those teachers who administered pretests and posttests are presented.

An analysis of teacher background looks at some of the more pertinent teacher variables that were obtained from teacher responses to the presurvey, such as educational level, undergraduate major, and years of teaching experience (see Table 2). There appear to be some differences between the treatment and comparison teachers in terms of their background and experience in teaching science. These differences suggest that there could be "teacher effects" that could explain results, above and beyond the impact of the curriculum units.

Table 2: Teacher background data

	Group 1	Group 2
Educational Backgrounds		
Undergraduate in science	3 (12%)	1 (4%)
Undergraduate in education	8 (44%)	18 (69%)
Other undergraduate degreee	7 (39%)	7 (27%)
Holds graduate degree	7 (39%)	13 (50%)
Average number of years spent teaching	8.6	11.3
Average number of years spent teaching science	8.0	10.5
Average number of years spent teaching at grade level	5.9	7.1

Table 3 shows the descriptive statistics for each instructional unit for which pretests and posttests were given by both Group 1 and Group 2. The data is reported by group, including the number of students in the group, the mean and standard deviation for both the pretest and posttest, and the mean difference.

Table 3: Comparative statistics for pretests and posttests by unit and group

	N	Pretest Mean	Pretest Std Dev	Posttest Mean	Posttest Std Dev	Difference
Unit 1 – Sound						
Group 1	38	12.08	2.67	12.92	2.39	+.84*
Group 2	154	11.95	2.37	13.48	2.45	+1.53***
Unit 3 – Sensing						
Group 1	126	4.77	1.67	5.79	1.7	+1.02***
Group 2	35	5.11	1.23	5.89	1.78	+.77*
Unit 6 – Temperature						
Group 1	252	8.29	4.7	8.44	4.49	+.15**
Group 2	140	6.98	4.27	6.86	4.25	-.10
Unit 11 – Pressure						
Group 1	30	5.33	1.21	6.57	2.00	+1.23**
Group 2	42	6.60	1.90	6.05	2.74	-0.55
Unit 12 – Motion						
Group 1	244	6.57	2.67	8.01	2.69	+1.44***
Group 2	44	6.93	2.27	7.84	2.28	+0.91

* $p < .05$, ** $p < .01$, *** $p < .0005$

Group 1 students showed significantly higher gains from the pretest to the posttest than Group 2 students in two of the five units: Temperature and Pressure. In each of these units, Group 1 scores showed statistically significant gains, while Group 2's scores decreased slightly. A t-test comparing the gains for each of these units showed that gains of Group 1 were significantly higher than for Group 2.

In the other three units, Sound, Sensing, and Motion, the data show that Group 1 students also made statistically significant gains from pretest to the posttest, and so did Group 2. A t-test comparing the gains showed that for each of these units, the gains of Group 1 were no different from the gains of Group 2.

Overall, these analyses suggest that students in both groups showed learning gains on the tests administered to them for the units. In addition, students who took the Temperature and Pressure tests in Group 1 significantly out-gained students who took those tests in Group 2. For the Pressure test, the magnitude of the effect was actually quite large.

Qualitative Findings

In post-surveys, teachers indicated that they liked the units very much, and felt that they were age-appropriate and neither too easy or too hard. Teachers reported that they themselves felt comfortable with the science content and the amount of background information provided. They also provided specific feedback about the units that were used in making revisions. The teachers said that they were looking forward to using the materials next year, and to having more time to spend on the units with their students.

All the teachers participated in the on-line professional development course, in which they learned how to use the materials themselves and then tested them out with their students. Through the on-line course discussion board, teachers were encouraged to report on their experiences using the materials in their classrooms. The teachers posted enthusiastic reviews about the units, reporting that the students were eager to use the sensors, and that "this high interest contributes to the student learning." Teachers described specific examples of students learning science concepts, such as learning to interpret motion graphs or sound waves:

> They have never understood any graph's meaning as well as they did when they had to actually make their own body motion match the line drawn on the pre-existing graph for them. It was incredible to watch even my most cynical students concentrating so hard trying to make their bodies behave the way the predrawn graph did.
>
> My students are using the sound grapher and are really enjoying 'seeing' sounds they make themselves. It is so neat to see the graphic for sound waves. We've learned a lot.

Teachers also appreciated the conceptual questions that are part of each unit, noting that "the questions also caused my students to ask more questions, a true component of inquiry learning."

An observer for the TEEMSS2 project visited three classrooms during the time period that the teachers were using the units. The classrooms observed were of 7th grade students using a motion sensor to make graphs for the Motion unit, 5th grade students measuring changes in humidity for the Monitoring a Living Plant unit, and 3rd grade students using a light sensor to learn about animal senses and eyesight in the Sensing unit. In each case, the students were observed to be engaged and interested in the activity, and learning the concepts being taught. The technology worked and the lesson went smoothly, and the teacher was reportedly pleased with the materials.

Concluding Remarks

In summary, the evaluation of TEEMSS2 in year 1 showed that the teachers were able to implement the materials in their classrooms, and when they did so, there was both quantitative and qualitative evidence of student learning. It was found that overall, students taught by Group 1 teachers, using the materials, showed slightly larger test gains than students taught by Group 2 teachers using traditional teaching methods. Teacher surveys and observations also indicated that both teachers and students were enthusiastic and successful with the materials. Year 1 also allowed the project to test the units, the software, and the sensors and to address any technological issues. The project is now prepared and looking forward to a successful year of summative evaluation in year 2.

In year 2, both groups of teachers will participate in the summative evaluation, each teaching three of the TEEMSS2 units with their students during the school year. For all teachers, student learning will again be assessed through pretests and posttests. For Group 1 teachers, a comparison with the year 1 data will provide the opportunity to evaluate the effects of prior exposure to the materials. For Group 2 teachers, student gains in year 1, without the TEEMSS2 materials, will be compared with student gains in year 2, with the materials.

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