

SKY MATH FINAL EVALUATION REPORT

REVISED VERSION

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INTRODUCTION

In 1995, a team of mathematicians, educators, curriculum specialists, and scientists began the challenging work of designing a middle school module that would weave mathematical learning into a real world context of high interest to students. The subject of focus selected for this unit was weather phenomena and real-time weather data. The plan was to extract math-rich content from the science topic, engage students in hands-on learning, and use technology as a curricular support.

The original proposal provides this description of the SkyMath project:

The University Corporation for Atmospheric Research (UCAR) received funding from the National Science Foundation to prepare a middle school mathematics module incorporating real-time weather data. The goal of the pilot project is to demonstrate that acquiring and using current environmental and real-time weather data in middle school classrooms, in ways that embrace the dynamic and the uncertain natures of these data, will promote the teaching and learning of significant mathematics, consistent with the standards set by the National Council of Teachers of Mathematics (NCTM).

The SkyMath educational strategies and materials [have been] prepared by the Education Development Center, Inc. (EDC) of Newton, MA, a nonprofit research and development organization, in a flexible curriculum module that includes guidance and tools for exploration, plus a collection of resources and activities that use weather and real-time data to teach math concepts.

The end-product will be a loose-leaf handbook, available in on-line or hard-copy form. It will contain a series of activities accompanied by: suggestions for sequencing, assessment strategies for evaluating what students learn and understand, help – for students and teachers – with technologies needed in the classroom, a narrative describing successes and obstacles that have been encountered in the use of SkyMath concepts, and an invitation to assist in further module development. The SkyMath handbook will be completed in 1997.

In Spring 1995, EDC began the module development by working informally with two classroom teachers and interacting with key members of the SkyMath Design Team, a select group of mathematicians, mathematics educators, atmospheric scientists, science educators, technology specialists, and precollege teachers. During the 1995-1996 school year, exploratory tests of the module were conducted in selected classrooms and subsequent revisions were made. In Fall 1996, the module underwent a final, formally-structured field test. After three years of development and revision cycles, the SkyMath module is now in polished form and available for wider distribution to schools.¹

The purpose of the *SkyMath Final Evaluation Report* is to summarize highlights of the process of developing and testing the SkyMath module and present findings from the Fall 1996 exploratory

¹ The SkyMath module and other resource materials are available cost-free through the SkyMath homepage at <http://www.unidata.ucar.edu/staff/blynds/Skymath.html>. Reproducible masters of SkyMath activities are also available in Spanish.

test so that potential users of the module and those who want to broaden its dissemination will have a good understanding of SkyMath's value as a tool for teaching and learning mathematics.

SUMMARY OF EVALUATION FINDINGS

Over the course of development and field testing, the SkyMath module has proven to be a highly effective tool for teaching and learning middle school level mathematics. Some key contributing features are:

- linkage of the SkyMath learning goals to mathematics standards
- connection of mathematical learning to real-time scientific data of high interest and the integration of other subject areas
- ease of use of the module and inclusion of supporting resources for teachers
- use of hands-on learning strategies and application of learning
- inclusion of unit quizzes and the end-of-unit assessment test
- integration of technology that supports the mathematics curriculum and learning goals in a meaningful way

Some key findings that emerged from the evaluation of SkyMath are:

- Students are learning mathematics through SkyMath. The unit strengthens basic math skills, deepens understanding of mathematical concepts, and improves communication about mathematics.
- SkyMath is aligned with national standards for the content, teaching, and assessment of mathematics and science in grades five through eight.
- SkyMath can be aligned well with state and district mathematics standards and district mathematics curricula that build on NCTM Standards.
- SkyMath works effectively as an integrated math and science unit. Students learn mathematical skills in the course of scientific exploration.
- The module can be used successfully with 5th through 8th grade students under a variety of formats and schedules. It can be used as a stand-alone unit or integrated into a school's math curriculum.
- Teachers can adapt the SkyMath materials to accommodate the learning needs of students with a range of math abilities and experiences. Students at all performance levels, including special education, benefit from the SkyMath activities.
- SkyMath is relatively easy for teachers to use – teaching instructions, background information, teacher stories, and resources are all included in the cost-free materials.
- SkyMath offers a non-threatening way for teachers to try new hands-on pedagogy to enrich their teaching repertoire.
- Teachers and students enjoy using the SkyMath module. The study of real-time weather data and the use of technology motivates students to learn mathematics.
- The use of technology and real-time data in the module supports mathematical learning.

Challenges to implementing the SkyMath module are:

- Many teachers are not able to complete the entire module within the estimated six-week time frame due to schedule constraints. Longer blocks of time and schedule flexibility are more conducive to using SkyMath than short class periods.
- Teachers and students need a basic level of computer know-how to use the technology in the module. Schools need a basic level of computer hardware and an Internet connection to support using SkyMath.
- The technology components of SkyMath do not always run smoothly and this causes frustration. Some classes have had difficulty logging onto Blue Skies and the Internet.
- In some schools, SkyMath stands alone as the only hands-on, integrated mathematics unit, unconnected to previous and subsequent mathematics instruction. This limits impact and viability.
- If teachers do not closely coordinate implementation of the module with partner schools, e-mail messages between students are not meaningful and do not meet the communication goals of the unit.
- The SkyMath approach appeals to teachers with a hands-on teaching style. More traditional mathematics teachers may not be as interested in trying the module or in team teaching.

FOCUS OF THE EVALUATION

Documentation and evaluation of the SkyMath module operated on two levels simultaneously during the three years of development – on internal and external levels. The internal evaluation process involved project developers and staff, members of the Design Team, and teachers who were testing the module. Ongoing dialogue between these groups combined with feedback from two external evaluation efforts guided decisions about revising the module. InSites, an independent organization that works with groups on curriculum development and other school change efforts, was primarily responsible for the external evaluation of SkyMath. InSites' data collection activities aimed at gathering feedback from teachers, students, administrators, college faculty, and parents about the effectiveness of SkyMath. The SkyMath Assessment Team at the University of Colorado, Boulder conducted a more focused external evaluation. Their task was to design the SkyMath End-of-Unit Assessment instrument, and in the process also provide additional feedback on the module.²

During the past three years, the overall goals of the SkyMath external evaluation conducted by InSites were to help designers develop and revise the module, document how teachers were implementing SkyMath in the exploratory tests, and determine the effectiveness of the curriculum for teaching mathematical skills and concepts. During each year of development and testing of SkyMath, the InSites external evaluation focused on specific questions that were most appropriate for that phase of the process. The first two rounds of documentation provided substantial information on:

- initial benefits of the SkyMath approach to teachers and students, barriers and challenges to implementation
- patterns of usage, connections to pedagogy and professional development
- recommendations for revisions to the module

In addition, documentation contributed an emerging view of factors and systems that interface with the SkyMath module and impact its use, and a preliminary understanding of the module's impact on student learning.³

Findings from the first two years of the external evaluation were used by project designers to refine the module and by InSites evaluators to give additional focus to the evaluation design, which evolved over time as the module was tested. The focus for the final year of the evaluation expanded to include an exploration of strategies for dissemination and communication about SkyMath to a broader audience.

The guiding questions for the final year of evaluation are:

² In this report, the use of “external evaluation,” “evaluators,” and “evaluation team” refers to the evaluation work conducted by InSites. Discussions about the End-of-Unit Assessment data and analysis refer to the work done by the SkyMath Assessment Team at the University of Colorado.

³ Refer to Appendix A for a complete list of guiding questions for the first two years of the evaluation.

1. *How valuable is the module in supporting student learning of the identified mathematics concepts? (Consider both (a) the extent of student learning and (b) the ease of use and quality of the module as a teaching tool.*
2. *What further refinements are needed in the module before final production?*
3. *What methods of dissemination of the module are likely to be effective?*
4. *What should parents know about the module?*

DATA COLLECTION AND ANALYSIS

During the three years of work on SkyMath, the module went through a series of exploratory tests and revision cycles. During each round, SkyMath was implemented in the classrooms of selected teachers who received a stipend to participate and contribute their feedback to developers. In coordination with the field tests, the external evaluation team used the following methods of data collection to gather relevant information:

- discussions with the project Design Team and UCAR staff
- classroom observations of students working on SkyMath activities
- interviews with participating students and teachers
- teacher and student questionnaires and response forms
- site visits and interviews with teachers, university contact personnel, and school and district administrators
- focus groups of parents and educators.

In the words of one member of the development team, a teacher's primary job during the field test was to "make SkyMath your own and make it better."

YEAR ONE ACTIVITIES

The external evaluation work during the first year included these activities:

- participating in project planning events and discussions focused on measures of student learning
- reviewing information gathered by internal evaluators
- working with the project team on site selection for the Spring 1996 field test
- gathering baseline information at three pilot sites
- refining the evaluation design and data collection instruments

At the sites, evaluators observed in classrooms and interviewed students and teachers. The *SkyMath External Evaluation Year One Report* (August 1995) summarizes the information gathered at this initial stage.

SPRING 1996 EXPLORATORY TEST

The Spring 1996 exploratory test was conducted by seven teachers in seven different schools located in Colorado, California, Georgia, Iowa, and Massachusetts. Three of the sites involved classrooms using predominantly a science curriculum, while the other four included fully math-based classrooms. These sites were selected based on existing interest in the project by teachers and university people in these locations. Some teachers had a local university contact person to support their classroom efforts and serve as a liaison to the developers and evaluators, and others consulted with UCAR and EDC staff. Although the sites for this pilot test were selected based largely on convenience, they represented a broad range of situations, which varied in ethnic composition, district and community size, extent and nature of technology in the school, teachers' mathematics and science backgrounds, and student characteristics.

The participating math teachers began implementing the module in April 1996 and most of them used the SkyMath lessons until the end of the school year. The science-based teachers used various parts of the module and integrated these with lessons in their regular curricula. For this exploratory test, teachers were encouraged to use the module over a six-week time period and to use the whole module. However, the project directors did not insist on this because they wanted to see how teachers would “naturally” bring the materials into their instruction.

Data from the second year of documentation were gathered through a variety of formal and informal strategies. These included telephone and in-person interviews, classroom observations, and secondary analysis of extant data. Interviews were conducted with teachers, district and university personnel, students, university participants, members of the design team, and the instructional developers. Classroom observations were conducted by members of the evaluation team who focused on implementation and the teaching/learning processes. Secondary analysis of extant data involved reviewing student work and the coding and sorting of recorded interviews. Video was used to record some activities for later review.

A detailed analysis of the field test is presented in the *SkyMath Summary Evaluation Report for Spring 1996 Exploratory Test* (August 1996). Findings from this phase of the evaluation guided the work during the final year of development and these findings are integrated into the text of this summative report.

FALL 1996 EXPLORATORY TEST

The SkyMath initiative entered its third year of development with a high degree of success based on the first two years of work. In the minds of people involved, there was little doubt that the SkyMath approach was a viable method for teaching mathematics in the middle grades. The remaining tasks were to gather further information on student impact and teacher practices, refine the module for final production, and focus on dissemination strategies.

To accomplish this, the Fall 1996 field test of SkyMath involved ten teachers at eight different schools in California, Colorado, Georgia, Iowa, Massachusetts, Ohio, and Texas. All were either math or elementary classroom teachers.

This phase of the pilot study was designed to be more structured, with definite guidelines spelled out for implementation. Of the ten teachers selected to participate, five were designated as Level I teachers and five were Level II, each level carrying with it different expectations for involvement. Level I teachers agreed to implement the entire module with 6th or 7th grade students within a six to nine week time period, use the quizzes included in the module, participate in site visits and interviews with evaluators, arrange for students to be interviewed, have students complete final projects, and administer the end-of-unit assessment according to schedule. Level II teachers committed to using as much as the module as possible within a more flexible time frame, use the module quizzes, and have some students work on final projects. Some evaluation activities were optional for Level II teachers. All teachers were asked to complete questionnaires before and after using the module, fill out teacher response forms on each of the module activities, and have students fill out response forms to get their feedback on activities.

The Fall 1996 field test began in mid-October. As it turned out, most of the participating teachers extended the implementation period longer than expected, but eight out of ten completed the

module and most of their responsibilities related to the field test and evaluation.⁴ Given the time pressures experienced by most teachers, SkyMath evaluators anticipated that it would take some time to collect all the data from the schools. The variety of strategies used proved to be worthwhile in giving a rich picture of the implementation process. However, in future efforts it would be wise for project staff and evaluators to have a more realistic time frame when developing, piloting, and evaluating a new curriculum – both in terms of how long it takes teachers to pilot the materials (interrupted by schedule changes and other demands like standardized testing) and the time it takes for teachers to respond to evaluation materials. For the Fall field test, both activities took longer than predicted.

Teacher Demographics

The average number of years of teaching experience for the Fall 1996 teachers is 15 years, with the Level I teachers having an average of six years more than the Level II teachers.⁵ Most of their collective teaching experience has been primarily in grades four through eight. One Level I teacher has taught at her current school for 18 years. The rest of the teachers, not including this one, have averaged five years working at their schools.

Two Level I teachers and one Level II teacher have extensive experience teaching math (15 to 21 years), while the rest ranged from two to eight years. Teachers who have taught or are teaching at the middle school level have generally taken more college semester credits in math and math education (from 14 to 40) than the two elementary teachers participating (only 4 to 6 credits). All teachers in the pilot test have earned considerably fewer credits in science and science education (from 3 to 16 credits). Only two teachers took a class with weather or atmospheric science content.

Student Demographics

Most teachers used SkyMath with one or two of their math classes, but some included more in the field test. The majority were 6th grade classes, one site each tested the module with 5th grade and 7th grade, and two teachers involved 8th grade students (one teacher used parts of the module with six of his 8th grade classes).

Six of the teachers are working at schools where students are grouped by math ability, achievement, or prior background. This situation gave them a chance to try SkyMath with a select level of students, while other teachers introduced the materials to a broad range of students. Overall, the student groups included a variety in terms of math ability, achievement, attitudes, drive, and interest level, and many of the classes included identified special education students as well. Two teachers tested SkyMath only with students who have low to average abilities. At another pilot school, the student population draws from both the highest and lowest socio-economic groups in the city. The total number of students involved in the Fall 1996 pilot was 26 in 5th grade, 250 in 6th grade, 46 in 7th grade, and 230 in 8th grade for a total of 552.

Before starting the module, each Level I teacher selected a group of six to nine students to participate in the evaluation activities designed for this field test. They set the groups up to be representative of all student perspectives on SkyMath. For example, one group included a high

⁴ A family emergency and a job transfer interrupted two teachers' work.

⁵ Data is based on responses from eight of the ten participating teachers.

math student, two special education students, one with behavioral problems, two with average math ability, and two ESL (English as Second Language) students.

Site Visits and Focus Groups

As part of the final pilot test of SkyMath, external evaluators visited four of the participating schools in Colorado, Iowa, Ohio, and Texas. At the time of the site visits, two teachers had completed the module and two were close to finishing it. The evaluation team interviewed SkyMath teachers and other teachers involved at the school, and talked with the group of students selected to participate in the study and reviewed their SkyMath work. Evaluators also interviewed school administrators and university support faculty.

To gather information about how the SkyMath module could best be disseminated in the schools and districts, the evaluation team convened two types of focus groups at two of the pilot sites. There were two parent meetings and two groups of educators including university faculty in math education, a technology specialist, SkyMath teachers, some teachers who have not tried SkyMath, principals, a president of a state math educators' organization, and an atmospheric science college faculty. All participants brought a unique perspective, useful suggestions for distribution strategies, and information to emphasize in materials about SkyMath.

Data Analysis

Data from the teacher questionnaires and teacher and student response forms were analyzed using both quantitative and qualitative methods to determine emerging patterns in all key areas of the study. Information from the site visits, interviews, and focus groups were correlated with this data and synthesized into the findings section of this report. Throughout the year, teacher feedback on the module was communicated directly to EDC staff for their immediate consideration.

SPRING 1997 FIELD TEST

Although not included in the original SkyMath initiative, a final, more informal field test of SkyMath was conducted during the Spring 1997 semester. The SkyMath Principle Investigator (PI) organized this additional pilot test because there was a great deal of interest among other teachers to try the SkyMath module. Technology support personnel at four universities participating in the National Aeronautics and Space Administration's (NASA) program, the Minority University-Space Interdisciplinary Network (MU-SPIN), helped contact teachers for the Spring field test. The MU-SPIN sites and number of schools participating were: University of Texas at El Paso, TX – three schools, Elizabeth City State University, NC – one school, NASA Langley Research Center, VA – four schools, and Morgan State University, MA – several schools. In addition, teachers at four schools in the Bronx, NY participated in the field test, and another school in Colorado joined this round.

These new university contact people helped generate regional interest in SkyMath. For example, the technology specialist at the NASA research center in Virginia worked on selecting four teachers for the field test, she gave them information about SkyMath, and trained them to use data collection software and hardware, Blue Skies, Netscape, and e-mail. Then she matched classes with partner schools and resource contacts. Because teachers in Virginia were all in the

same geographical area and tried the module at the same time, they were able to meet and talk about the process together.

Teachers began implementing SkyMath on March 1, 1997 using a flexible time frame. This phase of testing was not as extensive as the former two rounds. Rather, the intent was to see how successful teachers were in managing the new curriculum independently. After the initial set up, teachers received very little direction from the project developers – a good test of whether the module functions on its own. Teachers in the Spring 1997 field test could opt to give their students the end-of-unit assessment. Some completed a questionnaire that was available electronically and designed by the PI to get additional feedback on SkyMath.

SKYMATH END-OF-UNIT ASSESSMENT

In Spring 1996, the SkyMath Assessment Team at the University of Colorado at Boulder began the task of developing a high-quality assessment instrument that would be used to gather student data on mathematical skills, abilities, and understanding at the conclusion of the SkyMath module. The assessment was developed, piloted, and revised in conjunction with the module field tests. In Spring 1996, teachers administered the assessment to students at three of the schools. The next Fall, the test was piloted at five SkyMath schools. Teachers gave the test after finishing the entire module, using consistent procedures during the testing sessions.

The SkyMath End-of-Unit Assessment was designed around three primary constructs: National Assessment of Educational Progress (NAEP) items, SkyMath short-response items, and several performance-based items. All items are mapped back to the goals and objectives of the SkyMath curriculum. The test is divided into two sections to be given over a two day period.

The end-of-unit assessment instrument, scoring profiles, and rubric are cost-free to download from the SkyMath homepage (<http://www.unidata.ucar.edu/staff/blynds/Skymath.html>).

THE SKYMATH MODULE

NEW APPROACH TO TEACHING MATHEMATICS

A

“With the old way of teaching math, kids could do the mechanics, but they didn’t know what it meant. With SkyMath they really understand the concepts behind the mechanics.” –Teacher

This section of the report presents a brief description of the SkyMath module and some information about the interactive processes used to develop both the module and the end-of-unit assessment piece.

THE SKYMATH MODULE

Module Description

The *SkyMath Module: Making Mathematical Connections, Using the Science and Language of Patterns to Explore Temperature* is described by project designers as follows:

SkyMath is designed to support mathematics education in accordance with new standards set by the National Council of Teachers of Mathematics. It is a flexible curriculum that can be taught as a single unit over the course of six to eight weeks or in smaller sections throughout the school year. It builds on the experience, interests, skills, and knowledge that students already have and develops these through hands-on activities, real data, and students’ own questions and projects.

SkyMath activities use a developmental approach. Through a combination of structured experiences and open-ended explorations, student understanding moves from particular examples to general cases, from small data sets to large ones, from off-line activities to on-line investigations, and from concrete images to abstract ideas. SkyMath students learn mathematical concepts as they collect and analyze real-time weather data using different kinds of thermometers, computers, data loggers, and the Internet, as well as newspapers, TV, and radio. These experiences, which culminate in student-initiated final projects, go beyond basic skills to elicit higher-level thinking, reflection, and the communication of mathematical ideas.

The *Making Mathematical Connections, Using the Science and Language of Patterns to Explore Temperature* unit is intended to be the first in a series of three middle school level modules that use real-time scientific data as the basis for learning mathematical skills and concepts.

SkyMath Design Principles

The SkyMath Design Team worked from this set of “design principles” which describe the essential nature of the approach:

- ***Generate mathematical connections by constructing mathematical ideas from real-world data.*** The module uses exploration of temperature to develop the concepts of estimation, measurement, linear scaling, graphical representation, data analysis, and linear function. It can be a replacement unit that uses connections to mathematical concepts in data analysis,

graphing, number and number relationships, patterns and functions, and statistics and measurement.

- ***Embed the KWL text-comprehension model.*** This research-based feature is commonly used in reading instruction. Students are actively engaged in learning through sharing what they know or think they know (K), what they want to know (W), and reflecting on what they have learned (L).
- ***Use activities and instructional procedures that promote student direction of the learning process.*** The module provides guidance to student learning while allowing increasing degrees of student independence in the development of ideas and activities.
- ***Employ multiple levels of assessment.*** Performance is assessed at three levels. Two of these (lesson-by-lesson assessment to guide instruction and summary assessment through an extended project) are internal to the module. The third level is an external assessment with a comprehensive test of the module's key mathematical concepts.
- ***Provide basic teacher support within the text of the module.*** An array of teacher inservice features are intended to make the module self-standing, i.e., usable without formal inservice by outside experts.
- ***Use a single visual and organizational format for all activities.*** A typical lesson begins with an overview page that describes the math goals, the ongoing assessment, and the necessary advanced preparation. Following this are descriptions of student activities with associated teacher stories. Background information and explanations of the technology used are included, followed by assessment guidelines.
- ***Support student learning with appropriate technology.*** Technological tools are introduced as needed throughout the module: a computer-mediated temperature probe for data collection, spreadsheet software for analysis, and the Blue Skies Internet program for national and international weather data. Students share their studies with partner classes by exchanging e-mail messages.
- ***Provide supplementary content support through Internet and in-school resources.*** A Web site identifies Internet resources that give teachers needed information about temperature, thermometers (and other simple instruments), weather maps, etc.

In the opinion of the teachers who tested the module, these principles emerged as actual strengths in the implementation process. The Findings Section of this report elaborates on what teachers say about these and other key features of SkyMath.

Mathematical Content

In the SkyMath module on the first page of each activity, the project designers list the mathematics content included in each section. In June 1996, the Design Team asked Dr. Fernand J. Prevost to do an independent, external content analysis of the SkyMath module for the purpose of affirming and detailing the content alignment of the module with nine of the 13 content standards for grades five through eight found in the *Curriculum and Evaluation Standards for School Mathematics* of the National Council of Teachers of Mathematics (NCTM, 1989). The SkyMath writers and staff then matched his analysis with the content lists in the module to be sure these were accurate, clear, and complete.

The Module Content Matrix in Table 1 displays the mapping of the SkyMath activities onto the nine NCTM standards. Another piece of Dr. Prevost’s study, the Summary of Mathematics Content located in Appendix B gives a more detailed look at the mathematical substance included in each SkyMath activity.

Skymath Activity	NCTM Standard ⁶									Technology	
	1	2	3	4	5	8	9	10	13		
1	x		x		x					x	
2		x	x	x	x	x ⁷		x	x		
3	x	x	x	x	x			x	x		
4		x	x			x		x	x		x
5			x		x			x	x		
6	x		x	x	x			x	x		
7			x		x	x	x	x	x		x
8			x		x			x	x		
9		x			x			x			
10	x	x	x		x			x			
11	x	x	x		x	x	x	x			
12	x	x				x	x	x			x
13		x	x		x	x	x	x			
14	x	x	x					x			x
15	x	x	x		x	x	x	x	x		x
16 ⁸		xx									

Table 1 – Module Content Matrix

⁶ At the grades five through eight level, the NCTM Curriculum and Evaluation Standards for School Mathematics (NCTM 1989) identifies four process standards (1-4) and nine content standards. These are all addressed in the SkyMath materials. Those Standards which are given explicit conceptual development are shown in the above chart. A tenth column has been added, [*Use of Technology*], since this aspect of the work in SkyMath deserves to be highlighted as well. Number work is always present, and the nature of the module infuses problem solving into every activity.

- NCTM Standard 1: Mathematics as Problem Solving
- NCTM Standard 2: Mathematics as Communication
- NCTM Standard 3: Mathematics as Reasoning
- NCTM Standard 4: Mathematical Connections
- NCTM Standard 5: Number and Number Relationship
- NCTM Standard 6: Number Systems and Number Theory
- NCTM Standard 7: Computation and Estimation
- NCTM Standard 8: Patterns and Functions
- NCTM Standard 9: Algebra
- NCTM Standard 10: Statistics
- NCTM Standard 11: Probability
- NCTM Standard 12: Geometry
- NCTM Standard 13: Measurement

⁷ The work with patterns and functions is implicit.

⁸ Activity 16 will most likely include all of the areas, and perhaps others as students reflect on their work and share results. Since communication is so central here, a “xx” has been placed in that column to show that emphasis.

THE DEVELOPMENT PROCESS

The process of creating the SkyMath module was an innovative approach to curriculum development. The work of the project teams and the evaluation and assessment teams was woven together into a unique and effective effort. SkyMath's development process was distinctive because it involved scientists and mathematicians on the Design Team⁹ collaborating with UCAR staff and writers and educators at EDC. To ensure the quality of the module and the accuracy of the math, science, and technology content, experts on this team periodically reviewed the SkyMath module over the three years.

External evaluators, teachers who piloted the module, and the SkyMath Assessment Team also played major roles in the development process. Field tests raised important issues for the designers to consider, and modifications were made to the module in response to evaluation feedback. Piloting of the end-of-unit assessment contributed to the revision process as well.

For example, teachers in the Spring 1996 field test found that small group work was a very effective strategy to use with SkyMath, so they suggested the module include guiding principles on cooperative learning for teachers not accustomed to working this way. In response, module designers added an entire introductory section with information on cooperative learning, communicating about math, posing questions for study, and the use of e-mail as a learning tool.

The Spring field test revealed that some students were unsure about what math they were learning from SkyMath. After the independent content analysis was done on the module, project staff and EDC checked the results against the module to make sure that the "math" in each activity was stated clearly on the first page of each section. This helped to make the learning more explicit to teachers and students.

Appendix C lists some examples of the kind of feedback teachers in the Fall 1996 field test gave the SkyMath Design Team to help in decisions about final revisions to the module.

Scoring of the SkyMath End-of-Unit Assessment also contributed to the revision process. At the June 1996 and January 1996 scoring sessions, performance-based items were scored on a five-point rubric by assessment designers, UCAR staff, university faculty, and SkyMath teachers. Before the actual scoring of papers, participants worked and discussed each item, examined how the rubric would be applied to the tasks, and scored anchor papers to help scores equilibrate with each other. The process was interactive and as people worked with actual results, ideas emerged for improvement of the test instrument as well as suggestions for refining the module.

⁹ Refer to the previous description of the design team in the introduction section of this report.

FINDINGS

Information about the development and testing of SkyMath has been analyzed across all three years and organized into this section of the report. Subsections focus on these thematic areas:

- patterns in the way teachers use the module
- observations teachers have made about the design and implementation of SkyMath
- teacher and student opinions about the impact of SkyMath on student learning
- systems that support use of the module
- strategies for dissemination of SkyMath to a broader audience

PATTERNS OF USE

“I have been using SkyMath for three years. The unit becomes easier to use and allows for many extensions.” –Teacher

Preparation for Teaching the Module

When considering using a new curriculum, teachers are usually concerned about the time it will take for their own preparation. Overall, SkyMath teachers found it relatively easy to preview the SkyMath module and get ready to teach it.¹⁰ Some felt it was enough to read through the materials and try out activities before teaching them to students. Very little of the module content was new to teachers in the Fall 1996 pilot group,¹¹ and this reduced their preparation time.

Technology was the area that presented the most challenge for SkyMath teachers. Some had to learn how to use the Internet connection and e-mail, and others needed practice with spreadsheets. Before piloting the module, some teachers received technology training from EDC staff or university faculty and others asked computer resource teachers at their schools to help fill in the gaps. Having to upgrade computer skills did not seem to be a problem for teachers, however, since many were attracted to SkyMath because of the technology aspect. One teacher who has piloted the module three times said, “I’m still getting comfortable with technology. SkyMath helped, but I still need more work.”

Some teachers needed to supplement their understanding of the science content in SkyMath. One asked a scientist some questions and another got in-depth information on science topics from an Internet search. One teacher is a licensed pilot who checks weather data all the time, but even she learned more detailed information about weather through SkyMath.

Different Formats for Teaching SkyMath

One positive aspect of SkyMath is the flexibility of the module. Teachers can adjust activities to fit their grade level, context, and time frame, and gear the pace of instruction to match student progress. Although SkyMath is designed to run for six weeks of approximately 50 minute class

¹⁰ Refer to the SkyMath Overview link at the SkyMath homepage for a complete list of materials and equipment needed (<http://www.unidata.ucar.edu/staff/blynds/SkyMath.html>).

¹¹ On the final questionnaire, teachers gave “extent to which SkyMath content is new to me” a rating of 2.3 on a scale of 1 to 5 where 1 = Not At All, 3 = Moderately, and 5 = Very Extensively.

periods, very few teachers finish in this time. Some plan it that way – they choose to integrate the module into other curricula and spread it out over a longer period of time. Other teachers take detours and pursue extensions related to the SkyMath content. In some cases, short class periods make it difficult for teachers to complete the module in a reasonable time frame.

Although some teachers are frustrated by class time or schedule constraints, SkyMath is designed to be flexible so that implementation can move forward under a variety of circumstances. The following examples illustrate how three of the Fall 1996 teachers used SkyMath in their schools:

School #1. At one middle school, the 6th grade math and science teachers have consecutive 45 minute blocks of time with the same group of students. On SkyMath days, the math teacher can combine these blocks into a 90 minute period to allow students extended time to work in-depth on activities. The computer lab is located right down the hall, adding to the convenience and flexibility of this situation.

School #2. The school schedule was a problem for this SkyMath teacher because she was limited to 43 minute class periods (and on some days, only 35 minutes). She could teach SkyMath successfully in this format, but activities were more spread out. For example, it took three days for her 7th grade class to make bar graphs. On the first day excitement was high, but “it seemed as though we’d just get started on something,” the teacher explained, “and the bell would ring. The next day the kids’ enthusiasm had waned.” Despite frustrations, overall this teacher and her students enjoyed SkyMath.

School #3. A Gifted and Talented resource teacher introduced SkyMath to a 5th grade class at her elementary school. At first she did all of the teaching of SkyMath activities twice per week for 50 minutes. But this wasn’t enough time nor did it provide enough continuity, so she and the classroom teacher decided to team up instead. The classroom teacher began to teach SkyMath on the days the resource teacher was not in her room and this collaboration worked quite well.

Working within time limitations, teachers have used SkyMath successfully in these and other classroom arrangements, and on a daily basis or as little as twice per week. Having a 50 minute class period is beneficial, but not necessary as some of the teachers in the field test demonstrated. In reference to the time problem, one parent at a SkyMath focus group raised a relevant point when he said, “SkyMath is such a creative program. Why does it have to be limited to the classroom?” He suggested that teachers encourage students to pursue more extensive study of weather data at home, beyond the limitations of classroom schedules.

Teacher Recommendations for Use of the Module

Although SkyMath was designed to be primarily a 6th grade curriculum, it was piloted in classrooms ranging from 5th through 8th grades. Teachers involved in the field test have shown that SkyMath activities¹² can be used effectively within this range. One limitation was raised by a 5th grade teacher. Her students had trouble grasping some of the module concepts so she recommended using SkyMath during the second semester of 5th grade, when students of this age have gained more mathematical skills and experience.

¹² A list of the SkyMath activities can be found in Appendix D.

Another teacher suggested that for best results, an entire team of 6th grade teachers need to teach the module, not just one teacher in isolation, and that the approach be continued and reinforced by 7th and 8th grade mathematics teachers as well.

Using the module for the first time is a learning experience for teachers. It appears to be easier to use the second and third time around. One teacher comments: “There are so many things I would approach differently the next time. ... If I had it to do over I would use the unit with two back to back classes so I wasn’t putting one thing away and getting out another. ... I do think this is a good unit, I just need a second chance!”

Based on the experiences of teachers in the pilot study, these recommendations emerged as potentially the best formats for implementing SkyMath:

- a self-contained classroom where the teacher can arrange blocks of time for instruction
- a middle school where there are flexible blocks of time, or where math and science teachers team together to teach the module

Those in less than ideal situations can use the entire module, or they may want to pull out select activities to use. One teacher who had a very difficult schedule said, “The only way I would probably use the whole SkyMath module again is in a team situation with a science teacher.” In this sense, the module promotes teacher collaboration and content integration.

DESIGN AND IMPLEMENTATION

“SkyMath has a good balance of both guided practice and independent practice. This gives students the freedom they never had before.” –Teacher

Overall, teachers in the field tests found using SkyMath to be a positive experience. Not only did they enjoy the unit and find it very accessible, but they discovered some fundamental characteristics built into the module and connections that emerged through the process of implementation that were very beneficial, and reinforced their initial interest in the unit. This section of the report highlights those strengths that make SkyMath a viable method for teaching mathematics and presents some of the challenges teachers face when using this new approach.

According to teachers in the pilot test, SkyMath is effective because:

- It is a flexible, hands-on, student-centered, thematic, and integrated approach.
- It uses real world weather data, aligns with mathematics standards and curricula, includes accountability systems, integrates technology, and draws on a range of teaching methods.

Teachers point out these challenges to using SkyMath:

- teachers and students gaining the technology skills needed to use the module
- schools providing computers and connections to the Internet for maximum benefit
- trouble shooting software and on-line technology glitches
- bringing the SkyMath approach into more traditional mathematics programs
- coordinating communication with SkyMath partner schools

SkyMath is a Flexible and Sequential Curriculum

As previously discussed, the SkyMath curriculum can be used over a flexible period of time and can be adapted for use at different grade levels, but its flexibility goes beyond that. Teachers think SkyMath achieves a good balance between predetermined learning outcomes and a flexible structure that accommodates a range of information, teaching strategies, and possibilities for student learning. A significant feature that emerged from the pilot tests is that teachers can adapt SkyMath for use with a full range of student abilities and interests, and to reinforce their district science goals. Flexibility of the module also helps teachers capitalize on real-time events and pursue extensions. Because the mathematical content and skills are clearly defined in the materials and the approach encourages teachers to act as learning facilitators, making adaptations within and beyond the unit appears to be quite manageable.

Other aspects of the module contribute to its quality as a teaching tool. Teachers like the sequential structure of the module. The unit builds on students' prior knowledge and on the skills and knowledge gained in each successive activity. This provides a continuum that is useful for teams of teachers who want to extend the content over several grade levels.

SkyMath is an Effective Learning Module for All Students

“One class of 24 has 11 inclusion students – mostly inclusion for emotional reasons – so this is a challenging class to motivate.” –Teacher

Mathematical Learning and Real Time Data

*“Weather is inherently motivating to students. This on-line data is real and so it makes students believe that math has some connection with real life.”
–Teacher*

After trying SkyMath out in the exploratory test, teachers felt confident that the module was meeting the needs of diverse learners. They used SkyMath successfully with students in low and grade-level ability math groups, and mixed classes including gifted students and inclusion students, and found that all were challenged and benefited.

According to one teacher, “The beginning of the unit was a bit slow (in terms of kids learning about math), but the end was jam-packed with great math concepts.” These include concepts related to estimation, measurement, linear scaling, graphical representation, data analysis, and linear function. Some subjects covered in the module, like bar graphs, and mean, median, and mode, are not completely new to all students, but teachers say that SkyMath enhances abilities in these areas and deepens understanding for students at all levels.

In one class, students were presenting their final projects and they were explaining and interpreting the data pictured on their graphs. Some students talked on a more concrete level, discussing their conclusions in terms of point to point comparisons. Others were at a more abstract level of thinking and identified general patterns across the data and explained their conclusions in terms of trends. Each of these students, on his or her own level, had learned how to research, present, and compare temperature variations between the two cities they had chosen for study.

According to SkyMath teachers, students are motivated to learn by their interest in the real-time weather data which forms the basis for mathematical instruction in the module. Teachers think their students benefit by being actively engaged in hands-on learning about a subject of interest that connects math to the real world. A university faculty observed one teacher as she led her students successfully through the work on Fahrenheit and Celsius temperature scales. When these students were then asked to design their own temperature scales, this turned out to be a “grand challenge for them,” the professor recalled. “The teacher was surprised, but she was also pleased that the lesson was getting at an important gap in her students’ understanding of mathematics.”

In-Depth Learning of Mathematical Concepts

This leads to a key point that teachers have made – SkyMath helps students gain a deeper understanding of mathematical concepts that underlie computational skills. For example, many students have had some experience with bar graphs before SkyMath. In the module, they learn how to make line graphs – a new skill – but in addition, they also start to learn how to select the appropriate type of graph to display a particular data set and explain why it works best. This learning supports and goes beyond computational skills.

One teacher had this experience. Most of her students could calculate a mean, median, and mode before SkyMath. “The kids could mechanically do all of these things, but they had no concept of what central tendency actually means.” That’s where a SkyMath activity came into play. The activity asks students to find the average temperature in their classroom. Her kids measured 36 data points in the room, but they didn’t want to add up all of the numbers, so they started talking about what data was the most important to use. Conversation included comments like, “We don’t want to count that kid’s reading because he put the thermometer on the heater and it read 125 degrees and that’s not really how it feels in the classroom,” or “That student put her thermometer up against the window and that doesn’t really represent the temperature in this room.” By going through this exercise, her students began to realize that some of the data was not relevant. The discussion then turned to the local weather broadcast. Students wanted to know where in the city people recorded “official” temperatures, since they now realized from their own experience that variation in temperature occurs. The teacher said that now her kids are more aware of how statistics are derived and reported and SkyMath has given them a higher level of understanding of the concept of average. They have struggled with the question of how to best represent the temperature in the classroom. Their teacher concludes, “It’s a huge problem and a scientist’s problem and a how-you-use-your-numbers problem and it’s worth it to me to use (SkyMath) with kids because they really get this understanding.”

SkyMath in Special Education Classes

“When working with kids with limited experiences, connections to the real world are really important.” –Teacher

At two schools involved in the Fall field tests, special education teachers selected parts of the SkyMath module to use with their students. One teacher who works with multiple-handicapped students especially liked the interdisciplinary aspect of the module. She usually takes this

approach, so she saw the value of using SkyMath's link between math, geography, and weather to "jump start" her students' interest and build success into their mathematics lessons. Many of her kids have a "can't do" attitude, but she thinks SkyMath will help to turn this around because it is "user friendly." She explained by saying, "SkyMath is an equalizer. Since it is new for everybody, my (special education) kids did not have to play catch-up."

A special education teacher at another pilot site used several parts of the SkyMath module three days a week to supplement his classes. His students enjoyed using Stowaway. They measured temperatures in the refrigerator and freezer and were able to figure out why the temperature was changing in the freezer – their conclusion being that warm air had gotten into the freezer when they opened the door and that caused the fluctuations. His students worked on temperatures, conversions, bar and line graphs, and made a chart of the city's high and low temperatures. These are the main things he felt his students learned: the connection between math and weather, how to use a thermometer, and beginning skills in reading line graphs.

This teacher explained that for SkyMath to be included as a curriculum of choice in his district, critical skills would need to be identified within the module as the focus of instruction for special students. For example, reading a thermometer would be a critical skill, but making temperature comparisons would not. If a task analysis of the module were done to break it down into smaller steps, this would make it even more useful and attractive to special education teachers. This is something teachers can do themselves, but it takes a lot of time.

Learning Extensions

Another thing that teachers like about SkyMath is its potential for expansion. Teachers can extend the learning by adding creative extensions related to the module activities or integrating other subjects or areas of interest for enrichment. For example, one teacher would like to have students do more work with integers, statistics, and variables.

SkyMath Works as an Integrated Curriculum

"SkyMath is a good way to integrate math and science while providing real experiences in both areas." –Teacher

"SkyMath teaches students the math application skills needed for scientific exploration." –Scientist

"SkyMath helps kids understand that weather is unpredictable. You can predict it, but it comes out different than you thought." –Student

Curriculum designers did not fully anticipate the reach SkyMath has had as an integrated math and science unit. The interdisciplinary aspect came out strongly in the field tests as teachers made good use of the scientific connection to motivate mathematical learning. Some science teachers tried the module out in the Spring 1996 field test and others are looking at how they might use it to support science standards and curricula. In districts where math and science are integrated at the middle school level, SkyMath may prove to be especially useful because it supports a basic tenet of the middle school concept.

The weaving together of math and science learning did not go unnoticed by students. In fact, some who were interviewed said they were learning as much, if not more, science as math from

SkyMath. In the evaluation interviews, teachers and students also mentioned positive connections with social studies/geography, art/visual learning, and writing. The work with weather maps extends what kids are learning in geography. According to one teacher, computer access to maps and weather information has really opened up her students' world. "Kids are completely amazed about where cities are located."

SkyMath fits well with one school's overall focus on developing writing skills across all subjects. One teacher said she would like to see even more writing activities added to the module as extensions. A 6th grade language arts teacher said her work with students complements the math work in several ways: she teaches kids how to make data charts to help organize research information and has them generate their own questions to explore in writing.

A student offers her insights on integration: "Math isn't all about adding and subtracting numbers. It's about other things like weather and temperatures changing." Another student said that at his school the science teacher teaches math and the math teacher teaches science and sometimes when kids walk into class they don't know what's in store for them. They like this fluidity of learning. For some students the weather and temperature content is new and exciting.

A scientist who participated in an evaluation focus group offered this perspective: "I started thinking about how good something like this is because it gives students an effective background to begin to understand science." Specifically, students have to deal with the same issues involving data that scientists do. Measuring temperature data in a classroom can be extrapolated to the challenges scientists face in studying global warming. Some SkyMath teachers would like to invite scientists into their math classrooms to enrich the lessons or have students ask scientists questions by e-mail.

Using an integrated curriculum like SkyMath is not problem-free. Some see a downside to the approach. One teacher in the field test found it difficult to take the time to pursue more in-depth scientific learning because class time was limited and she felt pressured to cover the math content. Another teacher liked the idea of kids writing about math but did not want to deal with reading volumes of work and editing for grammar and spelling errors.

SkyMath Supports Mathematics Standards and Curricula

SkyMath Aligns With Mathematics Standards

Teachers pointed out that another strength of the SkyMath module is its close alignment with district mathematics curricula and with state, district, and NCTM mathematics standards. On the teacher questionnaire, SkyMath's alignment with both mathematics standards and curricula were highly rated.¹³ (Table 1 in this report details the connection to NCTM Mathematics Standards.) Strong areas of alignment are problem solving, communication, reasoning, mathematical connections, number relationships, patterns and functions, algebra, statistics, and measurement.

The module helps students achieve not only math standards, but also science and technology standards, due to its integrated design. The connection to standards appeals to administrators as well as teachers, and gives the module broad applicability.

¹³ The average responses were as follows: alignment with district standards and math curricula was rated 4.0 and alignment with NCTM standards was rated 4.5 on a scale of 1 to 5 where 1 = Not At All, 3 = Moderately, and 5 = Very Extensively.

Curricular Fit

*“When using SkyMath I am covering the curriculum and doing it better.” –
Teacher*

*“This program dovetails with our curriculum, as it includes many of the
skills and problem solving techniques that are listed for 6th grade.” –
Teacher*

The majority of teachers who tested the module feel that SkyMath can be integrated into their curriculum successfully. They can teach SkyMath and still cover the content required in their school and district math curricula because many of the required skills and concepts are addressed in the module. Teachers in the Fall 1996 field test reported these areas as congruent with the topics that are covered at their grade level: central tendency, scaling, rate of change, problem solving, understanding of patterns, integers, data collection, graphing, range, use of a calculator, fractions, decimals, and making comparisons. Several teacher said their students are getting more advanced work through SkyMath than would normally be included in the 6th grade curriculum. For example, a discussion of discreet and non-discreet numbers came up during one teacher’s lesson on graphing.

All of the teachers in the Fall 1996 pilot test have a mathematics curriculum in place in their district, but delivery of instruction and points of emphasis are generally flexible. In one district the math teachers wrote the curriculum. “While we have a curriculum in place,” another teacher noted, “it is one we are always reviewing and updating. We have the option to try new things. In fact, we are encouraged to do so.”

For some, SkyMath also fits well with the district science curriculum, as in one school where weather is a topic required in 6th grade science.

An administrator who was interviewed by evaluators said that SkyMath complements two of his school’s goals which are to focus on in-depth learning and to integrate math and science through thematic units. Another principal said she is interested in real world applications for learning, so SkyMath fits well with her school’s focus.

SkyMath and Technology

Technology is a key feature of SkyMath that contributes to its effectiveness and presents challenges for teachers and students.

Teachers in the field tests think SkyMath successfully demonstrates how technology can support and complement content learning. Students gain computer expertise in a way that is connected and applies to the topic of study, rather than learn about technology in an unrelated or isolated context. With SkyMath technology is interactive and purposeful. Students find the information they need to do the mathematics activities. In fact, two SkyMath teachers prefer to have one accessible Internet hook-up in their classroom rather than have the connection only in a computer lab. With this direct link, students can use the computer on an as-needed basis to support what they are learning in class.

Technology Set Up

“If we had enough computers for teams of three to gather data daily, it would have enhanced our work considerably.” –Teacher

Some of the difficulties teachers have encountered in teaching the SkyMath module center around limited or delayed access to technology and lack of experience with computers. At this initial pilot stage, it is not a surprise that some teachers lack the necessary technological skills, but that is not likely to be the case in the future as schools access more equipment and training to keep pace with the computer age. What was an initial barrier for some in the field tests will most likely not be as much of a restraint in the future. In fact, successful modules like SkyMath reinforce the push for schools to invest in technology.

Technology requirements for SkyMath are minimal. In the Fall 1996 field test, however, access to computers and the Internet presented problems at a few schools. One teacher had only one computer and Internet link in her classroom and no connection in the small, outdated computer lab. Four teachers worked with students primarily in their school computer labs and had enough computers for all students to work comfortably, and two had both school labs and a classroom computer/Internet connection. One school did not have any computers and so implementation of SkyMath was restricted at this site.

Lack of equipment limits how often students can access Blue Skies and send e-mail, and it cuts down on the level of hands-on participation for all students. An ingenious and committed teacher can overcome these odds; however, it takes a lot of planning and work. To do the module spreadsheet activity with all her students, one teacher borrowed enough computers from other teachers, but it took two hours to set them up in her room and another two hours to return them.

The Technology Experience

Although SkyMath teachers have more to learn about using technology as a teaching and learning resource and they encountered some frustrations with managing the equipment, teachers generally enjoyed working with the technology connected to SkyMath. Responses to the Fall 1996 teacher questionnaire, which indicate overall impressions about teachers' experience with technology, are summarized in Table 2 below. (Average ratings are given using a scale of 1 to 5 where 1 = Not At All, 3 = Moderately, and 5 = Very Extensively.)

Teachers enjoyed working with the SkyMath technology.	4.3
Teachers were adequately prepared for the technology.	3.7
The technology was useful in teaching math concepts.	3.6
Teachers could troubleshoot technological mishaps on their own.	3.6
Teachers were able to access Blue Skies or e-Mail with ease.	3.1
Students were adequately prepared for the technology.	3.0
Students were able to troubleshoot on their own.	2.8

Table 2 – Fall 1996 Teachers' Perceptions of SkyMath and Technology

Students who were interviewed during both field tests were excited about using technology with SkyMath. Generally students worked at computers in pairs or groups of three or four, and most participated actively. In the Fall 1996 study group, students' prior experience and training on

computers varied considerably. Some started with no experience. At one school students came into it with excellent computer training. At another school, some students had already used the Internet to gather research information for another class. But most students were only moderately prepared for the level of technology involved in the module and many had not learned to use the Internet. Generally students had some previous instruction in keyboarding skills and use of software. The media specialist at one school is training a cadre of students to be a technology resource team.

The main problems encountered were technical difficulties accessing Blue Skies and insufficient time for composing and sending e-mail messages. Several classes experienced delays in logging onto Blue Skies, a problem when time in the computer lab is tight. Students were frustrated when the computers did not respond. One teacher took her class all the way over to the high school's computer lab and then they couldn't get Blue Skies to run. This was a big disappointment. She has since decided to use other weather sites listed in the module.

In classes that did not have regular access to a lab, only a few kids each day could work at collecting weather data from Blue Skies. Despite the problems, kids said they felt confident in knowing how to use the program and were interested in using Blue Skies again if it was "more reliable." One teacher adapted to access problems by having students collect weather data from *USA Today* instead.

Some students in the field test did not get adequate time to communicate by e-mail with their partner schools because of limited access to computers or having only one Internet link available, and this too was disappointing. As capacities build and teachers have more experience, these technical problems should be alleviated. A parent at one of the focus groups suggested that students with access to the Internet at home try sending e-mail messages and exploring other weather sites during their after-school hours. This raises an equity issue concerning students who don't have home access, but libraries may be a potential resource for them.

SkyMath and Teacher Pedagogy

"Conversations and discussions in group work have been lively and loud, but a definite learning process has taken place." –Teacher

SkyMath takes an active, hands-on approach to mathematical learning. This feature makes it a good transition tool for teachers who have taught only in a more traditional manner and would like to broaden their repertoire of teaching methods. Teachers who used SkyMath identified the following as the key teaching strategies incorporated into the module: accessing student prior knowledge, learning through hands-on activities, use of real time data, problem solving that focuses on students posing their own questions, teachers serving as facilitators, student-designed projects, cooperative group work, and peer teaching.

Many of the teaching strategies incorporated into SkyMath were not new to teachers participating in the two exploratory tests. In fact, one reason these teachers may have volunteered to try SkyMath in the first place was they were already oriented toward a more innovative and active approach to teaching math. On the teacher questionnaire respondents said they were very successful in adapting their usual approach to teaching SkyMath. This could mean two things – that the module is flexible enough to be used by teachers with a variety of teaching styles or that the teachers who tested the module have a style that is very congruent

with the SkyMath approach, making such adjustments easy. There are many math teachers who use more traditional methods, and as the use of SkyMath spreads, the challenge will be to get these teachers involved in trying new pedagogy.

For instance, hands-on learning is not a new teaching strategy, but it seems to be less commonly used for math instruction than in some other content areas. For math teachers who want to try hands-on learning, but are uncertain about how to begin, SkyMath is a comfortable and engaging introduction. Some teachers fear they will lose control of their classes if they change tactics, but teachers in the field tests saw their students reacting positively to the approach and focusing on their work. Districts and schools interested in active learning are looking for innovative curricula like SkyMath that can help teachers make the transition away from an “overhead mentality.”

Impact of Pedagogy

Teachers in the Fall 1996 field test offered their perceptions of how pedagogy intersected with their SkyMath work. A summary is presented in Table 3. (Average ratings are given using a scale of 1 to 5 where 1 = Not At All, 3 = Moderately, and 5 = Very Extensively.)

I was able to adapt my usual teaching methods to teach the module.	4.6
SkyMath pedagogical strategies will work well with other subjects.	4.4
Strategies in SkyMath were useful for teaching math concepts.	4.3
SkyMath generally improved my teaching methods.	3.6
The various SkyMath teaching strategies were new to me.	2.1

Table 3 – Fall 1996 Teachers’ Perceptions of SkyMath and Pedagogy

Use of Teaching and Assessment Methods

Before testing SkyMath, teachers in the Fall 1996 field test used a varied approach to teaching mathematics, with a balance between teaching methods considered more traditional and those that are more innovative. To implement the SkyMath module, teachers in both the Spring and Fall 1996 field tests continued to use a combination of teaching methods. Most were familiar techniques, but some of the teachers tried methods that were new to them in math instruction. Table 4 lists teaching methods the Fall 1996 group used before the field test, methods that were new to some of these teachers when implementing SkyMath, methods new to students in math classes, and methods teachers feel support mathematical learning.

When asked to describe the similarities and differences between instructional practices used in SkyMath and their typical approach to teaching math, teachers listed these similarities: use of hands-on activities, a focused unit, the problem-solving approach, relating math to real life applications, and collecting and manipulating data. The differences were: the science connection, use of real data, use of e-mail as a motivator for learning, and extensive use of technology. One teacher elaborated in this way: “In SkyMath the context is weather for learning the math – usually we teach the math concepts to fit them to some context.”

Before SkyMath, teachers in the study group used a more limited range of assessments. All of the teachers in the Fall group use open-answer quizzes and tests. Many use projects and teacher-student discussions. Half use multiple choice quizzes and tests, and journal writing for

assessments. A few use essays, portfolios, and reports or papers. Other assessment methods used are Problems-of-the-Week, self-reflection, target tasks, and teacher observation. The methods least likely to be used by this group are dramatic events/poetry, self-assessments, peer evaluations, and time-on-task. When implementing SkyMath, teachers used the quizzes designed for the module, but they also used some of these other methods.

Even though the pedagogy was not new to them, the SkyMath teachers feel that using SkyMath helped improve their teaching methods and the approach was very useful for teaching math concepts. One very experienced math teacher had never involved her students in data collection or manipulation before and so this was a significant change for her. Another teacher used mixed-ability groups for the first time in her math class, and she was impressed with how independently and successfully students worked together on SkyMath. "I am amazed the groups have worked and have had very little trouble."

Methods Used Before SkyMath	
Class discussion	Homework assignments
Data gathering	Interpretation/evaluation activities
Discovery/exploratory activities	Lecture
Small cooperative groups	Problem-solving activities
Data manipulation	Real-life experiential exercises
Methods Used During SkyMath	
<u>New to Some Teachers</u>	
Data manipulation	Field trips
Data gathering	Real life experiential exercises
<u>Useful for Teaching Mathematical Concepts</u>	
Very Useful:	Moderately Useful:
Real life experiential exercises	Interpretation/evaluation
Data gathering	Data manipulation
Small cooperative groups	Discovery/exploration
Problem-solving activities	Class discussion
<u>New to Students in a Math Class</u>	
Very New:	Moderately new:
Data gathering	Discovery/exploration
Data manipulation	Interpretation/evaluation
	Real-life experiential exercises
	Small cooperative groups

Table 4 – Teaching Methods Used by SkyMath Teachers for Mathematics Instruction

The NCTM mathematics standards call for teachers of grades five through eight to use more of these instructional practices: active learning, small cooperative groups, applying mathematics in both a mathematical and real-world context, using technology, using concrete materials, assessing

learning as an integral part of instruction, and teachers facilitating learning. SkyMath’s pedagogical focus fits well with these standards.

IMPACT ON STUDENT LEARNING

“These students have all struggled with math in the past. With SkyMath, they don’t realize it’s math they’re learning because they’re not struggling.” –Teacher

Based on feedback from teachers and students in the pilot studies, it is clear that both groups enjoyed using SkyMath. The essential question is whether students were learning math in the process. Data from the evaluation interviews and questionnaires shows that students and teachers believe that valuable mathematical learning was taking place in these areas: graphing skills, data collection and interpretation, measures of central tendency, and temperature scales. Data results from the SkyMath End-of-Unit Assessment indicate that many SkyMath learning goals were met by students in the field test and pinpoint areas for improvement.

This section of the report presents data on student performance as measured by the end-of-unit assessment, teacher and student perceptions of what students were learning through SkyMath, and information about SkyMath’s impact on student attitudes.

SkyMath Curricular Goals

SkyMath goals for student learning in mathematics are listed in Table 5. The end-of-unit assessment was designed to measure achievement of these goals.

Matters of Scale	Central Tendency	Data Representation/Change
<ul style="list-style-type: none"> • Read Celsius (C) and Fahrenheit (F) temperature scales accurately • Determine numeric intervals for two different scales • Add and subtract signed numbers • Record and match temperatures in two different scales • Describe relationships between points on two scales using ratios • Read and interpret a coordinate graph • Look for and describe mathematically significant patterns in data 	<ul style="list-style-type: none"> • Determine which measure of central tendency best describes typical or average in a given situation • Take into account the effects of sample size and variability on measures of central tendency • Describe an appropriate method for finding an average temperature for a given location • Make a bar/line graph using data and interpret the data from the graph • Calculate and distinguish between range, mean, median, and mode as applied to given sets of temperature data 	<ul style="list-style-type: none"> • Informally compare rates of change • Construct bar/line graphs to show changes in temperature over time • Read and interpret data presented in bar/line graphs • Compare patterns and trends in bar/line graphs • Calculate differences between high and low temperatures • Compare rates of change

Table 5 – SkyMath Curricular Goals

Student Performance on the SkyMath End-of-Unit Assessment

Educators are interested in knowing how a unit like SkyMath might impact student scores on standardized tests. Data from the SkyMath End-of-Unit Assessment cannot provide a definitive

answer to this question, but does give some indication that SkyMath students are competitive when compared to national norms. Results from the Spring 1996 and Fall 1996 rounds of testing showed that students learned many of the math concepts and skills presented in the SkyMath module. The test revealed areas of strength and difficulty in student learning and provided information useful to designers for improving the instrument.

In Spring 1996, students from three of the pilot schools took the end-of-unit assessment test. After some revisions were made to the instrument, students from five schools in the Fall 1996 field study took it. This second group had a diverse student population, from 5th grade to 7th grade, from low and average to high math abilities and experiences, and with many inclusion students involved.¹⁴

The analysis of assessment results compiled by test designers showed very similar patterns emerging for both the spring and fall groups. Overall, the spring group of students scored higher on more of the items than the fall group, but the spring group was less diverse. During both rounds of testing, students scored above norms on many of the NAEP and short-answer items, but overall scores were lower on the performance-based questions.¹⁵

NAEP Items. These “released” norm-referenced items allow testers to compare SkyMath students to a national sample of students experiencing a variety of other math curricula, and provide a familiar and traditional measure of student performance. NAEP items are multiple choice or short response questions.¹⁶

- **Results?** The spring group matched or outperformed the equivalent grade-level sample on all items. The fall group outperformed (or performed at an equal level) the equivalent grade levels on all items except five. Refer to Table E-1 and Table E-3 in Appendix E for a more detailed look at fall results.

Short-Answer Questions. These items were designed to align with the SkyMath curriculum, teachers’ approach to classroom instruction, and use of math in the context of weather-related problems. They demonstrate students’ ability to use mathematics in the context of weather-related problems.

- **Results?** According to researchers, “for the most part SkyMath students demonstrated their ability to successfully apply their mathematical knowledge to these short response items.” The spring group performed above 70% on most of the items while the fall group performed above 70% on half of the items. Refer to Table E-2 and Table E-3 in Appendix E for more details on the performance of the fall group.

¹⁴ The fall testing group included classes of 5th grade students with average and high math ability, 7th graders with low and average ability, including learning disabled and at-risk students, 6th graders with low and average ability including special education students, and 6th grade students with a range of low to high ability, including special education students. Descriptions are based on teacher self-reports of student abilities.

¹⁵ The analysis of Fall 1996 results can be found in the *Final Report of the SkyMath Assessment Team* (May 1997) through the SkyMath homepage (<http://www.unidata.ucar.edu/staff/blynds/SkyMath.html>).

¹⁶ Due to copyright restrictions, the National Assessment of Educational Progress (NAEP) items are not included in the version of the SkyMath End-of-Unit Assessment available through the SkyMath homepage. Information about NAEP test items can be obtained by contacting the Educational Testing Service (ETS), Princeton, NJ.

Performance-Based Tasks. The performance-based or extended-response test items consist of multiple, related parts that build in complexity and require students to apply math in meaningful situations that draw on problem solving, reasoning, communication abilities, and the ability to make connections within the discipline of math and across other content areas.

- **Results?** The spring group was given two tasks, one designed to align with the SkyMath curriculum and the other a pre-developed, released item. For the most part, spring students scored in the Level 1 to Level 3 range, using a 0 to 4 point holistic rubric. Few scored on a Level 4, which is exemplary. Students scored slightly better on the temperature task than the generic task. The fall group completed four performance-based tasks, three based on the SkyMath curriculum and the one released item. Fall students scored in the range of Level 1 to Level 2. They scored better on the Rainfall task, which most closely reflects the SkyMath curriculum, than on the others.

In general, students have not had much experience with performance-based questions as part of their mathematics testing, so it was not surprising that scores were in the lower range on these SkyMath items. In fact, results on the performance-based questions at this point can be seen primarily as useful baseline data from which to judge future progress in student learning. According to one Design Team member, “the newness of this type of assessment item confounds the analysis of what was learned at this level.” Members of the SkyMath Assessment Team felt it was significant that students were able to respond as they did to the performance based items during this round of testing.

Another way to look at the results of the end-of-unit assessment is to look at scores on test items as they match up to the SkyMath curricular goals.¹⁷ After doing so, researchers concluded the following: “As we reflect on the diversity of mathematical ability represented by the SkyMath students, we are encouraged by their overall performance and mastery of the SkyMath curricular goals.”

Areas of particular strength for the field test students were:

- read Celsius and Fahrenheit temperature scales accurately
- add and subtract signed numbers
- record and match temperatures in two different scales
- make a bar/line graph using data and interpret the data from the graph
- calculate and distinguish between, mean, median and mode as applied to given sets of temperature data

Problematic areas for the pilot groups were:

- convert temperature readings between Fahrenheit and Celsius
- concepts of minimum, maximum, and range
- identify the point at which water freezes on both temperature scales
- determine a pattern when given sets of numbers, and then apply that pattern

¹⁷ Refer to Table 3 in Appendix E.

Some of the fall students had trouble manipulating negative numbers and using a graph to determine the specific relationship between two data points. Various other difficulties cropped up at individual schools in both study groups. The analysis of results indicate that students in the field test need further work on the following curricular goals:

- describe relationships between points on two scales using ratios
- take into account the effects of sample size and variability on measures of central tendency
- compare rates of change, informally and formally

A strong point of the SkyMath module is that it addresses some areas that are often difficult for students to learn. One activity is not enough exposure to some concepts to expect full mastery, but SkyMath provides a good beginning.

The Teachers' View: Students are Learning Math Through SkyMath

“As students got into the more math-rich activities, the work became more meaningful to them.” –Teacher

“Math is a curiosity now. My daughter understands that math is part of life.” –Parent

“At first, many of my students didn’t think it was ‘math’ because they were having so much fun,” a teacher points out. But because “they were completely involved in the activities,” SkyMath opened up new learning opportunities for them.

For the fall field test, one teacher purposefully used the module with students who traditionally test low in math to see if SkyMath could motivate them to greater achievement. She says, “Weather is something they think they know by experience and so this makes a good context for new math learning. ... The value of SkyMath for them is that they’re getting math from a completely different angle.”

This new angle seems to work quite well. Teachers who participated in the field test said that SkyMath teaches new math skills and enhances skills in areas that are already familiar to students. In particular, SkyMath deepens student understanding of the basic concepts underlying mathematical computations. In the questionnaire, teachers said SkyMath’s content was generally new to students participating in the field test and that their mathematical learning improved a moderate to very good degree in the process. Table 6 summarizes perceptions teachers have about the impact of SkyMath on students.

Students with a range of math skill/ability levels and experiences feel challenged by SkyMath and can do the activities successfully. Teachers confirm that all their students are learning something from SkyMath, but they are learning at different levels. The participating teachers see growth in each of these areas of student learning:

- skills in data collection and analysis
- knowledge of mathematical concepts and deeper levels of understanding of concepts
- learning math skills and application of computational skills
- higher level thinking, reasoning, and problem solving skills

The use of real-time data was useful for learning math.	4.7
Students benefit from the pedagogical strategies embedded in SkyMath.	4.3
Student math learning was improved by SkyMath.	4.0
The extent to which the SkyMath content was new to students.	3.8
Student math skills and knowledge were improved by SkyMath.	3.5
Student attitudes about math were improved by SkyMath	3.3

Table 6 – Teachers’ Perception of the Impact of SkyMath on Students¹⁸

A 5th grade teacher believes that one reason SkyMath works well for 5th graders is that it is not a purely computational module, but it exercises deductive reasoning, logical thinking, predicting, and questioning which she considers important math skills. In fact, a few SkyMath teachers used this strategy as a way to assess their students’ learning – they informally compared the level and content of the questions students asked at the beginning of the module to those posed toward the end to look for signs of deeper understanding.

One teacher reported that during the first SkyMath activity her kids’ questions were primarily of this type: What’s the sun’s temperature? What’s the difference between Fahrenheit and Celsius? At the end of the unit they were more concerned with sampling. They asked questions like: How long did these people collect the data? How did weathermen keep records so they know what the record highs and lows are? Her kids now understand how it is possible to get local averages of temperatures, but they aren’t convinced that people who publish books with weather data have done the work needed to find averages for cities. They have become more educated and cautious data consumers.

Based on feedback from teacher questionnaires and interviews, the major mathematical learning students have gained from SkyMath falls into four main categories – graphing skills, data collection and interpretation, measures of central tendency, and temperature scales. Details are as follows:

1. Graphing Skills

- creating and interpreting line graphs (the first exposure for most)
- the value of graphing data
- the concept that graphs can show trends or change over time
- how scale impacts the appearance of the data
- how to select the best type of graph for data display

2. Data Collection and Interpretation

- collecting real data and organizing it in a meaningful way
- interpreting data, extracting meaning from numbers, and understanding patterns
- looking at data from different perspectives

¹⁸ Based on responses from eight out of ten teachers and rated on a scale of 1 to 5 where 1 = Not At All, 3 = Moderately, and 5 = Very Extensively.

- skills in sampling and an understanding of the impact sampling has on data

3. Measures of Central Tendency

- the concepts of mean, median, and mode and how to calculate these numbers (most already knew how to calculate an “average”)
- how to select the best measure of central tendency for a particular situation

4. Temperature Scales

- concepts of maximum, minimum, range, and ratio
- constructing temperature scales and understanding intervals
- reading and converting Fahrenheit and Celsius temperature scales
- concept of temperature variation

5. Other Mathematical Learning

- applicability of mathematical learning
- introductory skills in adding and subtracting negative numbers
- improved measuring and predicting skills
- new sources for math learning besides textbooks

In addition, some teachers said students learned a lot about weather and how to access weather data, they improved geography skills, and learned to use the scientific method through SkyMath.

Several of the SkyMath teachers questioned the value of teaching the Celsius to Fahrenheit conversion formula, which has been a source of frustration for some students. In fact, although some teachers interpreted it as such, the derivation and application of a formula for Celsius to Fahrenheit conversion was not a stated goal of the SkyMath unit. Rather, the Design Team’s intent was for students to use paired Celsius and Fahrenheit readings to construct an approximate formula for conversion as just one of many exercises focused on the recognition and description of linear relationships in paired data. The true goal was for students to be able to use sets of paired data from any two temperature scales to develop a way to translate measures from either scale to the other.

The Students’ View: Learning Through SkyMath

“Because of SkyMath, I think it’s a lot easier to think of math as creative. I didn’t think this way before.” –Student

“With SkyMath it is much easier to learn, even though the activities are harder, because you are working with something you can understand and sticking with the same subject longer.” –Student

What students are saying about SkyMath is quite straightforward – SkyMath is fun and we are learning. After the Fall 1996 field test representative groups of students from four pilot sites were interviewed by evaluators. A key finding from these interviews was that most students were able to identify quite readily the math they were learning from SkyMath. Their responses corresponded closely to what teachers were saying. Students talked about a variety of SkyMath activities and most could explain what they thought were the purposes behind these activities.

Students also identified new things they learned in science (weather) and technology. From the student perspective as well, SkyMath emerges as an integrated learning experience.

Students said that what they learned through SkyMath is focused primarily in these areas:

- **Graphing Skills.** Students learned new types of graphs (line) and new methods for graphing data. Some learned how to select the best format to display a specific data set.
- **Measures of Central Tendency.** Students learned about mean, median and mode, and how to calculate these measures. These were new terms and concepts for some and a review for others. Some found it a challenge to calculate averages using negative numbers.
- **Temperature Scales.** Students learned how to read and compare temperature scales. Some learned how to convert Fahrenheit and Celsius, others did not. Although learning the conversion was difficult, some students listed this as one of the main things learned.

Some other areas of math learning that students mentioned are: learning about range, applying basic math skills, adding and subtracting negative numbers, working with spreadsheets, finding patterns on data charts, and learning about absolute zero. One student said he had to practice his division in order to calculate averages.

One teacher asked her class to graph the same temperature data first using a Fahrenheit scale and then using Celsius. Her students were impressed with how this changed the overall appearance of the data. Using the Celsius scale flattened the curve. The kids talked about which graph they would use if they wanted people to think there wasn't much temperature change and how different presentations of data can tell different stories. The graphic comparison helped students understand the differences visually.

Student Attitude and Engagement in Learning

“When kids get on the computer and they see the weather all over the United States – where their grandparents live or where their father’s from – and they can collect all that data and do something with it, that’s tremendous! They’ll work with numbers like they’ve never worked before ... when they have a reason to do it.” –Teacher

“SkyMath has been very enjoyable for my students and for myself. We’ve become collectors of information and we’ve learned how to record items in a useful manner. My students have become more aware of their environment and the changes that take place in and around school.” –Teacher

Students as well as teachers enjoy working with SkyMath and are motivated to participate. Throughout the SkyMath module, learning is active and tied to information and events that are interesting and relevant to students, so it is no surprise to learn that they are very enthusiastic. Teachers who piloted the module experienced how the hands-on approach, weather content, group work, and use of technology engages students in mathematical learning. Specifically, teachers agree that using real-time data is an extremely valuable tool in this respect. Students seem to agree.

In one class 6th graders rotate daily between SkyMath activities and regular math assignments. To them, regular math means working individually with overheads and dittos to solve math problems. SkyMath involves using some dittos, but the students also work in cooperative groups, take temperatures around the room and outside, and access weather data on computers. "Regular math equals the overhead," one student commented. "Regular math deals with situations that could have happened, but never did," he goes on to say, "But SkyMath involves stuff that actually happens around us, that involves us."

SkyMath is designed to get students to make progressively more learning decisions. At the beginning of the module, students pose their own questions about the content and as a final activity they design projects to pursue an area of interest. Students enjoy working on math in small cooperative groups and benefit from this by learning to work independently from the teacher and to take initiative within a group.

These aspects of SkyMath contribute toward building a positive attitude toward math, according to teachers in the pilot study. At several of the schools, teachers noted a marked improvement in student attitude, even among those with lower math ability, while at one school the change in attitude was only moderate, perhaps indicating that these students had a more positive outlook to begin with.

The impact on low-end students appears to be significant. Students who did not feel much confidence in math before SkyMath, have become more involved. For example, one student who rarely did any of his work is now using the computer, participating in his group, and turning some of his assignments in. At all the schools visited, half of the students interviewed said they like math more now than before SkyMath and the other half like it about the same. Some students admitted that they used to "hate math." One explained, "I was never good in math, but now I like it a little better." Another said that now he "can't wait for 7th period math all day." A student who has always liked math said he thinks a lot of kids who didn't, "are enjoying it a whole lot more." Even students who are skilled in math are not bored and feel they are challenged to learn new things.

One teacher explains her school's situation, "We do not have a lot of weather changes here in (the Southwest) and the students think all the weather changes elsewhere are great." It just so happened that during December and January, when her class was doing SkyMath, the area experienced unusually cold temperatures with some snowfall. This turn of events made their work especially interesting. Kids were excited about coming back from the holiday break to read data on the temperature probe.

Student Opinions About SkyMath and SkyMath Activities

*"It's easier for me to do hands-on stuff than having it explained in words."
-Student*

During interview sessions, students talked about the SkyMath activities they liked best. Some of their favorites are:¹⁹

¹⁹ Before these interview sessions, two groups had finished the entire module while the other two had not.

- ***Temperatures in the Classroom.*** Students enjoyed working with thermometers; recording, comparing, and averaging temperatures; and learning about how placement of the thermometer in the room affects temperature readings.
- ***Graphing.*** Students learned how to graph temperature data and what to consider when choosing between bar and line graphs to display data.
- ***Weather Maps.*** Students liked making weather maps because they were learning US. geography, using computers or *USA Today* to access data, and they were drawing.
- ***Stowaway Temperature Probe.*** Kids liked figuring out how often they needed to take the temperature given the number of bits of memory in Stowaway. Some students took the probe home to record data.
- ***Charting Thermometer Scales.*** Students enjoyed learning how the first thermometer was made and then inventing their own. Some liked figuring out intervals on a scale. One group particularly enjoyed the story-based scaling activity where they came up with a rationale for locating various temperatures on the thermometer.

In addition, some students also liked these activities: using the mean, median, and mode; recording weather logs; sending and receiving e-mail messages; and using Blue Skies to access weather information. Several classes did not do the spreadsheet exercise, but one group of 7th graders who did enjoyed this activity.

SkyMath activities that some students did not like:

- taking SkyMath quizzes and doing homework
- working with the Fahrenheit and Celsius conversion
- trying to log onto Blue Skies when computer systems were slow or disabled

Appendix D contains a set of charts that show ratings teachers and students in the Fall 1996 field test have given to each individual SkyMath activity.

When comparing SkyMath to regular math classes, students shared their perceptions of some advantages to SkyMath. Almost all the students interviewed identified hands-on learning as a very positive and engaging component of the curriculum. Many also said they could learn math better through activities, rather than by just doing worksheets or reading from a text.

Students said that learning with SkyMath means less homework, less textbook and overhead work, and fewer tests, and they think that's great. Aspects of SkyMath that were new to these students in the context of math are: working in small groups (generally kids have done group work in other subjects), doing projects, using the computer, and integrating math with another subject. One student pointed out another plus to SkyMath – kids are taking down their own notes, not copying the teacher's. "You can decide for yourself (what is important)," she goes on to say, "instead of writing down what someone else discovered."

Communicating Mathematical Learning

SkyMath is designed primarily to help students learn important math skills and concepts. A complementary goal woven into the curriculum is to develop student skills in communicating with and about mathematics. The second year SkyMath evaluation reported that students were not able to articulate much about their math learning. In response, the module was modified to be

more explicit in regard to the skills and concepts being covered. When students were interviewed for the final pilot study, they were quite capable of talking with teachers and evaluators about the math they were learning, an encouraging sign that this group is developing a mathematical language. Although SkyMath students can identify mathematical learning, it is not certain whether they can describe the mathematical functions and processes embedded in the module outside of the context of weather and temperature. This is something SkyMath teachers may want to look at more closely as their students apply new skills and knowledge to new situations.

According to the teachers, most e-mail communications between students and their partner schools did not show much depth of communication about math. Students were sending personal messages and school information, and were exchanging data, but they were not going beyond that in terms of processing or sharing what they had learned about math. Some teachers tried to leverage more focused communication by requiring students to include math information in their messages. Communication about learning is still an area for more development.

For example, one teacher asked her students to write to the partner class about how they had figured out the typical temperature in their classroom. Kids had collected a large amount of data and from it had computed the median, mean, and mode. First students had to decide which figure best represented the typical temperature and then, in their e-mail message, they had to explain to the other class why they had made this choice. This proved to be a very challenging thinking and writing assignment. Different groups of students came up with different rationales to support their choice of most typical.

One teacher pointed out that it is important for teachers at partner schools to coordinate SkyMath lessons so that e-mail messages between students are timely and meaningful in terms of mathematical learning, otherwise this activity does not meet the module communication goals.

In addition to using e-mail, SkyMath teachers came up with these suggestions for the most effective ways for students to communicate their mathematics learning:

- in-class discussions that involve oral explanations to teachers and the entire class
- group activities that require students to make decisions about how to present information
- activities that involve transfer or application of new concepts and prior knowledge to new situations

Teachers also recommend promoting communication about math through student reports, written explanations, assessment questions, interaction and discussion in small groups, student demonstrations, and charts and graphs of data.

Transferring Skills and Knowledge Gained Through SkyMath

At this preliminary stage of testing the module, there are emerging signs that the skills acquired through SkyMath transfer to other areas of student learning. One example is worth mentioning. At one of the fall field test sites, 6th grade SkyMath students are involved in a science project that draws on skills in data collection and interpretation gained from SkyMath.

The school received a grant to do some planting in the school's outside atrium. The 6th grade science, math, and resource teachers teamed together with all 346 6th graders to work on this science project. They started by cleaning and preparing the space and then planting bulbs, seeds,

and bedding plants. The goal of the study is to compare the actual rate of growth of the garden plants to the predicted growth based on information provided by growers, and to look at variables like water, temperature change, and other conditions that affect this growth. Here is where SkyMath skills contribute. Students are using Stowaway to record temperature data which they will graph to determine range and rates of change. Students are making observations of germination time, plant growth, the quality of plants, and number of germinated seeds, and they are monitoring temperature conditions in the atrium. They record all activities and data in science journals.

How did the learning in SkyMath transfer to the Atrium project? The math teacher says that SkyMath taught her students a lot about predicting, variables that impact data results, and data collection and interpretation, and this understanding applies directly to the atrium work. Students are thinking about what is supposed to happen and looking at what actually happens as measured through data. SkyMath helped them practice this. Last year they planted poppies which were expected to bloom in March, but because it was a mild winter, they bloomed in January. Now this year an unseasonable cold front moved into their area and this had a different impact on their garden.

Students commented that they are applying what they learned about weather and temperature through SkyMath to their atrium work. They said using Stowaway to collect data was very useful for this project too. They learned what the minimum temperatures are that the plants could tolerate and then checked actual temperatures to compare the two.

Summary of Information on Student Impact

Based on the experiences of teachers and students in the SkyMath exploratory tests, the module appears to have a strong and positive impact on students. Students of all ability levels enjoy the activities and become engaged in mathematical learning by working hands-on, with real-time data and technology. They learn important concepts and skills identified as the SkyMath learning goals and begin to build a base of understanding for more difficult and advanced mathematical concepts. Students perform well on NAEP test items, and in some areas out-perform their peers. There are some strong areas of learning indicated on the SkyMath End-of-Unit Assessment, some topics that need more improvement to gain mastery, and room for growing competence on the performance-based items.

SUPPORT SYSTEMS

Teachers who were involved in the exploratory tests of SkyMath received both internal and external support for their efforts. This section reviews these systems and the ongoing support that will be available to teachers using SkyMath in the future.

Teacher Resources Included in the SkyMath Module

The background information segments written into the text of the SkyMath module are valuable learning tools for teachers. The module also includes references to a variety of resources teachers can access to expand their content knowledge in both math and science. During the initial stages of the field test, teachers shared their experiences and ideas for extension activities and these were written up and included in the module as “teacher stories.” The story segments give a real picture of the implementation process and examples of how teachers have adapted different lessons to fit

their own situation. These built-in resources have been useful to teachers during the exploratory tests.

Professional Development

To teach the SkyMath module, teachers need a basic knowledge of computers. They also need some resource material on the science concepts, which is provided in the background information included in the module. Teachers can prepare to teach SkyMath without any outside training, but they can benefit from planning together with other interested teachers in their school or district. Teachers may also want to identify local contacts for science and technology support. Some may want to upgrade their knowledge of basic weather concepts, computer skills, and take an in-depth look into teaching methods like cooperative groups, peer learning, hands-on techniques, and student-centered methods in conjunction with implementing SkyMath.

Support Systems

“This will be my third year working in the SkyMath program. EDC has been of great assistance. Our school now has a weather station.” –Teacher

Project developers gave each teacher in the field tests a copy of the SkyMath module, access to a Stowaway data probe, and a stipend to participate. Now that the development period is over, the complete module and all support materials are available to teachers free on the Internet. A school needs approximately \$200 to purchase the Stowaway data probe and thermometers.

During the field test, the intent of the SkyMath project was to build strong connections between university faculty and classroom teachers. This became a significant factor at two of the fall sites, where university professors visited classrooms, interacted with students, brought undergraduate assistants to help, and provided technical support for computer work. At other sites this connection did not materialize. Some UCAR faculty offered on-line consultation with teachers. One university faculty helped a teacher secure computers for her school.

SkyMath’s Principal Investigator took a strong lead in supporting all teachers during the pilot tests. She was instrumental in setting up partner schools, establishing an on-line list service, initiating lines of communication with teachers and between teachers, and recruiting new teachers to pilot SkyMath in Spring 1997. Although most teachers did not use e-mail very much themselves, the PI modeled how effective this electronic medium can be for communication and support.

In one district, a separate NASA educational grant financed Internet hook-ups in the schools, including the SkyMath pilot school. The NASA project coordinator at the local college supports all teachers, including SkyMath teachers, in using the new technology.

Keeping up with changing technology is a challenge for everyone, and the SkyMath program directors have run up against some problems in this area. One of the main resources written into the module is Blue Skies, yet teachers and program designers have experienced problems with this program. The staff at EDC is trying to keep updated on the many changes that are being made to Blue Skies and at the same time looking for comparable resources to emerge on the web.

On-Site Support

“My principal encourages teachers and students to take ‘risks.’ I feel this is necessary for units like SkyMath to be successful.” –Teacher

According to teachers in the Fall 1996 field test, school and district administrators, other school faculty, and parents were all very supportive of their SkyMath work. Half of the teachers have administrators who encourage teachers to try new curricula and new ways of teaching, and this builds a good climate for the expansion of SkyMath. Administrators generally are quite interested in teachers incorporating technology into lessons, and many back this up with whatever funding they can muster.

SkyMath teachers find that other teachers at their schools are interested in learning more about the module and parents who know about SkyMath are very supportive.

Ongoing Support

Although funding for the development of SkyMath has ended, UCAR and UNIDATA²⁰ staff are committed to maintaining and updating the SkyMath Home Page on the World Wide Web as an ongoing support system and dissemination mechanism. The module, this report, the end-of-unit assessment, and other resources are accessible to download cost-free from the SkyMath Web site (<http://www.unidata.ucar.edu/staff/blynds/Skymath.html>). UCAR will continue to provide a listserv for teacher and student e-mail correspondence.

According to UCAR leaders, there is a growing emphasis at UCAR on education, particularly on programs like SkyMath that connect geosciences and mathematics. UCAR staff are concerned about educational issues, especially equal access for women and minorities to secondary math and science classes that support careers in the geosciences. UCAR has a supporting role to play in the educational arena, but does not have the funds or expertise to direct major projects. Math is unlikely to ever be a central focus for UCAR, but recognition of the value of the connections between math and science that SkyMath represents is present. It was among the hopes of UCAR leaders to stimulate better cross-talk between these two areas. This connection is also reflected in the cross-disciplinary focus of the new science standards. A new UCAR program called PAGE (Program for the Advancement of Geosciences Education), which focuses on undergraduate education, may link to some of the SkyMath work.

Two efforts spearheaded by the SkyMath PI are supported by UCAR and UNIDATA. First, the PI is working with a publisher to get a simplified, bound version of the module published. Second, UCAR leaders support the PI's efforts to get new funding for the development of more SkyMath modules. According to one UCAR leader, “This is something we should pursue since it is part of UCAR's mission to address education including K-12.” UCAR will help in this effort by meeting with potential funders and looking into private grant sources.

The PI has also started creating a cadre of teachers who are enthusiastic about the SkyMath module and who are willing to serve as SkyMath Research Teachers and be available as electronic resource people.

²⁰ UNIDATA, which stands for University Data, is sponsored by the National Science Foundation and managed by the University Corporation for Atmospheric Research in Boulder, Colorado. It was established in the early 1980s to enable universities to acquire and use atmospheric and related data.

Teachers involved in the pilot tests suggested that university faculty and scientists can assist teachers who are implementing SkyMath in several ways: by coordinating and pairing partner schools, mentoring and providing moral support to new SkyMath teachers, trouble-shooting technological problems, providing higher level insights on weather content, providing enrichment experiences for math classes, helping students get a broad understanding of resources available through expert scientists, and helping students set up weather stations.

At the time of this report, at least one TV weather station was getting actively involved with SkyMath (for more information, visit the SkyMath homepage).

STRATEGIES FOR DISSEMINATION

At the preliminary stages of development and implementation, SkyMath has proved to be an effective tool for teaching and learning mathematics. Published in final form on September 1, 1997, the SkyMath module is ready for wider dissemination and use. The information in this section of the report would be of interest to administrators, teachers, and educators who want to support expansion of SkyMath in their schools, districts, and regions. The section begins with a discussion of potential barriers and what is already being done to disseminate SkyMath. Then it presents recommendations for strategies to extend current efforts and for the most compelling information to communicate about SkyMath. Although this discussion is geared specifically to SkyMath, parts are relevant to the process of spreading and integrating any new math curriculum within a system.

Potential Challenges to the Broader Use of SkyMath

As with any change effort in the schools, the old familiar barriers appear – limited time and resources, and an often unwieldy bureaucracy – which tend to thwart or divert action. Much of what people are doing in support of SkyMath and the suggestions made in this report for additional strategies take these factors into account and try to work within these constraints. The fact that the module itself can be obtained at no-cost and expenses for materials are minimal appeals to educators. Some districts lack funds for upgrading to the level of technology called for in the module and this can be a limiting factor, but one that appears to be changing rapidly in many school systems. Access to the Internet is the most expensive part.

One group of educators who gathered to talk about expanding the use of SkyMath in their area believe that SkyMath teachers play a key role in this process. Their concern, however, is finding the money to pay for release time so these teachers can travel to other schools, provide some introductory training and modeling of SkyMath for other teachers, present at professional conferences, and demonstrate SkyMath to university preservice classes. Another group of SkyMath teachers in a large school district are facing another barrier. Layers of bureaucracy and channels of approval in the district delay the adoption of new curricula into the system.

Political factors can create barriers to dissemination. In one state, control over teacher professional development is quite centralized in the sense that the state's urban center is considered the locus of educational expertise. Although there is a lot of local expertise throughout the state, teachers generally don't have the confidence to lead professional development activities because they buy into the idea that "it must come from the experts." This attitude inhibits teacher initiative for educational leadership.

Mechanisms In Effect

Some strategies are now in operation and contributing to the expanded use of SkyMath. The SkyMath principal investigator, UCAR staff, university faculty, and SkyMath project developers are active in these types of efforts:

- **Recruiting** other mathematics teachers around the country to try out the module.
- **Providing** free access to the SkyMath module on the Internet and including useful supplementary materials for teachers at the SkyMath homepage.
- **Linking** the SkyMath homepage to other Web sites that are math and science related. For example, a meteorologist/educator has linked SkyMath to these two Web sites: Eastern Iowa's Weather Connection at www.kgan.com/wx/ and WeatherEye, a free weather education program at weathereye.kgan.com.
- **Making connections** with other math and science networks and reform systems such as NASA, CES, CONNECT, the National Network for Educational Renewal, and rural, urban, and state systemic initiatives.
- **Collaborating** with congruent programs like LEARN II, CoVis, and the American Meteorological Society, and with universities offering summer coursework for educators.
- **Presenting** information about SkyMath at professional meetings and conferences of math, science, and middle school educators focusing on SkyMath as an integrated curriculum.
- **Conducting** teacher workshops on SkyMath, including one for project LEARN II and one for a technology educators group (TIE).
- **Discussing** the merits of SkyMath with scientists and university faculty.
- **Publishing** articles on SkyMath in education journals and involving SkyMath teachers in writing these papers.

In January 1997, as the SkyMath grant was winding down, project developers met to brainstorm ideas for dissemination of the module and delegate responsibilities for follow-up efforts. As a result of that meeting, some of the activities listed above and several additional efforts were launched. For example, an EDC staff person is now working with middle school math teachers in a large midwestern urban school district to help build a hands-on system for math instruction. She is using SkyMath as a teacher development tool for this program.

The SkyMath PI and a university faculty have been working with NASA project directors to incorporate SkyMath into their education work. In summer 1997, they presented a workshop to 40 math teachers participating in the NASA program. Now SkyMath will be featured in a series of NASA summer workshops, including ones at Goddard and in El Paso. Modules like SkyMath can help NASA sites become more focused and accountable for their use of educational grant money. The SkyMath curriculum development process could provide NASA with a useful model to apply to their own design efforts.

In addition, the SkyMath PI presented a workshop on SkyMath to math teachers through the National Security Agency. As part of the session, teachers developed extension lessons that build on the SkyMath module.

Here are some things that SkyMath teachers have been doing locally to spread the word:

- Teachers are sharing information about SkyMath informally with other teachers in their schools and districts.
- With the help of other teachers and a local university faculty, a teacher gave a presentation on SkyMath to staff from other middle and elementary schools in her articulation area. It was titled, “Integrating the Internet in the Classroom.”
- A media specialist had the module activity worksheets translated into Spanish so Hispanic parents could be more informed about SkyMath.
- Teachers made presentations about SkyMath to parents at back-to-school open houses.
- When personnel from the state department visited her classroom, one SkyMath teacher used the opportunity to show them Stowaway, the data collected by students, graphs they had made, and how to access the SkyMath module from the Internet. The state director of an initiative that hooks schools up to the Internet copied some SkyMath activities to show as exemplars of technology-related lessons to educators in other states.

Strategies for the Dissemination of SkyMath

“The strongest model for dissemination is where one teacher tries the module and then gets other teachers to try it.” –Teacher

During this year’s evaluation interviews, site visits, and focus groups, administrators, teachers, university faculty, and parents offered valuable suggestions for how to broaden the use of SkyMath in the schools and districts. Some tactics are broad and some are more targeted strategies. A sample of these ideas are described in this section.

Communication Strategies

There are key people within a school system and community who need to hear about SkyMath. The target audiences may vary in different situations, however, there seem to be some communication links that are vital for dissemination. SkyMath tends to grow primarily at the grassroots level. Teachers usually talk about SkyMath with other teachers in their department and school and this gets the word out locally. But teachers need to look beyond their school setting and expand the scope of their dissemination work. They need to identify key people in the district, region, and state and communicate information about this innovative curriculum to them. Teachers might not have direct access to district and regional administrators or school board members and they might not be aware of who has decision making power over funding for professional development.

With this in mind, a first step might be for teachers to talk to building administrators about SkyMath, gain their support, and encourage their partnership in advocacy efforts at higher levels. It takes an organized approach to reach a wider audience, but the payoff could be great. Curriculum coordinators are very interested in finding good math and science units, especially those that incorporate technology. Strong articulation systems within a school and across schools also help to spread the use of SkyMath.

Strategies to Get Teachers, Administrators, and University Faculty Informed and Involved

Linkages on the Internet. According to one source, there are about 50 strong math and science networks on the Web and SkyMath can be linked to most of these sites. For example, one site of

interest is called SAMI, the Science and Math Initiatives Web site. It has 3000 links that teachers visit for lesson plans and other resources. Although the Internet reaches so many people, a downside is that it is very time consuming to sort through all the information available electronically. Some teachers just don't have the time to do this.

Word of Mouth. Some say the best tactic for dissemination is teachers recommending SkyMath to other teachers. According to one educator, teacher testimonials carry a lot of weight and SkyMath can best be "germinated by teachers within the building." Principals are sent more new curriculum materials than they can ever possibly review, so some principals depend primarily on recommendations from teachers and professional journals.

Integrated Approach to Teaching SkyMath. Someone suggested that more traditional math teachers might be hesitant to try SkyMath because of the amount of time spent on non-math content. A strategy to counteract this would be to encourage math teachers to team teach the SkyMath module with a science or language arts teacher and approach it as an integrated unit. This arrangement would give the math teacher peer support for trying hands-on teaching, because team colleagues might have more experience with this approach. Administrative support would be necessary to back up teachers who want to work collaboratively.

Gradual Approach to Implementation. Some teachers who are not comfortable with a hands-on approach to teaching mathematics may want to begin by using only select parts of the module at first. Other teachers and administrators can support them in this tactic as these teachers work gradually toward full implementation and broaden their methodology.

Funding Sources for Professional Development. Districts that would like to train teachers in SkyMath may be able to tap into Eisenhower money or funds distributed by math and science systemic initiatives and designated for scaling-up efforts. They may also be able to incorporate SkyMath into pedagogical inservices for teachers and link SkyMath to school-to-work programs.

Technology Training. In many districts training teachers in technology is a high priority. Through SkyMath, some teachers welcome the chance to try integrating technology into their math classes. SkyMath may not be as appealing to others who have less computer expertise. For this reason, one way to spread SkyMath in some schools and districts may be to set up a technology workshop. SkyMath teachers could show others how to use the technology related to SkyMath (data probe, e-mail, Internet, spreadsheets, etc.) and help new teachers overcome any discomfort they feel about this aspect of the curriculum.

Technology Initiatives. An ideal venue for promoting SkyMath is through the various initiatives that fund the purchase of computer hardware for schools across the country. School administrators are eager to show that new equipment is being used to enhance learning, so they are looking for quality units like SkyMath. Program directors who oversee technology grants are in an excellent position to help disseminate the module. One NASA grant coordinator has set up an electronic network between schools and teachers with whom he is working. These networks are built-in audiences for SkyMath.

Electronic Mentors. To help disseminate SkyMath, experienced SkyMath teachers could serve as advisors by e-mail connection to teachers who are using the module for the first time. The dialogues between teacher and mentor could be saved and listed as story-based resources available at the SkyMath Web site.

Visual Presentations. Slide shows, videos, or in-class demonstrations of SkyMath would be a compelling way to get teachers involved.

Incorporating SkyMath into Teacher Training Programs. The UCAR network includes 62 universities. UCAR faculty could get the word out about SkyMath and encourage professors to include it in their teacher preparation and math/science methods courses. Colleges need some good hands-on units to show preservice teachers. Effective dissemination on campus would require communication between math and science departments and colleges of education. According to one university instructor, there is a lot to cover in an undergraduate math methods course and not much time to do this. She suggests presenting SkyMath to preservice teachers as an exemplary unit which students could then try out while student teaching. In addition, SkyMath teachers who are supervising student teachers could encourage them to use SkyMath activities. Another idea is to have experienced SkyMath teachers come into a college methods class and teach a lesson for the college students, and they could bring kids along as part of their demonstration.

Strategies to Promote Parental Support and Involvement

Parents who attended evaluation focus groups offered suggestion for how educators might communicate effectively with parents about SkyMath, gain their support, and get them involved in the activities. Communication is key. Several parents at the focus groups had not heard the name SkyMath until they were invited to the meeting and did not realize their kids were involved in a special math program. What is the lesson here? Don't depend on middle school-age kids to tell Mom and Dad what they are doing in math class.

Here are some ideas to consider:

- ***Pre-Module Meeting.*** Parents enjoyed the evaluation group meetings. They think it would be very beneficial to have a parent meeting before beginning SkyMath at the school. At this meeting, teachers could explain the skills and concepts to be covered, why these are important, and model a sample lesson. Then parents would be better prepared ahead of time to help their students at home.
- ***Sample Lessons.*** Rather than have a meeting, parents could be given a packet with sample SkyMath lessons and information about the unit before their children start the module. Some parents might like a list of math concepts covered by the unit and a brief explanation of how these will be taught. One parent said he would like a list of terms and definitions related to the module.
- ***Information Flyers.*** A less costly approach to getting information out to parents would be to send home a one-page information sheet with the option for parents to request more detailed materials. The flyer could include directions for how to download the SkyMath module from the Internet. Parents appreciate flyers that are clear and concise. Some would like to get weekly or bi-weekly updates while their kids are working on SkyMath.
- ***Student Logs.*** Parents are used to consulting math textbooks to see what kids are learning. When there is no text, they feel at a loss. One SkyMath teacher had her students keep a daily agenda of their work and send these home so parents would know what they were

learning. This is a simple strategy, but one that helps to educate parents about instructional strategies that go beyond textbook work.

- ***Parent/Student Project.*** One parent suggested having some SkyMath-related activities for parents and students to work on together at home. Parents could sign-off that the project was completed. Most parents would probably follow through, given that the weather content in SkyMath is of high interest and very accessible to both adults and children. Teachers might choose an activity that is fun and easily understood and perhaps related to a parent's job, family interests, or a real-life situation.

Most parents want to be involved with their kids' learning, but feel overwhelmed if asked to do too much, so teachers need to be selective and reasonable in their requests. Educators should not overlook this strategy, however, because it could be a great way to build a local cadre of parents who support SkyMath and this type of approach to teaching math. Teachers say that parents who get involved with SkyMath are usually very positive. These parents might become advocates and begin to generate a momentum of their own for expanding SkyMath in the schools and districts.

Information About SkyMath

“SkyMath is so nicely packaged that even if this isn't your teaching style, it seems like it's easy to learn to use.” –Teacher

“I thought the real life aspect would be interesting to my students. I also wanted to try the program because of the technology involved.” –Teacher

Participants in the SkyMath evaluation offered their opinions about the kind of information educators and parents would want to know about SkyMath or any new mathematics unit. Some main points to address are outlined in this section.

What Teachers, Administrators, and School Board Members Want to Know About SkyMath

What mathematical knowledge and skills do students learn through SkyMath? The SkyMath module lists explicit math learning goals for each activity. Teachers can go beyond and use this math-rich curriculum in a way that incorporates other concepts and skills as well. Students practice and apply basic math skills in addition to learning important math concepts. Teachers who have used the module feel that a primary benefit to SkyMath is that students gain an in-depth understanding of these concepts.

Is SkyMath congruent with mathematics standards? Teachers who have used the module agree that SkyMath fits well with district, state, and NCTM math standards and it successfully incorporates some science and technology standards as well. SkyMath helps teachers implement a standards-based approach. Teachers are interested in looking at a content analysis of the module to help them link SkyMath with standards and their curriculum. Such an analysis of SkyMath activities and a chart showing connections to the NCTM standards are included in Appendix B.

Is there accountability for student learning built into the module? The SkyMath module includes periodic quizzes and an end-of-unit assessment to measure student learning (this would be of particular interest to school board members as well). In addition, the learning approach used in

SkyMath is consistent with the types of state assessments being developed, including performance assessments.

What kind of support do teachers need from administrators to try this new module? Ideally, administrators would negotiate some release time for SkyMath teachers to instruct others, for new teachers to attend professional development, and for teachers to model SkyMath lessons in the classroom. Administrators would promote a culture that supports innovation and sharing of new ideas among the staff. Some on-site support for computer troubleshooting is helpful to teachers who want to use technology as a teaching tool for SkyMath and other curricula.

Does SkyMath work in the middle school format? As an integrated module that adapts well to a team teaching situation, SkyMath is very congruent with the philosophy that underlies the middle school concept and, this is an aspect supporters could highlight.

Some Other Things Teachers Want to Know About SkyMath

Why would a teacher want to use this module? Students and teachers enjoy SkyMath and it is an effective tool for mathematical learning.

How can teachers teach this unit and still cover their regular math curriculum? The SkyMath module is designed to be flexible. It does not have to be done in six weeks straight. Teachers can integrate the activities into their regular curriculum over a longer period of time or just select parts of the unit to use. The teachers who piloted the module said they could teach SkyMath and still cover their required curriculum content because SkyMath teaches important pieces of the curriculum. In fact, SkyMath can best be used as a “replacement module” because it covers mathematical concepts normally found in the middle school curriculum (data analysis, number relationships, patterns and functions, statistics, and measurement), but does so in a different way. SkyMath replaces the approach rather than the content.

Is SkyMath easy to use or does it involve a lot of extra preparation time? Teachers who have used SkyMath say the module is easy to follow, it provides good background information on science content and instructions for using the technology, it lists materials needed, and describes examples of how other teachers have used it. Everything is written down and it’s just a matter of teachers reviewing each lesson and trying out the technology. It requires very few materials and a very basic level of teacher and student computer experience.

Is SkyMath accessible to teachers who have a traditional teaching style? Some teachers who have used SkyMath feel confident that even a teacher who does not generally use a hands-on, conceptual, or communication-based approach to math, will find the unit easy to use and very accessible.

How can the content in SkyMath be extended to provide a challenge for the advanced student? The module contains teacher stories that illustrate ways teachers have adapted the work to fit the needs and interests of a range of students. Students at all ability levels have the opportunity through SkyMath to work independently or as a group to pursue in-depth learning.

What Parents and School Board Members Want to Know About SkyMath

Many of the points made above are also of interest to parents and school board members, but their specific concerns center around these areas:

- **Math Skills.** Parents want to know what math skills are being taught. They feel more comfortable talking about skill development than talking about concept learning, but both are important to communicate.
- **Student Motivation.** If they don't hear this directly from their kids, parents like knowing that students enjoy SkyMath and that teachers think it motivates kids to learn math by working with weather data and computers. Some parents did not have very positive math experiences themselves, so it means a lot that their kids might enjoy math.
- **Math Curriculum.** Parents want to know how SkyMath supports and enhances the regular math curriculum, and they are interested in knowing how the math integrates with science learning.
- **Administrative Support.** Parents want to know what the school administration is doing to support piloting of new curricula in terms of schedules, equipment, and teacher training.
- **Resources Required.** Parents like knowing that the only equipment students need to provide for SkyMath is a thermometer and schools usually have these to loan. Families are not being asked for any additional resources.
- **Real-World Application.** Parents are impressed with how SkyMath connects math to a real-life context for learning. SkyMath shows students that numbers are applicable and useful in the real world. Teachers should emphasize this aspect when speaking to parents.
- **Technology.** Parents like knowing that SkyMath makes use of technology to support the study of math. They believe computer literacy is an essential skill in our world.

For some parents, SkyMath's connection to standards may be meaningful, but this may be of less interest to others who have had little exposure to standards.

Summary and Implications for Dissemination of SkyMath

Now that the SkyMath module is published in final form, its distribution presents the next challenge for SkyMath supporters. Getting a new curriculum broadly adopted takes more than just making it available. SkyMath is a quality product, and the fact that it can be obtained at no-cost appeals to many educators. However, this is not enough to spread it significantly into schools and districts. There are strategies that supporters can use to help create an environment conducive to new mathematics curricula like SkyMath. The six general mechanisms below summarize ways to bring SkyMath to a broader audience and embed the approach into mathematics curricula:

1. **Teachers Sharing With Other Teachers and Administrators.** SkyMath teachers play a key role in the dissemination process by sharing on a one-to-one basis with their colleagues and presenting the module at workshops and conferences. Teachers need time and support from administrators to carry out these activities.
2. **Connections With Like-Minded Reform Efforts.** The teaching and learning approaches used in SkyMath align with other whole school and systemic change efforts. SkyMath supporters can disseminate the module through these connections.

- 3 ***Linkages to Technology Initiatives.*** Educators who are involved in initiatives designed to upgrade schools' technological capacities are interested in finding innovative curricula that incorporate technology. SkyMath can be introduced through these channels.
- 4 ***Professional Development.*** SkyMath can be incorporated into district professional development plans and included in teacher preparation courses at the universities.
- 5 ***SkyMath as a Curriculum Development Model.*** The SkyMath curriculum development process and the module format can serve as models of excellence for new mathematics curriculum design.
- 6 ***Parent Involvement.*** By providing information to parents and involving them in some SkyMath activities, teachers can build a cadre of support in the school community for SkyMath.

SkyMath as a Model for Curriculum Development

The fifth mechanism listed above is of particular interest and worth expanding upon. An unanticipated outcome of the SkyMath program is the module's emergence as an exemplary model for curriculum development. Several unique features characterize SkyMath's process of development.

The Design Team

The structure and role of the SkyMath Design Team was quite different from the structure and role of many project advisory boards. Developing SkyMath was an ongoing, collaborative process that brought together curriculum specialists with mathematicians, mathematics educators, atmospheric scientists, science educators, technology specialists, assessment specialists, and classroom teachers. Broad and varied input contributed to the quality of the product, but the structure and purpose of the team meetings were most significant – these were working sessions rather than reporting sessions. They differed from a typical advisory board meeting where members are generally called to hear a progress report on what has been decided and executed by a project staff, and give their stamp of approval. In contrast, the SkyMath Design Team met as frequently as budget would allow to design each phase of work, assess the work accomplished, and coordinate all work with the original specifications and feedback from the field trials. The content of SkyMath was continually shaped by the Design Team as it progressed from outline to final format.

Roles and Contributions

The mathematicians and scientists on the Design Team worked hard to understand the distinction between using this approach in SkyMath – making mathematical connections by using a real-world context to create or extend mathematical ideas – versus simply making mathematical connections by using known mathematics to explain real-world phenomena. The successful resolution of their struggle and subsequent focus on the former perspective comes through in the SkyMath module and is reflected in plans for another module which have been outlined by one of the scientists.

The mathematics and science educators on the Design Team ensured that the module was exemplary of national content, teaching, and assessment standards in their fields. They suggested

specific topics to develop, contributed outlines of activities, edited drafts of the module, aligned the materials with standards, and enforced the application of the design principles (detailed in the description section of this report).

The module writers played an important role at the Design Team meetings. While their work was subjected to intense review, they listened, probed, explained but did not defend, and incorporated the advise of the team into each draft.

Input from teachers on the Design Team and those participating in the classroom field tests resulted in significant modifications to the module that ensured that grade-level appropriateness of the materials for students and needed support materials for teachers were both incorporated. The field tests of SkyMath provided valuable feedback that wove together the work of teachers and students, the evaluation team, and the assessment team. Teachers also contributed effective module activities. Scientists, mathematicians, and teacher educators visited trial classrooms and brought back useful input from these experiences.

Early entry of the SkyMath materials onto the Web site was also an important step in the development process. The SkyMath Web site developed naturally as a technological companion to the module, increasing the accessibility and flexibility of the module and providing a rich array of supplemental resources.

In the words of one of the Design Team members:

“Looking back on the module’s development, I think that Design Team members would agree that the process was both rewarding and difficult. The content, presentation style, and format of the module changed dramatically as a result of the Team’s regular and active participation. Moreover, it is clear that all Design Team members ... made significant contributions to the final product. Moreover, a group that came together as a collection of individual talents emerged from the experience as true collaborators.”

APPENDIX A EVALUATION QUESTIONS

GUIDING FOR YEARS ONE

AND TWO

Some of these questions were addressed sufficiently in the first two years of the evaluation and others are questions that were ongoing through the third year of the SkyMath evaluation.

Student Processes

1. *What do students learn through the module?*
2. *What do students find most appealing about the module (both in terms of content and instructional process)?*
3. *What learning is needed by students, teachers, and others prior to using the SkyMath module in the classroom?*

Teacher Roles

1. *How did teachers use the module and how appropriate was the approach?*
2. *What characteristics of the pedagogical approach appear most related to student learning?*
3. *What revisions are needed in the module to make it easier/more productive for teachers to use?*
4. *What are the professional development implications for teachers and others prior to, and during, the use of the module?*

Environmental Conditions

1. *What support is needed by teachers that is not part of the SkyMath module (e.g., technological support)?*
2. *How do contextual factors such as ethnic composition of the school, economic status of the community, extent of technology, existing linkages to universities, and community size affect the implementation of the SkyMath module?*
3. *What role can university faculty best play in supporting the use of the SkyMath module?*
4. *How does the module fit within the rest of the mathematics curriculum of the school and district?*
5. *What is the nature of the working relationships, roles, and responsibilities among teachers, school and district administrators, students, and others that need to be considered to support successful use of the module?*

Mathematics Content

1. *What do students learn through the module?*

2. *What, if any, are the special benefits of using real time weather data in the module?*
3. *What revisions are needed in the module to improve student learning?*

ANALYSIS OF THE SKYMATH MODULE**Summary of Mathematics Content**

The Summary of Mathematics Content gives a more detailed look at the content covered in each SkyMath activity and is based on the independent analysis done by Dr. Fernand J. Prevost in June 1996.

Activity 1:

- Students identify questions and pose problems that can be solved using mathematics.
- Students are introduced to the Celsius and Fahrenheit temperature scales.

Activity 2:

- Students review what state, national, and world weather data are available and how those data are collected.
- Students design a process for collecting data to answer local weather-related questions.
- Students decide on a common set of data to be collected.
- Students learn how to read a thermometer in Fahrenheit and Celsius scales.
- Students learn how to use a Weather Log, read and record temperatures, and calculate changes.

Activity 3:

- Students read a min-max thermometer.
- Students record minimum and maximum temperatures and analyze differences.
- Students use maps to identify locations.
- Students look for patterns of differences across the United States.
- Students learn to use *Blue Skies* to access and upload temperature and weather data.

Activity 4:

- Students learn to read Celsius and Fahrenheit thermometers with intervals representing one and two degrees, respectively.
- Students match Fahrenheit and Celsius temperatures.
- Students add and subtract signed numbers (integers).
- Students look for patterns and discuss rules.

Activity 5:

- Students make a list of events (statements) which are measured by temperature. Students rank order the list and discuss reasons for the order they chose.
- Students review how Fahrenheit and Celsius created their temperature scales.

- Students make and calibrate their own temperature scales by identifying fixed reference points.
- Students find differences and use other operations.
- Students measure distances and divide them into equal intervals.
- Students assign temperatures to the events.

Activity 6:

- Students graph number pairs on a coordinate system.
- Students discuss properties of their graph, such as slope and intercepts.
- Students use the slope of the line to informally develop and describe a rule for converting Fahrenheit and Celsius scales.
- Students translate an informal rule into a formula using a spreadsheet.
- Students create spreadsheets for converting between Celsius and Fahrenheit and describe the rule.

Activity 7:

- Students read analog thermometers.
- Students examine the concept of calibration (equating scales so that all instruments read the same at the same location and the same time).
- Students make conjectures about room temperature.
- Students make bar graphs.
- Students consider maximum, minimum, and range of temperature readings in the room.

Activity 8:

- Students examine the concept of “typical,” or average, and explain their reasoning.
- Students are introduced to measures of central tendency: mode, median, and mean.
- Students discuss which measure of central tendency best describes the “typical” temperature in the room and in a given situation.
- Students explore the effects of extreme data points on the mode, median, and mean of a data set.

Activity 9:

- Students discuss ways to gather data to determine the “average temperature” at a location.
- Students report on and critique their plans.
- Students are encouraged to consider how the choice of measure of central tendency is affected by sample size, placement of recording devices, timing, range, and repetition of specific readings.
- Students identify extremes, compute the range, and find the mean, median, and mode of given sets of data.
- Students make decisions based on an analysis of data.

Activity 10:

- Students read and interpret line graphs; they discuss scales, axes, and labels.
- Students construct line graphs to show changes in temperature over time.
- Students use line graphs to informally compare rates of change.
- Students use line graphs to informally discuss slope.

Activity 11:

- Students interpret line graphs and discuss patterns in the data.
- Students use the LogBook software to construct a line graph and import data into a spreadsheet.
- Students use the data from StowAway to create a table of temperature highs, lows, and range.
- Students identify patterns and trends in line graphs and tables.
- Students compare weather log data with StowAway data.

Activity 12:

- Students calculate the rate of change between high and low temperatures.
- Students explore the meaning of a positive (or negative) rate of change.
- Students relate rate of change to the slope of a line in a line graph.
- Students compare rates of change.
- Students write about data collected outside the classroom using StowAway data, noting patterns in the data.

Activity 13:

- Students read and interpret a temperature map and discuss legend, labels, patterns, and differences between predicted and actual high temperatures.
- Students use computers to gather data about high temperatures in selected cities and compare the actual high temperatures with the predicted highs.
- Students represent national highs as color bands on a map.
- Students construct a temperature map of the United States and compare actual to predicted highs for the day.
- Students discuss reasons for differences between predicted and actual temperatures.

Activity 14:

- Students consolidate knowledge and skills acquired in previous sections.
- Students pose and solve authentic problems.
- Students apply reasoning and problem-solving skills to independent projects.

Activity 15:

- Students use mathematical communication to explain the results of their work on a final project.
- Students explain how they solved problems.
- Students reflect on what they have learned.
- Students assess their own progress and achievements.

APPENDIX C

SUGGESTIONS FOR THE SKYMATH MODULE

Teachers and faculty made a variety of observations and suggestions about the design and implementation of SkyMath, and their input was communicated to the Design Team to help in making final revisions to the module. Some examples of teacher suggestions are:

1. Provide some guidance in the module for how teachers, new to SkyMath, might select just some of the activities initially, rather than doing the whole module for the first time. Some teachers want suggestions for how to bypass some of the preliminary, non-math activities at the beginning of the module in order to spend more time on the math-rich activities.
2. Reduce the span of time for Stowaway data collection from eighteen days to two shorter time periods. The longer time stretches the attention span of 6th grade students. The first short run could be tied to the line graph portion of the module and the second Stowaway activity could be related to the concept of range. Logging temperatures is another activity that students tend to lose interest in over time.
3. Include some simpler activities on measuring to prepare students for the section on scale or include suggestions for an optional lesson if teachers feel their students need this. In the section on Celsius/Fahrenheit conversion include the method one teacher developed for helping students create a close approximation of the conversion formula. Add more activities to help students compare a variety of scales.
4. Include more activities on range.
5. “The module needs work regarding the introduction to spreadsheets. It needs to assume that teachers know a bit less about spreadsheets; it needs to account for students who know a bit more about patterns.” For those who see the patterns readily, provide an extension activity for them to do while the teacher works with others for whom this is more difficult. One teacher thought it would be useful to export the spreadsheet information to Claris to create graphs.
6. In the section II quiz, revise questions 4A and 7A. The wording was confusing to students.
7. Make a list of critical skills for each activity and a task analysis that could be used by special education teachers to adapt the module for use with their students. Or include special supplements identified for special education students. Or add some teacher stories that describe some modifications used for special education.
8. Emphasize how important it is to coordinate the timing of lessons with partner schools so that kids really can communicate effectively about math through e-mail.
9. Include more suggestions for writing activities since many of the SkyMath activities lend themselves to integration of language arts.
10. Suggest in the module that teachers try this assessment strategy – ask students to pose new questions for study at the end of the module too. Teachers then compare the quality and content of student questions at the beginning of the module with those they ask at the end to

evaluate whether their level of thinking and understanding has changed. Do students ask more questions about math, or primarily science-related questions and are questions more in-depth? This could also be a way for teachers to encourage extension activities or to demonstrate how there are new questions to explore even after the module is completed. This could be included as a teacher story.

11. Use the previous version of the US weather map for activity 13.
12. Incorporate a more realistic estimate for how long it will take to implement the module.
13. List the mathematics standards that are addressed by each of the module activities on the first page of each activity section.
14. List math objectives – both skills and concepts – more prominently in the module.
15. Encourage students to explore other weather-related sites on the Web and ask them to report on the types of information available and evaluate each site in terms of usefulness.
16. On the scale exercise, change the length of the thermometer used to 10" so that initially, it is easier for students to break it down into familiar units. Then students can build up to more difficult scales.
17. Include a list of possible topics for the final projects or reports.
18. Include work on integer operations which are emphasized in some 7th grade curricula.
19. Include suggestions for how to work math/science teaming.

APPENDIX D

TEACHER AND STUDENT RATINGS OF SKY MATH ACTIVITIES

SkyMath Activities

Section I: Getting Started

- A-1 Brainstorming: Temperature and Temperature Changes (prior knowledge and questions)
- A-2 Be a Weather Watcher (log temperature data)
- A-3 Introduction to Blue Skies (computer access to weather data)

Section II: Matters of Scale

- A-4 Reading Celsius and Fahrenheit Scales (practice reading temperatures)
- A-5 Make Your Own Temperature Scale
- A-6 Making a Rule to Convert Between F° and C°

Section III: Central Tendency

- A-7 Is Our Room All One Temperature? (measure temperatures in classroom)
- A-8 How Can We Describe Our Room Temperature? (determine typical temperature)
- A-9 Sampling and Comparing Temperatures

Section IV: Data Representation and Change

- A-10 Line Graphs
- A-11 Exploring the Stowaway Data (analyze data)
- A-12 What's Been Happening? (calculate rates of change recorded by Stowaway)
- A-13 Were the Predictions Correct? (make weather maps)

Section V: Pulling It Together

- A-14 Answers and Questions (reconsider questions from the beginning of unit)
- A-15 Presentations and Reflections (present student projects)

Skymath Activity Ratings

How much of the activities teachers generally covered.	4.7
How well the activities fit with district math curricula.	4.7
How much teachers enjoyed doing the activities.	4.6
The extent to which technology in the activities is easy to use.	4.4
The extent to which the activities are useful in teaching math.	4.3
The extent to which students see the activities as math related.	4.0

(Averages are based on a scale of 1 to 5 where 1 = Not At All, 2 = Very Little, 3 = Reasonably, 4 = Very Much, and 5 = Completely.)

Table D-1 – Teachers' Overall Ratings of the 15 SkyMath Activities

Question	Activity Number							
	1	2	3	4	5	6	7	8
Number of Teacher Responses	5	6	5	4	6	6	4	5
Range of Time Taken (mins.)	50-150	60-150	45-150	75-135	50-135	75-120	75-150	90-150
Like Doing Activity	4.3	3.5	4.4	5.0	4.8	4.1	4.7	4.6
How Much of Activity Done	5.0	4.5	4.6	4.8	5.0	4.5	5.0	5.0
Fits Math Curricula	3.7	4.0	4.4	5.0	4.7	4.8	5.0	4.8
Useful in Teaching Math	3.3	3.3	3.8	4.8	4.2	4.8	4.8	4.6
Students See as Math Related	3.0	3.3	3.6	3.8	3.3	4.5	4.5	4.4
Ease of Technology	3.8	4.7	4.2	3.7	4.0	4.3	5.0	4.5

Question	Activity Number							
	9	10	11	12	13	14	15	
Number of Teacher Responses	4	5	5	3	4	2	2	
Range of Time Taken (mins.)	75-150	50-250	50-200	50-200	50-200	100-135	100-135	
Like Doing Activity	5.0	4.8	5.0	4.7	4.8	4.5	4.5	
How Much of Activity Done	5.0	4.6	4.6	4.6	4.5	4.5	4.5	
Fits Math Curricula	5.0	5.0	4.8	5.0	4.5	5.0	5.0	
Useful in Teaching Math	4.8	4.8	5.0	5.0	4.5	3.0	4.0	
Students See as Math Related	4.8	4.8	5.0	4.7	4.3	2.5	3.5	
Ease of Technology	4.0	4.7	4.4	5.0	5.0	NA	NA	

(Averages are based on a scale of 1 to 5 where 1 = Not At All, 2 = Very Little, 3 = Reasonably, 4 = Very Much, and 5 = Completely.)

*Table D-2 – Data on Individual SkyMath Activities from Teacher Activity Response Forms**

Question	Activity Number						
	1	2	3	4	5	6	7
Number of Student Responses	14	21	12	7	21	14	12
Like Doing Activity	3.2	2.7	3.4	3.6	3.2	3.5	3.3
How Much of Activity Done	3.1	3.7	3.3	3.6	3.5	3.8	3.8
Helpful for Learning Math	2.4	3.0	2.6	3.7	3.2	3.6	3.7
Interested in Activity	3.4	2.8	3.3	3.6	3.2	3.6	3.3
How Much Math Content	2.2	2.8	2.4	3.4	3.3	3.6	3.7

Question	Activity Number						
	8	9	10	11	12	13	All
Number of Student Responses	20	13	12	12	7	14	
Like Doing Activity	3.4	3.1	3.3	3.8	3.4	2.7	3.2
How Much of Activity Done	3.9	3.5	3.7	3.9	3.3	3.4	3.6
Helpful for Learning Math	3.1	3.8	3.1	3.1	3.1	2.6	3.1
Interested in Activity	3.2	2.9	3.2	3.3	3.1	2.7	3.2
How Much Math Content	3.3	3.8	3.3	3.2	3.1	2.9	3.1

(Averages are based on a scale of 1 to 4 where 1 = Not At All, 2 = A Little, 3 = Some, and 4 = A Lot.)

*Table D-3 – Data on Individual SkyMath Activities from Student Activity Response Forms**

* Numerical scales on the teacher and student tables are not comparable.

APPENDIX E

SKYMATH END-OF-UNIT ASSESSMENT DATA

Data Tables from the Fall 1996 SkyMath End-of-Unit Assessment Final Report

(These three tables were taken from the SkyMath Assessment Team's final report and analysis of the Fall 1996 End-of-Unit Assessment results.)

School	Test Item																						
	B1a	B1b	B1c	B1d	B1e	B2a	B2b	B3	B4	B5a	B5b	B5c	T1a	T1b	T1c	T2	T3	T4a	T4b	T4c	T5d	T5e	T5f
Number 1	100	88	96	96	79	96	50	42	71	46	71	50	100	92	38	88	38	83	71	63	67	63	54
Number 2	100	100	92	72	84	100	68	44	76	56	88	84	100	84	40	84	36	92	84	76	72	68	64
Number 3	95	88	83	83	90	93	90	62	74	50	69	60	97	90	51	82	23	69	77	64	77	28	49
Number 4	94	96	90	81	79	98	81	63	92	44	58	63	100	98	46	94	31	90	81	77	83	71	69
Number 5	93	96	91	91	96	98	87	64	87	62	80	78	100	98	49	87	9	78	85	71	87	87	73
Total																							
NAEP	Test Item																						
	B1a	B1b	B1c	B1d	B1e	B2a	B2b	B3	B4	B5a	B5b	B5c	T1a	T1b	T1c	T2	T3	T4a	T4b	T4c	T5d	T5e	T5f
3rd Grade	84	85	65	70	50	56	7						94	49	24	29		67	29	44			
4th Grade								42															
7th Grade	95	94	91	94	85	94	77	42		43	61	41		90	60	77		87	64	86	26	38	40
8th Grade																	25						
11th Grade	97	97	94	97	91	96	84	69		65	83	70						91	74	95	40	47	41

*Table E-1 – NAEP Items**

School	Test Item																			
	B6a1	B6a2	B6b1	B6b2	B7a	B7b	B8a	B8b	B8c1	B8c2a	B8c2b	T5a	T5b	T5c	T6a1	T6a2	T6b1	T6b2	T7a	T7b
Number 1	75	71	42	0	96	38	54	79	79	13	67	96	92	63	79	88	0	0	100	63
Number 2	80	80	76	0	100	40	48	72	64	8	60	100	96	68	100	96	0	0	88	36
Number 3	79	55	69	19	98	29	57	76	50	10	55	90	90	46	56	82	10	21	82	46
Number 4	79	81	83	33	94	31	56	71	63	19	58	96	92	65	81	94	42	65	94	60
Number 5	93	89	786	7	98	58	64	71	69	7	67	96	95	87	76	89	4	2	93	67
Total	82	76	72	14	97	40	57	73	64	11	61	95	93	68	77	90	14	21	91	57

*Table E-2 – SkyMath Short Response Items**

* Numerical values are correct responses as a percent of total responses.

Curricular Goal	M.C. Tasks	Short Response	P.B. Tasks
Section 2 – Matters of Scale			
<ul style="list-style-type: none"> • Read Celsius (C) and Fahrenheit (F) temperature scales accurately • Determine numeric intervals for two different scales • Add and subtract signed numbers 	T3 B1a-e, B2a-b, T1a-e, T2	B6a, T6a B7a, T7a-b B8a-b, T8c1	T8a T8b-d
<ul style="list-style-type: none"> • Record and match temperatures in two different scales 		B6a-b, B7a, B8c2, T6a-b, T7a-b	
<ul style="list-style-type: none"> • Describe relationships between points on two scales using ratios 	B4, T3	B6b, B7b, B8c2, T6b	
<ul style="list-style-type: none"> • Describe, develop and translate roles into a formula which can be used to convert between C and F scales 		B6b, B7b, B8c2, T6b	
<ul style="list-style-type: none"> • Read and interpret a coordinate graph 	B5a-c		T8a-d
<ul style="list-style-type: none"> • Look for an describe mathematically significant patterns in data 	B4, B5a-c, T3		T8b-d
Section 3 – Central Tendency			
<ul style="list-style-type: none"> • Determine which measures of central tendency best describe typical or average in a given situation 			B9a-c, B10a-c, T9a-b
<ul style="list-style-type: none"> • Take into account the effects of sample size and variability on measures of central tendency 	B3		B9a-c, T9a-b
<ul style="list-style-type: none"> • Describe an appropriate method for finding an average temperature for a given location 			B9a-c, B10a-c, T9a-b
<ul style="list-style-type: none"> • Make a bar/line graph using data and interpret the data from the graph 	T4a-c		B10a-c, T8a-d
<ul style="list-style-type: none"> • Calculate and distinguish between range, mean, median, and mode as applied to given sets of temperature data 	B3	T5	B9a-c, T9a-b
Section 4 – Data Representation and Change			
<ul style="list-style-type: none"> • Informally compare rates of change 	B4, B5a-c, T3		T8d
<ul style="list-style-type: none"> • Construct bar/line graphs to show changes in temperature over time 			T8a
<ul style="list-style-type: none"> • Read and interpret data presented in bar/line graphs 	B5a-c, T4a-c		B10a-c, T8a-d
<ul style="list-style-type: none"> • Compare patterns and trends in bar/line graphs 	B5a-c		T8b-d
<ul style="list-style-type: none"> • Calculate differences between high and low temperatures 		B8a-b, B8c1	
<ul style="list-style-type: none"> • Compare rates of change 	B4, B5a-c, T3		T8d

Table E-3 – SkyMath Matrix of Curricular Goals and Assessment Items