Web-based Learning and Assessment Instruments: Development and Use
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0. Overview and Response to Preproposal Reviewers’ Comments
The overall goal of this three-year project is to develop and test software that enables a K-12 teacher to develop tools and a strategy for coordinating and delivering a standards-based curriculum. We propose to create a software package called OnX (Online eXercises/eXamination), an authoring tool that allows teachers to implement web-based learning and assessment instruments. With the help of participating math teachers, we then propose to use OnX to develop a math learning and assessment instrument called Math8, a web-based supplement to traditional learning materials for 8th grade math.

A pre-proposal for this project was submitted to the National Science Foundation earlier this year. Reviewers made a number of important and constructive comments. In developing the full proposal we attended to their questions and concerns. By way of introduction, we highlight our responses to their primary lines of questioning. Reviewers’ comments and questions are shown in italics; our responses are marked with bullets.

1. The proposal appropriately acknowledges the importance of providing students and teachers with ongoing and immediate feedback on learning, but it does not indicate how Math8 differs from the many other web-based assessment tools that are currently being developed?

- There are two important differences between Math8 and other available web assessment tools. First, Math8 comes with an authoring tool, OnX, and a guide on how to develop learning tools. Consequently, individual teachers, schools or school districts may modify the content of Math8. This feature will be particularly useful for teachers who are not part of the original development team. By simply providing a file name and indicating where the associated material fits with the standards, teachers can add materials to Math8. This allows the user to tweak Math8 content should the curriculum standards expand or change, as well as to adapt Math8 materials to the local learning environment, or even to develop a web-based learning tool with entirely different content.

  Second, Math8 will provide materials in a finely targeted fashion adapted to the specifics of the South Carolina State standards. The SC State Office of Curriculum and Standards lists six Principles of School Mathematics (see Figure 2), with anywhere from one to four Standards listed under each Principle, and various Expectations under each Standard. A total of fifty Expectations are on the list for 8th grade Math. Our objective is to collect a number of items (questions and answers and tutorials) for each Expectation, organize them, and provide convenient Internet-based assessments through tests, and learning materials through tutorials. For each expectation, materials will be available for specific levels of proficiency. The result is a supplementary tool to assist teachers to impart targeted 8th grade Math material without adding significantly to the teacher’s teaching load. Rules (to be developed with the help of experienced classroom teachers) will allow Math8 to guide students through the tutorials and the accompanying short quizzes. Other currently available web-based tools link instructional materials to standards, but only in a coarse manner. The materials managed by Math8 will link to specific expectations and particular levels of proficiency for each curriculum standard.
2. The proposal conveys somewhat overly simplified impression of what is needed to create a valid and reliable set of assessment items.

- Our short pre-proposal could provide little detail and clarity on the assessment process leading to this question. The expanded assessment discussion (Section 7) addresses this concern calling for two types of assessment items. The first are those items, called Math8 Tests I and II, used at the start of the school year to determine the instructional needs of individual students. Classroom teachers working on the project will develop these items drawing from their own experience and from existing, publicly available items. The second set of assessment items, those that consider the overall effectiveness of the Math8 program, will not be developed specifically for this project. Rather this important question will be assessed using standardized tests. A proposed assessment design is presented in the assessment section. The analysis will be conducted by an outside consultant who will also be given input into the final assessment design.

3. What will the items look like? All multiple choice?

- When collecting data, OnX will allow a wide range of possible item formats: multiple choice, check boxes, open-ended answers, with up to three media components (any combination of still images, audio, and video). To facilitate automatic grading, however, answers in Math8 will be limited to multiple choice and simple open-ended answers (e.g., integers, decimals, rational numbers, or mixed fractions). However, one should not overlook that the variety of instructional materials delivered by Math8 can be of any form. It is only when students provide feedback that this needs to be structured into a limited range of choices. Open-ended responses are possible but in such cases teacher intervention is required to evaluate this material.

4. How will teachers be trained to develop items?

- The primary activity of teachers will not be to develop items, but to select from available materials—instructional aids as well as assessment items. As the proposal details, there is no shortage of materials available (e.g., publicly released items from TIMMS, NAEP and PACT textbook supplemental materials, and items prepared by education associations, and individual districts, schools and teachers). The real issue for classroom teachers, in South Carolina and other standards-based educational settings, is to identify which items are associated with specific standards, expectations, and levels of proficiency. The teachers will map the landscape of available materials and link them with the current South Carolina 8th grade curriculum standards.

5. What criteria will be used to select items for inclusion?

- The primary criteria will be how well the item or instructional material matches and targets the expectation of a standard of the curriculum. The project goal is to cover all fifty expectations in the current curriculum. Multiple items will be required for each expectation as items will be classified according to four levels of difficulty (see Section 6 below). Teachers will review any reliability issues that appear in the first use of Math8 (Figure 1, Phase 2) and then will produce a modified set of items for use later in the project during the second year of Math8 implementation (Figure 1, Phase 3). As far as the items used to formally assess the effectiveness of Math8 these items will be wholly beyond the control of this project and its investigators, since two standardized tests, the South Carolina PACT and the MAT8 will serve this purpose.

6. How will the quality of the resulting assessment tool be evaluated?
• Dr. Deborah Switzer (Education) and Dr. J. Steve Davis (Management/Computer Science), both with Clemson University, will evaluate Math8 and OnX. Dr. Switzer will evaluate the effectiveness of Math8 as an assessment and learning tool. Dr. Davis will evaluate the quality of the database and software. The teachers will be able to provide anecdotal evaluation based on their experience using Math8 and OnX. We have identified a possible external evaluator, Dr. Thomas B. Hoffer, Senior Research Scientist, National Opinion Research Center, a research affiliate of the University of Chicago. Dr. Hoffer’s background is in the sociology of education and he is widely regarded as a leading expert in the design and implementation of student achievement research.

7. Will Math8 be a full CAT system?
• No, a more accurate description of Math8 is a computerized assessment (Drasgow and Olson-Buchanan, 1999 [10]) and instruction tool rather than a computerized adaptive testing (CAT) tool. Math8 will share many of the advantages of a full CAT system (e.g., flexible and individual scheduling of tests, immediate online scoring and dynamic item selection based on prior answers). However, if one follows a strict definition of a CAT system, where “each successive item in the test is chosen to optimize an objective function” (Van der Linden and Glas, 2000 [11]) Math8 is not a full CAT system.

8. How will teachers integrate this tool into the existing curriculum? Will it fundamentally change the way they teach or simply as an add-on used when there are a few spare minutes?
• We expect that teachers will initially use Math8 as supplemental material. As we have been told in our preliminary discussions with District personnel: With increasing calls for accountability and standards based instruction, “Time in the classroom is at a premium.” Math8 will provide students with individualized instruction without detracting from established patterns of group instruction. This feature of Math8 will be particularly useful in providing remedial instruction. The standards-based movement in South Carolina includes a requirement that schools provide remedial instruction for students scoring “below basic” on the PACT exam. Math8 would provide teachers with a useful tool to address this mandate. Beyond this, as teachers and students become more comfortable with Math8, the tool could also become a part of group instruction as well. Math8’s reporting function will go beyond reporting individual results to include summaries of group performance. In this way teachers may observe common patterns of instructional needs and make this a part of their group instruction.

Moreover, one goal of the proposed project is to discover just how teachers will use a tool such as Math8. The project will be working with experienced teachers and will give them the latitude to each use Math8 as they see fit. Teachers will use online journals to document how they in fact use the tool and we hope to learn how different patterns of use affect outcomes.

9. How will researchers work with local districts? Commitments?
• Clemson is located in Pickens County and the program schools are all within 45 minutes of the Clemson campus. During the content development phases of the project, a series of workshops with participating teachers will be held on the Clemson campus. Letters of support from a current 8th grade teacher in Pickens County and from the County Coordinator of Middle School Instruction are included among the supplemental materials. We expect equally enthusiastic support from the other 8th grade Math teachers as well.
10. Access to results, e.g., parents, suggest that researchers do not yet know how teachers plan to use the tool.

- See #8 above and further detail in the full proposal. Specifically regarding parental access, it should be noted that the reporting and monitoring features in Math8 will permit a parental report to be easily generated either as hard copy or in electronic form. This will allow teachers to keep parents informed as to their students’ progress toward meeting standards.

1. Proposal Goals and Objectives

This study has two goals. The main goal is to design, implement, use, and assess Math8, a web-based supplement to traditional learning materials for 8th grade math. Math8 will be used by participating teachers in some of their math courses during Phases 2 and 3 of the study. It will: (a) provide the student with a web-based math learning and exercise tool, (b) provide the student with immediate feedback regarding his or her abilities to answer questions on specific topics, and (c) assist the teacher in monitoring the progress of each of the students by providing precise reports detailing the strengths and weaknesses of each student relative to current curriculum standards.

The subordinate goal (which chronologically must precede the main) is to develop the authoring tool OnX, a PC-based software system which will be used to produce Math8. OnX will be developed by Clemson University researchers, guided by recommendations provided by the teachers, during Phase 1 of study. At the end of Phase 1, OnX will be used by the researchers to produce Math8.

Math8 assists the teacher in two general ways. First, the assessment module in Math8 will help the teacher identify specific areas in which a student may be experiencing difficulty. This will be done early in Phases 2 and 3 through two assessment tests (Math8 Tests I and II). Because the assessment is conducted with a web-based program, little or no additional effort on the part of the teacher is required. The teacher can, however, view or print individual reports detailing the results of the test. Second, Math8 learning modules will be assigned to students to help them understand those topics identified by Tests I and II as giving them difficulty. The learning modules will include instructional components (tutorials) and short quizzes assessing the student’s understanding.

While students work with Math8 independently, the teacher always has the option of generating a status report on each student’s progress. In addition to informing the teacher about the ultimate success or failure of a student on an exercise, this report can detail the student’s use of Math8, reporting when the student used it, how long he used it, how many attempts the student made to answer a question, and the exact sequence of answers the student attempted before arriving at the correct solution. This report can provide clues into the reasons behind a student’s difficulty with a topic far beyond simply knowing that the student ultimately came up with the right or wrong answer.

In brief, Math8 provides the teacher with a tool to identify and address student weaknesses, while giving students the opportunity to receive specific information on topics which have been identified as problem areas.

2. Project Evaluation.

Five tasks require monitoring and evaluation: (a) the development of the authoring tool OnX (Phase 1), (b) collection and organization of 8th grade math content (Phase 1), (c) the use of OnX in the development of learning tool Math8 (Phase 1), (d) use of Math8 as supplementary material
in 8th grade math classes (Phases 2 and 3), (e) the performance of the 8th grade math students themselves at the end of the school year (Phases 2 and 3). We have enlisted the help of Dr. J. Steve Davis and Dr. Deborah Switzer, both of Clemson University to assist in evaluation Tasks (a) through (d). Their bio-sketches are found among the supplementary materials.

Evaluation tasks (a) and (c) will be undertaken by Dr. Davis who has a PhD in Computer Science with expertise in database- and web-application development. His responsibility will be to review the overall software architecture of OnX, providing constructive criticism and offering suggestions for improvement. We will provide Dr. Davis with detailed descriptions of the structure of OnX in order for him to perform this evaluation. He will also review and evaluate the database structure of Math8, again providing constructive criticism and suggestions for improvement. The software developers, led by Dr. Pargas, will meet with Dr. Davis at least thrice during Phase 1, once at the start of the project, once midway through the development of OnX and the database tables that will hold Math8 questions and answers, and a third time at the end of the initial software development. Dr. Davis will provide a brief written report summarizing his evaluation of OnX and Math8 at the end of this period.

Dr. Deborah Switzer has a PhD in Education with experience in evaluating new pedagogical strategies. Her responsibility will include evaluating the initial content of Math8 at the end of Phase 1, the efficacy of Math8 in the classroom at the end of Phases 2 and 3, and an overall evaluation of the project at the end of Phase 4.

External evaluation of the final version of Math8 and its effectiveness as a supplementary tool for 8th grade Math is of primary importance. We are currently talking with Dr. Thomas B. Hoffer, Senior Research Scientist, National Opinion Research Center, a research affiliate of the University of Chicago about conducting independent analysis on all data, especially the PACT and MAT8 data collected over the three year period.

Finally, the Math components of the South Carolina Palmetto Achievement Challenge Tests (PACT) [1] and the Metropolitan Achievement Tests (MAT8) [2] will be used to evaluate task (e). These tests will be given to 7th and 8th graders according to the schedule listed in Table 1 (Section 7) and statistical analyses will be conducted at the end of Phases 2 and 3 to determine the effectiveness of the use of Math8 in the classroom. The details of the statistical approach are presented in Section 7.

3. Anticipated Products.

At the end of the study, two related software products will be delivered on CD-ROMs: Math8 and OnX, including all software required to install both on a Windows-based computer. Documentation on the process by which one installs and uses OnX to produce packages, such as Math8, will be provided. Moreover, a user manual entitled “Designing and Implementing Math8” will detail the procedure by which Math8 was developed, including such topics as item selection criteria, organization of subject content, entry of content using OnX, deployment on the web, etc. A second user manual entitled “The Use of Math8”, based on teachers’ journals, will document the different ways that the 8th grade math teachers used Math8 in Phases 2 and 3, what techniques succeeded and what did not.

At the end of the study, Math8 will be fully developed and ready for use by all 8th grade math teachers and students who are provided passwords to the system. The OnX authoring package may be used to modify Math8 or to develop new learning and assessment tools for other subjects. Once content has been collected, organized and entered into the database by experienced classroom teachers, a new learning and assessment tool for that subject is produced and may be
deployed on the Internet. One database may hold the content for multiple subjects; the items for different subjects reside in the same database but are logically separate.

Several scholarly publications are expected to emerge from this study, including papers describing the design and architecture of OnX and Math8 (audience: computer scientists) and papers describing the content development and use of Math8 (audience: educators). A separate paper will discuss design of the rules and skip patterns used in Math8 to move and promote a student through different levels of difficulty of a topic (audience: educators). Still other work will look at the educational impact of this type of instructional technology (audience: educators and social scientists).

Specific learning activities will be selected primarily by the participating 8th grade Math teachers. These activities will necessarily be experimental and will be based largely on the style of individual teachers. Clemson University researchers will not tell the 8th grade teachers how to use Math8. On the contrary, Clemson researchers will listen to comments provided by the teachers and will incorporate suggested changes to Math8 whenever feasible.

4. Rationale.

Disappointing results, particularly in math, for US students in international comparative studies have produced a strong call for a new national educational focus [3]. Compared to the US, other countries reap the benefits of coherent goals and similarly focused teaching practices. This proposal outlines a strategy for coordinating and delivering a standards-based curriculum using a web-based learning and assessment software instrument. During the study phase this instrument will be available to participating 8th grade Math teachers and students of Pickens County, South Carolina1. Beyond the study phase, however, the instrument will then be immediately available to teachers and students anywhere.

South Carolina, in particular, is in urgent need of tools that can provide supplementary instructional material to students without creating additional load on the teacher. One report [12] ranks the State last in average SAT scores for the years 1991, 1996, 2000, and 2001. With a high school graduation rate of 53.2%, SC ranks 49th in the country for the proportion of 9th graders in the State who complete high school in four years. Pickens County school district personnel have commented that a particularly difficult problem is how to help the handful of students who reach 8th grade deficient in 7th, 6th, for even 5th grade math skills. The teacher is stretched between spending one-on-one time with these students and working with the majority on the current lesson. One goal of this research effort is to develop a tool to help provide the remedial assistance required by these students.

5. Work Plan.

The proposed study spans three years (see Figure 1). The major activities are: subject content and tool development (Phase 1), two rounds of experimentation and tool use in the 8th grade Math classroom (Phases 2 and 3), and analysis and dissemination of results (Phase 4).

Phase 1 (January – August, 2003). From the outset this procedure relies heavily on

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1 [http://www.pickens.k12.sc.us/](http://www.pickens.k12.sc.us/) In large part, Pickens County was chosen for practical reasons. Clemson University is located in the County, simplifying communication, organization of workshops and meetings, etc. Beyond this, however, Pickens County is an ideal site for a pilot study. Pickens County has a diverse student population with students from a wide range of backgrounds. Pickens County is home to one of the finest middle and high schools in the State, but also to other schools that struggle with the characteristic challenges of rural, Southern schools (e.g., low-income households, low parental educational attainment and limited school resources).
teachers’ experience with the curriculum. Teachers from all five middle schools in Pickens County will develop relevant assessment and learning questions and answers drawing primarily on existing, publicly available materials, but also potentially by designing new sets of questions and answers, as well as instructional materials. Potential sources for questions and answers include: (a) The South Carolina Department of Education which provides a growing sample of PACT and PACT-like questions[1], (b) released items from previous years’ 8th grade mathematics assessment tests administered by various States [5], (c) testing items provided on CD-ROM by publishers of mathematics textbooks currently used in South Carolina[6], and (d) a very large number of websites[7], providing publicly available tutorials and banks of sample questions in mathematics.

Clemson researchers will first begin compiling lists of questions, answers and tutorial material from January through May 2003. Written permission to use any material obtained (e.g., from the Internet) will always be secured before such material is considered for inclusion in Math8. From June through August, 2003, the material will be reviewed by teachers who will meet regularly at Clemson University and who will select, classify, and edit materials from this list. At this time, the teachers may also include their own relevant material.

The teachers will select a sample of questions from each Standards task to form two parallel tests. These tests, called Math8 Tests I and II and administered at the start of Phase 2, will assess each 8th grade student’s strengths and weaknesses. The results of these pretests will allow assign Math8 to assign learning modules to students during Phase 2. Tests I and II are discussed in greater detail in Section 7.

Also during Phase 1, Clemson University researchers will complete development of the authoring tool OnX, which extends already existing software. A software package (called OnQ) was used to develop and deploy Survey2001 [8], a web-based survey of Internet users regarding issues of community, conservation, and culture. Available in four languages (English, Spanish, Italian, and German), Survey2001 is adaptive and dynamic, i.e., questions presented to an Internet respondent (client) are based on previously entered responses.

The effort to complete OnX will be incremental because much of the code and the database structure used in OnQ can also be used in OnX. After OnX is completed, the primary software development focus will be to document the process of building and using learning tools such as Math8 and to modify OnX in response to feedback from participating teachers.

The results of Phase 1 efforts include: (1) the set of questions and answers selected and/or developed by the teachers, (2) two parallel tests, (3) the authoring tool OnX, and (4) the learning tool Math8, created using OnX.

**Phase 2 (August 2003 – August 2004).** In August, 2003, at the start of Phase 2, all participating 8th graders will take the two tests developed over the previous summer. The second test will be administered two weeks after the first and the results of the tests will be correlated to gauge test reliability. The purpose of the tests will be to assess the strengths and weaknesses of the students in order to assign appropriate Math8 instructional material during the academic year. If the correlation of test results suggests low reliability, teacher judgment will be used to reconcile the results.

As soon as the assessment is complete (no later than November 2003), those 8th grade classes selected to be part of the experimental group will begin working with Math8. Hosted on a server at Clemson University, Math8 will be used by teachers as a supplementary teaching tool for students in the experimental group. Clemson researchers will continually modify and improve Math8 during Phase 2 in response to suggestions from the teachers. Modified versions of Math8
will be immediately available, as changes do not require reprogramming the instrument but simply modifying the content of questions or redefining the rules that permit students to move beyond one or more items.

The annual South Carolina PACT and the MAT8 in Math will be administered to all 8th grade students involved in the County in May 2004. The results will be collected and compared with those collected a year earlier in order to assess statistically whether or not the use of Math8 contributed positively to students’ learning of 8th grade Math. This is discussed in greater detail in Section 7. Moreover, the PACT and MAT8 in Math will be administered to all 7th grade students in Pickens County in preparation for the second year of Math8 use, during Phase 3.

From June through August 2004, the teachers will meet with Clemson researchers regularly to accomplish the following tasks: (1) documentation of how the teachers used Math8 during the 2003-2004 school year using notes from teachers’ journals, (2) teachers’ reflection on the effectiveness of Math8 as a supplementary teaching tool, (3) continued analysis of the strengths and weaknesses of Math8, including suggestions for improvement of the software. Also during the summer, Clemson researchers will statistically analyze the results of the 2003 and 2004 PACT and MAT8 Math tests to determine whether there is statistical evidence of greater improvement among the students who used Math8 over those who did not.

**Phase 3 (August 2004 – July 2005).** Phase 3 is a repeat of Phase 2 with an improved version of Math8. At the start of the 2004-2005 academic year, students will be given Tests I and II, which will be improved versions of the same tests administered a year earlier. The teachers will have modified the tests as needed during June and July, 2004. Math8 will again be used by the teachers in their classes but now with one year’s experience and with their suggestions and recommendations for modification incorporated. At the end of the school year, the MAT8 and PACT Math tests will be administered to all 8th grade students.

**Phase 4 (July 2005 – December 2005).** Phase 4 focuses on continued analysis of results, documentation, improvement of the code, critique of the process, and dissemination of results. Final modification to the software will be performed prior to transfer of the source code and all related documents to the South Carolina Department of Education for continued maintenance after the end of the project. Details on the dissemination of results are discussed in Section 10.

In addition, a three-day conference will be held at Clemson University, to which 25 teachers from around the State will be invited, slightly more than half the 46 school districts in South Carolina. The five Pickens County teachers and Clemson researchers will host the conference providing the conference attendees with a detailed look at OnX and Math8, the logic behind it, how to use it, what works best, what doesn’t work, etc. Pickens County teachers will draw on their two years’ experience with the software to point out the strengths and limitations of Math8. Researchers will show how to use OnX to develop other tools. A computer lab with at least 30 computers will be reserved in order to provide attendees with extensive hands-on experience with the software.

6. **Content and Pedagogical Strategies.**

The content and strategy behind this proposal are based on the South Carolina Curriculum Standards, which in turn derive from national standards. The South Carolina 8th grade math standards and expectations for one area (Numbers and Operations) are provided in Figure 2. The questions will be of different levels of difficulty and will be classified according to the 8th Grade Mathematics Standards set forth by the South Carolina Department of Education (see Figure 2).
For 8th grade Math, six areas are targeted: from Numbers and Operations through Probability, each with between one and four standards specified. Under each standard, specific tasks are set (as an example, only the expectations for Numbers and Operations, are listed as bullets in Figure 2; the interested reader is referred to Appendix A or to the SC Office of Curriculum and Standards[9] for the complete list).

These items form the building blocks for an adaptive teaching and testing instrument. We propose to use four levels of difficulty for each task (below basic, basic, proficient and advanced – corresponding to the four levels of PACT scoring) and to classify each question in the database according to the level of difficulty, the specific task, the standard, and the area. For example, a question may be classified as a basic question, for the first task (“Solve real-world problems involving fractions, decimals, and percents”) of Standard I under Numbers and Operations. A question may be classified in more than one way. A student who is weak in one task may be assigned by the program to work on first below basic, then basic, then proficient questions for that task. Math8 will move the student through the questions and will promote the student to the
next level of difficulty only when the student has mastered the current level.

For each standard the State further defines specific performance Expectations. For example, the first expectation under the first standard for number operations is that the student “solve real-world problems involving fractions, decimals, and percents”. It is these expectations that the PACT test is designed to measure according to four performance levels: below basic, basic, proficient, and advanced. A student who performs at the “below basic” level has not met minimum expectations for student performance. The student is not prepared for work at the next grade. Performance at the “basic” level means a student has passed the test and is minimally prepared for work at the next grade. A student who performs at the “proficient” level has met expectations for student performance based on the curriculum standards. The student is well prepared for work at the next grade. Finally, a student who performs at the “advanced” level has exceeded expectations for student performance and is very well prepared for work at the next grade.

PACT testing began in 1999 and over 300,000 students statewide took the fourth round of PACT tests in the spring of 2002. Official responses to the PACT results have been upbeat, pointing to yearly increases in mean test scores as evidence for the efficacy of a standards-based curriculum. Critics counter that these gains are simply a function of teachers learning to teach to the test and are not necessarily indicative of real educational progress. Other critics worry that administrative use of PACT results could serve putative purposes unduly punishing schools for poor student performance beyond the control of the school.

The fundamental concern of teachers, however, is that the reported PACT scores do not provide the diagnostic information necessary for instructional purposes. Individual results reveal how a student performed on last year’s standards, e.g., those tied to the 7th grade curriculum rather than the 8th grade curriculum, and can not be directly linked to the current curriculum. Moreover, the results from last year’s cohort of 8th graders only include summary measures for individual students rather than measures of performance relative to specific standards. However, it is exactly this information—student performance tied to individual standards—that is needed, if students are to adapt their teaching to the instructional needs of their students.

The State Department of Education has made an effort to provide standards-based instructional materials. Most notably the State has developed ABACUS, an online curriculum management program designed to assist teachers and students to achieve educational goals and maintain school accountability. The system consists of two key components. The first is a curriculum module with goals, objectives, and performance indicators. The second component is a resource module to identify and correlate resources to the curriculum standards. The State Department of Education makes this software freely available.

Though it provides a wealth of resources, ABACUS fails to provide South Carolina teachers with the instructional materials they need. ABACUS offers educational materials tied to current curriculum standards, yet the critical link to individual student performance is missing. ABACUS guides teachers to materials for particular standards but teachers still lack the means to determine the instructional needs of an individual student relative to a given standard. Moreover, the materials are not linked to levels of proficiency for particular standards, e.g., whether materials are appropriate for students at the “below basic,” “basic,” “proficient” or “advanced” level for a given standard. Teachers are presented with an overwhelming assortment of instructional materials but lack the information needed to match students and materials.

The research presented in this proposal is designed to address this need. Math8 is an integrated assessment and instructional software tool organized around the 8th grade math
Figure 2. SC Department of Education 8th Grade Mathematics Standards for the First (of Six) Areas. The complete list is found in Appendix A.

1. Numbers and Operations

**STANDARD I. Understand numbers, ways of representing numbers, relationships among numbers, and number systems.**
- Solve real-world problems involving fractions, decimals, and percents.
- Compare/order rational/irrational numbers; find their approx locations on a number line.
- Solve real-world problems involving the use of percents >100% or < 1%.
- Use scientific notation to write very large numbers and numbers less than one.

**STANDARD II. Understand meanings of operations and how they relate to one another.**
- Apply associative, commutative, and distributive properties to simplify expressions.
- Approx. to nearest tenth the sqrt of a number that falls between two perfect squares.

**STANDARD III. Compute fluently and make reasonable estimates.**
- Select appropriate methods/tools to solve problems requiring use of rational numbers.
- Compute with rational numbers to solve a variety of applied and math problems.
- Justify the reasonableness of an estimate of rational number computations.
- Analyze and explain each method for solving a proportion (equivalent ratios, unit rates, and cross-multiplying).
- Use proportional reasoning to solve applied problems and then justify the solution.

curriculum standards. At the outset of the school year 8th graders will participate in a short, online assessment (Math8 Tests I and II) which determines each student’s ability in each of the standards areas using a bank of PACT-like multiple choice items. Math8 will measure performance in each standards area according to the established PACT levels of proficiency. The results obtained from this initial assessment will then be used throughout the school year to provide students with instructional materials appropriate to their individual needs. During the initial phase of the project, experienced Pickens County 8th grade math teachers will collect and organize materials appropriate to the various levels of proficiency within each standards area. As detailed in Section 5, these materials will be identified by teachers in Phase 1 and categorized by standard, expectation, and level of proficiency. Through ABACUS and other programs the State Department of Education has made a variety of materials available, but the quantity, varying quality and range of difficulty covered by these materials is staggering. Math8 provides the link to directly tie these materials to the instructional needs of individual students.

Exactly how teachers use Math8 will be left up to the individual teacher - some may use it as an in-classroom supplement, other may have students use the program outside the classroom, at home or in the library. However it is used, students will be directed to appropriate online instructional materials based on their initial assessment performance. After working through the materials associated with a particular proficiency level for a given standard, a student will be given a brief online assessment. Upon successful completion of the assessment the student will then be tracked to the next proficiency level or next standards area. While this learning activity will take place without direct teacher intervention, student participation and performance in Math8 is monitored and stored in the Math8 database. The teacher reporting function of Math8 will permit teachers to easily monitor student participation, including frequency and length of use, as well as ongoing assessment results. The results reported to the teacher will not only record the outcome of the assessment, but will also include process indications of performance to
help the teacher identify students who may pass an assessment level through repeated guessing rather than substantive understanding.

7. Assessment.

Assessments of various types, formative as well as summative, are essential features of the proposed project. These assessment instruments are summarized in Table 1. The primary formative assessment tools are Math8 Test I and Math8 Test II. These instruments will serve as the primary means to tailor the instructional materials provided by Math8 to the needs of individual students. Throughout the academic year Math8 will provide students with instructional materials intended to address specific weaknesses identified by these instruments. The overall efficacy of Math8 depends on students receiving the appropriate materials; hence the proposal calls for two tests, Math8 Test I and Math8 Test II, to provide a test-retest framework to establish item validity. These assessments are to be developed by teachers participating in the development of Math8 and will be administered at the start of the academic year as parallel tests two weeks apart, to all 8th grade students in classes taught by Math8 program teachers. Assessment items will be selected to cover the full range of areas and sub-areas covered by the current State standards.

The PACT tests developed and administered under the auspices of the State Department of Education will serve as a second source of assessment information. This information will be more summative in nature, giving insight into the effectiveness of the Math8 program. As Table 1 indicates 7th and 8th grade individual PACT test information from 2002, 2003, 2004 and 2005 may be used for assessments of this type. The first and most obvious comparison would be to look for differences in 2004 and 2005 8th grade PACT scores between students who had participated in the Math8 program and those who had not. An analysis of this type could consider mean differences in scores as well as differences between the two groups in score distribution and variance. Such an approach while straightforward is necessarily limited as neither students nor teachers will be randomly assigned to participate in Math8. Even with

<table>
<thead>
<tr>
<th>Table 1: Proposed Assessment Instruments. Group A: Students taught by teachers participating in study and using Math8 (experimental group). Group B: Students taught by teachers participating in study and not using Math8 (control group). Group C: Students taught by nonparticipating teachers (control group). Math8 tests are administered at the start of an academic year, PACT and MAT8 at the end.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students enrolled in 8th grade class</td>
</tr>
<tr>
<td>8th grade Math8 Test I                      2003 2004        --  --</td>
</tr>
<tr>
<td>8th grade Math8 Test II                      2003 2004        --  --</td>
</tr>
<tr>
<td>7th grade PACT score                           2003 2004        2002 2003     2004 2005</td>
</tr>
<tr>
<td>8th grade PACT score                           2004 2005        2003            2004 2005</td>
</tr>
<tr>
<td>7th grade MAT8 score                           2003 2004        --  2003 2004</td>
</tr>
<tr>
<td>8th grade MAT8 score                           2004 2005        --  2004 2005</td>
</tr>
</tbody>
</table>

statistical controls for obvious compositional differences between the two groups (e.g., socio-economic status or past achievement level) unobserved factors may be the source of differences rather than participation in Math8.

As Table 1 suggests, PACT test results from 7th grade provide one means to control for unobserved differences between the two groups. Equation [1] represents a simple lagged
regression framework to control for observed and unobserved differences between Math8 participants and other 8th grade students. 8th grade PACT scores, Y^8_i, are regressed on 7th grade PACT scores, Y^7_i, with \( \beta_1 \) representing the estimated relationship between 7th and 8th grade scores and \( \alpha \) the average change over time. If the effect of participation in Math8, \( \beta_2 \), is significantly different from 0 and is positive, then Math8 is associated with an above average increase in PACT scores, while a significant negative coefficient would indicate that Math8 actually leads to lower increases in PACT scores. P^M8 which indicates participation in Math8 can either be measured as a dummy variable (i.e., 0 = non participant, 1 = participant) or may be specified in greater detail to indicate the extent of student participation. Since Math8 records the frequency and intensity of each student’s use of the software it will be possible to consider the degree of program participation that is needed to derive any benefits.

\[
[1] \quad Y^8_i = \alpha + \beta_1 Y^7_i + \beta_2 P^M8 + e^8
\]

Five different teachers will be using Math8 and each will be allowed to use the program in a manner that best suits his or her teaching style. It is quite likely that the effects of Math8 will vary from teacher to teacher, accordingly equation [2] represents a model designed to capture teacher specific effects.

\[
[2] \quad Y^8_i = \alpha + \beta_1 Y^7_i + \beta_2 P^M8 + \beta_3k T_k + e^8
\]

Obviously, teacher specific effects go beyond whether or not the teachers involved in the Math8 project are using Math8. The teachers who will participate in Math8 will not be randomly selected and it is likely that highly motivated teachers will be involved in the project. As Table 1 indicates, PACT data for students taught by program teachers in the year prior to the use of Math8 figures in our assessment plan. As equation [3] indicates, extending the model to include an interaction term as to whether or not a particular teacher is using Math8 provides the means to consider teacher specific effects beyond the use of Math8. Data from the prior cohort of students makes it possible to estimate such a model.

\[
[3] \quad Y^8_i = \alpha + \beta_1 Y^7_i + \beta_2 P^M8 + \beta_3k T_k + \beta_4k P^M8T_k + e^8
\]

Just as equation [3] considers whether or not the effects of Math8 vary from teacher to teacher, this framework could be extended further to include interaction terms to test whether the effect of participation in Math8 systematically varied with student characteristics.

Extending equation [3] in this fashion does not, however, address fundamental limitations of lagged regression models. The main benefit of the lagged regression approach is that the lagged PACT score effectively controls for individual characteristics—unobserved as well as observed—to the extent that they affect 7th grade scores as well as 8th grade scores. This benefit, however, comes at a cost: the error terms associated with a lag regression model, most notably in the measurement of Y^7_i and Y^8_i, are likely to be correlated, leading to biased estimates of the regression coefficients. Under these circumstances one would typically employ an instrumental variable approach substituting a surrogate variable for Y^7_i, using a variable that is correlated with Y_i but is not correlated with the error term e^8. Moreover, such an approach is further warranted as 7th grade PACT test scores are not true lagged measures of 8th grade PACT test scores. While they are likely to be correlated, each is designed to measure achievement relative
to a different set of standards, i.e., one based on the seventh grade curriculum and the other based on the eight grade curriculum.

For this reason, we propose to administer the 7th and 8th grade versions of the mathematics sections of the Metropolitan Achievement Tests (MAT8) to the full cohorts of 8th grade students enrolled in 2004 and 2005. Each of these widely-used nationally-normed tests includes 78 items with a testing time of 80 minutes. These tests align with the structure set forth by the National Council of Teachers of Mathematics (NCTM), which in turn guide the South Carolina Curriculum standards. These tests include a comprehensive set of arithmetic items as well concepts and problem solving items organized in five clusters: 1) Number and Operations, 2) Patterns, Relationships, and Algebra, 3) Geometry and Measurement, 4) Data, Statistics, and Probability and 5) Problem Solving. Not only will these tests aid in assessing Math8, substituting for the PACT scores in the estimation of equations [1] and [2], but will also be of great use to local and State education officials as they seek to calibrate between grade achievement scores using the PACT.

8. **Professional Development.**

The software described in Section 4 will come with complete instructions on installation and use. Teachers will be provided with detailed manuals on how to develop software tools, such as Math8, and how to use such tools in classroom environments. Specific instructions will be provided to guide the teacher's development of the subject content in order that the ensuing reports will be maximally useful. An important benefit to teachers using Math8 will be a greater familiarity with and knowledge of the revised PACT 2000 standards. These are being used for the first time with the PACT 2003 so that classroom teachers are just making the transition to the new standards. These benefits will accrue most obviously to those teachers involved in providing content for Math8, but will be transferred to other teachers who subsequently adopt the program. Beyond this access to and use of a practically useful, web-based application such as Math8 may foster greater computer literacy and Internet familiarity among teachers.

9. **Community Involvement.**

Parents have direct involvement in the use of Math8 because the student is expected to work with Math8 at home or wherever an Internet-connected computer is available, such as in a public library. Teachers will assign problem sets for students to solve at home. Parents will also be given accounts to allow them to monitor the progress their children are making in the subject. Parents will be able to print out reports for themselves and will be provided explanation on the web, through brochures, or during parent-teacher meetings on how to interpret the reports. In this manner, the interested parent can keep up with their children's progress, or lack thereof.

10. **Dissemination and Implementation.**

At the end of the study, Math8 will be immediately available to any 8th grade teacher with access to the Internet. All software and all of the online materials related to this project will be donated to the South Carolina State Department of Education, putting the software in place to replicate the procedure. OnX will be available to teachers to create additional tools (e.g., Math5, Physics or GermanIII) through a basic three-step process: (1) experienced teachers develop and organize relevant content, (2) new content is entered into the existing database structure using OnX, and (3) a system administrator deploys the web-based learning tool also using OnX.

All documents and reports generated as part of this project will be made available by
Clemson University researchers in electronic (PDF) form on a Clemson University website as well as on the State website which will become the permanent home of OnX and Math8.

Moreover, the primary focus of Phase 3 of the proposed effort is to conduct workshops and seminars, present papers at conferences, publish in journals, distribute the software, and train teachers in the use of OnX and the development of tools such as Math8.


James Witte (Sociology) and Roy Pargas (Computer Science) of Clemson University will serve as co-Principal Investigators for this study. Both worked on Survey2001 and are currently awaiting response to a proposal to develop Survey2003: The Impact of Online Environmental Information, an online survey looking specifically at the use and impact of online information regarding environmental conditions and hazards. Pickens County School officials have already agreed to collaborate on this project and teacher reaction to the project has been enthusiastic. Ms. Libba Floyd, Coordinator of Middle School Instruction for Pickens County and Ms. Mary Bridges, 8th grade math teacher for Edwards Middle School, have expressed willingness to participate. We feel confident that the 8th grade math teachers from the four other Pickens County Middle Schools will be as enthusiastic. Dr. D. Switzer (Education) of Clemson University and Dr. J.S. Davis (Management/Computer Science) will participate as internal reviewers. Finally, we are currently talking with Dr. Thomas B. Hoffer, Senior Research Scientist, National Opinion Research Center, a research affiliate of the University of Chicago, to assist in the final evaluation of Math8.

12. Results of Prior NSF Support.

Research for this proposal is directly related to work done under the NSF funded project Survey2001: Information Technology’s Impact on Conservation, Community and Culture (ITR/Soc Award # 0082750). The primary activity conducted with this funding was an online survey data collection effort hosted on the National Geographic Society web page from October 2001 through March 2002. (Readers interested in the survey technology developed for this project should go to [http://130.127.59.115/start.html](http://130.127.59.115/start.html). Readers interested in Survey2001 itself should go to: [http://survey2001.nationalgeographic.com/ngm/servlet/Page1](http://survey2001.nationalgeographic.com/ngm/servlet/Page1)). The data base engine behind Survey2001 will be used in the current proposed project.

From this research several papers will soon be completed by the Survey2001 team at Clemson University: (1) Database Design for Online Surveys, R. Pargas, J. Witte, J.S. Davis, K. Jaganathan; (2) Implementing Skip Patterns in an Online Survey, R. Pargas, J. Witte, J.S. Davis, K. Jaganathan, (3) Analysis of IP Address Spread in an Online Survey, R. Pargas, J. Witte, (4) Development of an Authoring Tool for Online Surveys, R. Pargas, J. Witte, L. Brand, C. Hochriner. Four papers based on the Survey2001 data are under contract for the The Internet & American Life, Editors Philip E.N. Howard, Sociology, Northwestern University and Steven Jones, Communication Studies, University of Illinois-Chicago. Sage Publications [forthcoming]. (5) Survey Methods - Large Sample Design & Studying Life Online, J. Witte, Clemson University; (6) Reading and Leisure on the Internet, W. Griswold and N. Wright, Northwestern University; (7) Music Online, R. Peterson, Vanderbilt University and J. Ryan, Virginia Tech; and (8) Archiving Lives and Personalities, W. Bainbridge, NSF. It is anticipated that other researchers affiliated with the Survey2001 project, including Barry Wellman at the University of Toronto, will also be publishing work with the Survey2001.