Section D(2) Research Narrative

OVERVIEW

The problem

Algebraic Interventions for Measured Achievement (AIMA) recognizes the need for effective mathematics curricula to address the gaps in student learning that exist among algebra learners in the United States. According to the 2000 NAEP results, a 28 percent achievement gap in mathematics opened up between fourth grade white and black students. Hispanic students fared only slightly better with a 23 percent gap. Since only 33 percent of white students reached the proficient level or higher on the exam, the achievement gap data is even more distressing. The results were little better for eighth grade students: White students averaged only 34 percent proficiency or higher on the mathematics portion of the NAEP exam. The achievement gap between white and black students was again 28 percent; the gap for Hispanic students was 25 percent (U.S. Department of Education, 2001). These data indicate a dramatic need for interventions for all mathematics students, but especially for America's minorities, who continue to be at risk of being left in the wake of technology's progress.

According to the 1997 NAEP results, students are performing at comparatively low levels in algebra. Only 24 percent of eighth graders and 16 percent of twelfth graders demonstrated knowledge of linear equations, algebraic functions and trigonometric identities expected for their grade level (Wilson and Blank, 1999). To hide their lack of understanding, students often resort to memorizing rules and procedures and they eventually come to believe that this represents the essence of algebra (Kieran, 1992). This belief belies the fact that algebra is not merely rule-based arithmetic. Rather, it is a branch of mathematics that involves symbolic representation and evaluation, and many students find this leap from arithmetic to mathematic symbolism difficult. Unfortunately, much of the curricula being taught in American schools do not deal with this approach, but emphasize instead arithmetic and drill (Good, Mulryan, & McCaslin, 1992) while at the same time, teachers are challenged to reach a classroom population for whom drill doesn't work (Steele & Steele, 2003).

As the workplace becomes more technical, the problem solving demands that algebra requires are becoming more commonplace, making algebra a type of gatekeeper for economic access. National and state assessments include algebraic skills at the eighth-grade level and many high school exit exams now test algebraic proficiency (Moses, 2001). Student failure rates on these high school exit exams further compound the problem. The California State Board of Education voted unanimously to delay its mandatory high school exit exam until 2006 because "An internal evaluation of the test last year by the state education department found that many students had not been taught some of the test's fundamental components, such as algebra" (Sack, 2003). States are coming to grip with the fact that their students are not performing at high levels, despite the best intentions of the *No Child Left Behind* legislation.

With more and more states and school districts mandating completion of algebra, teachers are facing the challenge of teaching a subject matter that is often misunderstood by even their well-prepared students. These teachers are doubly taxed when confronted with the necessity of providing instruction for their many unprepared students. In addition, students with a variety of learning disabilities may have particular problems understanding school algebra due to visual or auditory problems, memory deficits, or language disabilities (Mercer, 1997).

Proposed Solution

We believe that an intervention curriculum that targets particular trouble spots in school algebra will help a teacher provide the three “R’s” of student learning experiences that – based on student needs – *reinforce*, *refresh*, and *re-teach* algebra concepts. These intervention lessons will reinforce current learning for students who understand the particular concepts, building their fluency and confidence in the subject. The interventions will refresh students’ knowledge of concepts they may have already learned, but which need reinforcement. And they will re-teach concepts that students may have misunderstood or never learned. AIMA will develop such an intervention curriculum by pairing portions of Carnegie Learning’s successful *Cognitive Tutor*™ software with WestEd developed print-based curriculum materials that reflect the research on how people learn mathematics.

Based on the research about student mathematics learning and the most prevalent deficiencies in algebra, we have identified a set of specific topics and their learning objectives in order to generate a series of lessons. From these objectives, basic tasks have been specified. To determine appropriate task variants, we will perform in-depth task decompositions to provide the set of skills students must master to accomplish the lesson successfully. Diagnostics, created from these decompositions, can then be used by teachers to identify specific learning failures and then to track student progress. The results of the diagnostics will allow teachers to focus on students’ areas of weaknesses with appropriate AIMA lessons specifically targeted toward the identified learning goal. We expect to see a marked difference in algebra achievement after students engage in AIMA’s interventions.

A two-pronged approach, utilizing Carnegie Learning’s *Cognitive Tutor*™ software as well as teacher–directed lessons, will provide students with opportunities to immerse themselves in difficult topics, as well as to learn new concepts. Incorporated into an existing curriculum, either replacing or supplementing targeted lessons, AIMA provides additional learning opportunities and alternative teaching strategies for students who need more and varied experience with the content. The lessons can also augment or replace the supplemental curricula of extended or refresher mathematics classes where students are given additional time for mathematics learning. We believe that AIMA will provide a viable solution for students who are struggling to learn algebra and the educators who are struggling to assist them.

THE PLAN

AIMA Modules

“Translating theoretical ideas from research into practical ideas for the classroom can help teachers teach more effectively and students learn more efficiently” (Wagner & Parker, 1993). With our goal to increase student understanding and achievement, we seek to build an intervention curriculum that addresses the sources of difficulty students often encounter and one that equips teachers with materials and strategies to help reach this goal.

A review of the literature, analyses of various assessment blueprints, and focus group discussions among expert teachers of mathematics have contributed to our thinking about the content of the modules. Based on preliminary task analyses and identification of trouble spots in beginning algebra, we have targeted content for six modules to provide materials and lessons to help teachers re-teach, refresh, and reinforce important concepts, many of which may be considered prerequisites to a mature understanding of algebra. Thus, some lessons will focus on the prerequisite skills which students may find troublesome and which will impede progress if not mastered. While students who complete these lessons will be expected to have mastered the skills, we will emphasize an understanding of the concepts underlying these skills and the structure of the number system. This emphasis will lay the groundwork for algebra. We understand that the arithmetic thinking of number-proficient students is different from the thinking that is central to algebra. Whereas arithmetic focuses on number and numerical answers, school algebra focuses on relations. Students' numerical thinking can develop into algebraic thinking but their numerical thinking habits must be taken into account (Kilpatrick et al., 2001)

Algebraic reasoning and problem solving will be woven into all the modules, emphasizing student understanding. We agree with Steen (1999) that students who think about what they are doing and why they are doing it are more successful than those who just follow rules they have been taught. Thus, we will pose problems requiring analysis and thought, believing that successful students tend to analyze or reformulate a problem before selecting a strategy for solving it, whereas less successful students accept the problem as presented (Davis, 1984). Students will be encouraged to show multiple representations of problem situations and solutions. Fluency with multiple representations of mathematical relationships plays a significant role in the development of algebraic thinking. It is useful in math if we think of it as not only an image, such as a graph or table, but as a process. It also can help teachers see what students understand and what ideas are still developing (Coulombe & Berenson, 2001; Cai & Kenney, 2000).

Patterns

Because the concept of function is important in mathematics, and essential to algebra, an understanding of patterns can be a useful introduction to the study of functions. In lessons on Numerical Patterns, students examine a numerical pattern and extend or fill in missing members of the pattern. In lessons on Patterns Describing Relationships, students examine number sequences or tables containing the input and output showing the relationship of the numbers, and in Geometric and Algebraic Patterns students examine and analyze geometric patterns. Students then model figures of the pattern, create/complete tables with the pattern data, determine recursive rules and generalize the pattern (explicit rule) with algebraic notation and/or words. In these ways, students connect graphic representations of the patterns and improve logic, mathematical reasoning and problem solving skills. Additional activities featuring more complex patterns will be provided to reinforce and extend students' knowledge as they apply their understandings of patterns to more complex tasks.

Basic Numeracy

An understanding of our number system is crucial for success in algebra, both in terms of being proficient with the computational component of algebra and in understanding the mathematical structures underlying both arithmetic and algebra. Proficiency with and understanding of arithmetic can form the basis for subsequent mathematical thinking if the concepts underlying the arithmetic procedures make sense to students, while deficiencies in this area can form a barrier for subsequent mathematical thinking (Kilpatrick et al., 2001; Kieran, 1992). The underlying structure of the number system will be an important component of this module since some commonly-observed errors in algebra — such as the misapplication of the associative and distributive laws, errors in using exponents, and a misunderstanding of the properties of zero — have counterparts in operations on integers (Matz, 1982). Making meaning of the rules for operations on signed numbers will also be an important part of this module since problems with negative numbers may persist through subsequent mathematics courses when the rules are not made meaningful (Kilpatrick et al., 2001).

In addition, many students acquire informal knowledge about fractions, ratios, decimals, and percents outside of school. That knowledge needs to be made more explicit through carefully designed instruction because, typically, conceptual understanding and computational procedures are not appropriately linked with fractions and decimals. Decimal fractions are crucial in science, metric measurement, and advanced mathematics. Therefore it is important for students to understand how and why computational procedures work. And, because computing with common fractions sets the stage for computing with rational expressions in algebra, it is likewise important for students to be able to order fractions, find equivalent fractions, and use unit rates (Kilpatrick et al., 2001).

Intervention lessons in this module will target basic mathematics skills that are applied in algebra. Lessons on Operations on Integers will feature the ordering of integers, the arithmetic of integers, and field properties. Lessons on Order of Operations will extend practice and re-teaching with rational numbers through application problems. In lessons on Factoring, students will review prime and composite numbers, prime factorization, greatest common factor, and least common multiple. Lessons for Computational Fluency will include misconceptions around division by zero, the zero factor property, squares of integers, estimating, integer exponents, and scientific notation and provide opportunities for use with a variety of rational numbers. As appropriate, lessons will incorporate models such as number lines, vectors, two-colored chips, tiles and rectangular area models to reinforce number concepts.

Variables and Equations

The heart of this module is representing situations and relationships with linear algebraic expressions and equations and solving linear equations—a crucial step in the transition from arithmetic to algebra. The purpose of this module will be to help students move from arithmetic to algebraic representation and thinking. A common difficulty students have with learning algebra is making the transition from a numerical to a symbolic system involving variables, expressions, and equations (Matz, 1982; Sleeman, 1986; Wagner and Parker, 1993; Kilpatrick et al., 2001). Translating word problems into equations representing relationships between quantities will also be emphasized since this is a major area of difficulty for some students (Wagner & Parker, 1993; Kieran, 1992).

Particular attention will focus on the symbolic nature of algebra. Algebra involves changes in the meaning of some previously-encountered symbols: For example, in arithmetic the equals and plus signs are a prompt to write something, whereas in algebra they denote relationships; this is a crucial concept in learning algebra (Wagner & Parker, 1993; Kieran, 1992; Matz, 1982). In lessons on Variables, students will represent quantities with variables by translating verbal statements to algebraic expression, simplify variable expressions by combining like quantities and evaluate variable expressions and formulas. Lessons on Expressions will target misunderstandings and misconceptions such as notational issues, symbolic representation, confusion between conversion statements and use of letter as a variable, combining unlike terms, misuse of field properties (such as incomplete or incorrect use of the distributive law, division by zero, and thinking all operations are commutative), and order of operations. In lessons on Equations, students will represent simple relationships with algebraic equations, draw distinctions between identity (e.g., formula) and equations, understand properties of equality and identity (for basic operations, symmetry, transitivity, substitution), and solve 1- and 2-step linear equations in one variable over the rational numbers. Applications and word problems will be embedded in the tasks, including using formulas and translating word problems to equations.

Ratio and Proportion

This module will introduce ratio notation and the concept of rate, reinforce learnings with fractions by setting up equivalent ratios and informally solving proportions as equivalent fractions/ratios, and build proportional reasoning skills as lessons present more formal ways of solving proportions. Graphing and problem solving applications will reinforce the concept of slope as a rate of change (Cramer, et al., 1993). Lessons from this module may be used to extend Basic Numeracy lessons and be incorporated into or revisited in the Coordinate Plane module.

Coordinate Plane

In this module the concept of linear function will be developed fully. Various representations for functions (verbal, symbolic, tabular, and graphical) will be presented, with emphasis on the relationship between symbolic and graphical representations. The differences between an equation and functional relationships will be stressed. Students are usually required to make a conceptual leap from equations in which a single variable represents unknown values to functions in which two variables have a relationship in which they can take on an infinite number of values (Wagner and Parker, 1993; Kieran, 1997). Graphing functional relationships in the coordinate plane will be the focus of this module because students often have difficulty graphing functions and making connections between the various representations of a function, especially producing a formula from a graph (Kieran, 1992; Tall, 1992; Ferrini-Mundy and Lauten, 1993).

An introductory lesson will help students build vocabulary, locate points in the plane and reinforce the concept of an *ordered* pair. Subsequent lessons will address the Solution of an Equation in Two Variables, focusing on functions and relations, the vocabulary of functions (such as independent/dependent variables, domain and range), and linear functions, with emphasis on translating between multiple representations (symbolic, tabular, graphical, verbal). Lessons on Equations of Lines will include graphing a line, slope of a line (anticipating student difficulties in areas such as problems with fractions, slope = 0 vs. slope undefined, and *meaning* of slope as a rate of change), parallel and perpendicular lines, slope-intercept form of a line, and point-slope form of a line. Lessons on Systems of Linear Equations, relating algebraic and geometric interpretations of simultaneous solutions, will conclude the module.

Inequalities

Lessons in this module will reinforce and extend learnings from the Variables and Equations module as well as the Coordinate Plane module. Students will recognize solutions of linear inequalities by graphing solutions of inequalities in one variable and learn the addition, subtraction, multiplication, and division principles for solving a linear inequality, applying these to problem-solving situations. Students will look at ordered pairs as solutions to inequalities, and graph inequalities as well as solve systems of inequalities in problem solving contexts and applications.

Designing the Intervention

Carnegie Learning develops and markets products called *Cognitive Tutors*™ that incorporate computer software, print curricula, and teacher professional development. The products draw on twenty years of basic research in cognitive psychology and artificial intelligence at Carnegie Mellon University (Anderson, Corbett, Koedinger, & Pelletier, 1995) and have been shown to dramatically improve student learning as compared to traditional approaches of instruction (Koedinger, Anderson, Hadley, & Mark, 1997; Carnegie Learning, 2002a). For example, students using the *Cognitive Tutors*™ have: performed 30% better on questions from the Third International Math and Science Study (TIMSS) assessment; demonstrated 85% better performance on assessments of complex mathematical problem solving and thinking; shown 70% greater likelihood of completing subsequent Geometry and Algebra II courses; and displayed a 15-25% advantage on the SAT and Iowa Algebra Aptitude Test (Carnegie Learning, 2002a). In addition, a recent study (Carnegie Learning, 2002b) showed significant advantages for students using the *Cognitive Tutors*™ over a traditional curriculum, even when both groups of students had the same teacher. The same study showed *Cognitive Tutors*™ students to be more confident of their mathematical abilities and more likely to recognize the usefulness of mathematics outside of the classroom. Both minority and non-minority students showed equivalent improvements. [For more detail, see Appendix B: More About the *Cognitive Tutors*™ Software.]

AIMA will "repurpose" several of the *Cognitive Tutors*™ software units to blend with and support the intervention curricula. A task analysis and decomposition process, utilizing design principles based on cognitive research similar to the approach used to develop the *Cognitive Tutors*™ software will be employed to develop the lessons. This process will enable us to design effective ways to scaffold instruction with a series of subtasks, or smaller lessons, that address specific pit–falls in learning challenging concepts. Teacher–led and small group experiences will provide less automated presentations for students with a variety of learning needs while "bridge" activities will guide students between the software and the face-to-face foundation lessons, thus expanding students' opportunities to transfer learning to a variety of situations.

The AIMA modules, designed to address gaps in students' knowledge or understanding, may be used for reinforcement as well as replacement for a portion of the classroom curriculum. Diagnostic assessments at the beginning of each module will determine which lessons might best meet students' needs. End-of-module assessments will help determine student mastery of the important concepts.

Each module will contain approximately 10 lessons designed for small group intensive intervention at critical junctures. Teacher notes as well as student materials, including necessary manipulatives and tools (as appropriate) to help students move to more abstract levels of instruction (Steele & Steele, 2003) will be provided with each lesson. The purpose of the lesson will be explicitly stated so that students and teachers know the focus of the mathematical ideas and what students should know and be able to do when the lesson is completed. The teacher notes will contain specific background information as to typical misconceptions or trouble spots students may encounter, including prerequisites and resources for addressing those if students need re-teaching.

Based on detailed task analyses that identify the “hot spots,” the lessons will have complementary components providing *Foundation Focus* and *Conceptual Support*, and will connect to *Cognitive Tutors*™ exercises that will teach and reinforce the target concepts. To best meet individual student needs, lessons are designed such that after students receive whole group initial instruction on a key concept, some students will work individually on the software lessons while others receive small group, guided instruction from the teacher. The groups rotate, so that each receives both software and more direct instructional experiences. *Cognitive Tutors*™ exercises will have clear “entry” and “exit” exercises to ensure that students move into and out of the software content and understand how it relates to the objectives of the lesson.

Our intervention recommends small group work with ample opportunity for sharing among classmates. Individual learning opportunities—refresher, reinforcement, new learning—will come from *Cognitive Tutors*™ experiences as well as teacher-facilitated lessons. In this way, students learn not only while solving problems on their own, but also while working with peers toward common goals (Siegler, 2003). Tasks within lessons will be scaffolded to allow students to develop conceptual understanding by building onto and extending prior knowledge. The reinforcement of basic skills will be embedded in each task or lesson, and students will have opportunities to represent their knowledge and understanding through models, numbers, symbols, and language.

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Alto High School — to serve as test-beds for early versions of the curriculum. These schools will provide formative data to help us as we refine and improve the intervention before formal implementation evaluation takes place. The student populations in these schools reflect similar demographics to the sites where we will conduct our randomized studies (see next section). Summit Prep has 100 students, 51% whom are classified Hispanic and 4% African American. A third of their students qualify for free or reduced lunches and 34% are English language learners. East Palo Alto High school has 215 students, 71% Hispanic, 16% African American, and 10% Pacific Islanders. Over half of these students (i.e., 58%) qualify for free or reduced lunches and 30% are English language learners.

A full schedule of product development/production activities can be found in Appendix B.

RESEARCH AND EVALUATION

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The research setting

Six school districts have agreed to serve as research sites for this project. All are located near WestEd offices, thus providing efficiency and economy to the project. They represent a range of size and configuration as shown in Table 2 below. Common to each of these districts are the large number of students who qualify for free or reduced lunch programs and who are non-native speakers of English as well as those from populations traditionally underserved. All students within these districts are required to pass a course in algebra in order to graduate from high school, thus Algebra is a course offered in grade 8 and higher in each district.

Table 2: AIMA School Districts

District	# Schools	# Students	Free or reduced lunch	English Language Learners	African American Students	Hispanic Students
Sequoia Union High	6	7,680	20.6%	28.5%	6.2%	41.9%
Redwood City Elementary	17	8,813	53.4%	50.6%	2.6%	63.2%
Santa Clara Unified	23	13,623	38.4%	22.3%	4.3%	26.6%
Riverside Unified	45	40,888	46.5%	16.2%	9.8%	45.8%
San Diego City Unified	185	140,753	56.8%	28.7%	15.0%	40.9%
East Side Union High	11	24,409	29.0%	24.7%	4.6%	42.2%

During each year of the project, each curricular unit will be tested at 15 schools within the six districts. At each of these schools, two teachers will participate in the study. For a particular unit of curriculum, one of the teachers will present our new curricular material (treatment); the other will present the same topic using their existing material (control). As discussed below, teacher assignment to treatment and control conditions will reverse for subsequent curriculum units. Thus, all participating teachers will be asked to deliver our new curricular material at some point during the study. We expect each teacher to be teaching two classes of mainstream algebra students, with an average of 25 students each. Thus, the evaluation of each curricular unit will involve 1500 students, 750 of whom are piloting the new curriculum and another 750 serving as a control group.

Teachers will be randomly selected to participate from teacher rosters of all eligible algebra teachers in each school. Within each school, two randomly selected teachers will be recruited, with replacement teachers (chosen at random) recruited should teachers choose not to participate.

Professional development will be provided to all participating teachers so they are familiar with the AIMA modules and how to use the materials. This will include a general training for all teachers and then specific training for teachers in the experimental group. This design can mitigate some of the bias concerns, especially since the two groups of teachers change roles for subsequent modules.

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Section D(3) Personnel

AIMA KEY STAFF

Steve Schneider (Ph.D., Design and Evaluation of Educational Programs, Stanford University) is the Program Director of Mathematics, Science, and Technology at WestEd; PI of the NSF Center for Assessment and Evaluation of Student Learning, and the Co-Director of the WestEd Eisenhower Regional Consortium. Schneider was also the Principal Investigator of the California K-12 Mathematics Implementation Study, Project Director for the development of the AYA (High School) Science Teacher Assessment for the National Board for Professional Teaching Standards, and a lead evaluator for numerous large-scale evaluation efforts for NSF and the U.S. Department of Education (ED). Schneider will serve as PI for AIMA, overseeing institutional relations, and working directly with the school districts.

Tania Madfes (Ed.D., Curriculum and Instructional Design, University of San Francisco) is a

Senior Research Associate at WestEd where she directs both professional development and evaluation projects related to mathematics education. She is the Principal Investigator of the Evaluation of the California Mathematics Professional Development Institutes and the *24® Game* Evaluation. Madfes was also the Project Director for the Mathematics Implementation Study and served as the Principal Investigator of the U.S. Department of Education-funded project that was published by WestEd and NCTM (1999) as *Learning from Assessment: Tools for Examining Assessment Through Standards*. Madfes will serve as co-PI for AIMA, overseeing WestEd's curriculum development portion of the project, as well as coordinating the research study.

Steven Ritter (Ph.D., Cognitive Psychology, Carnegie Mellon University) is a Senior Cognitive Scientist at Carnegie Learning. Ritter, instrumental in the development and evaluation of the Cognitive Tutors™ for mathematics, currently directs Carnegie Learning's *Teaching Practices* study. As a postdoctoral associate and research scientist at Carnegie Mellon, Dr. Ritter was instrumental in the development and evaluation of the Cognitive Tutors™ for mathematics. He is the author of numerous papers on the design, architecture and evaluation of Intelligent Tutoring Systems and served as chairman of the IEEE Learning Technology Standards Committee working group on tool/agent communication. In 1998, he was one of the co-founders of Carnegie Learning. He will serve as co-PI for AIMA, overseeing and coordinating Carnegie Learning's software development portion of the intervention curriculum. Ritter will also work with Madfes coordinating the research study.

Kimberly J. Viviani (B.A., Mathematics, University of California, Santa Cruz) joined WestEd in 2003 as a Senior Program Manager for the Center for Assessment and Evaluation of Student Learning. Prior to joining WestEd, Kim served as the Director of Curriculum and Product Design for Academic Systems where she managed the development and maintenance of content for three products: Interactive Mathematics, Interactive English, and academic.com. She has also worked with Laurel Technical Services as a mathematician producing ancillary materials for various publishing companies, and editing a variety of mathematics textbooks. Viviani will coordinate the production of all curriculum materials for AIMA.

Ann Muench (M.S., Mathematics, Purdue University) is a Senior Research Associate and mathematics specialist with the WestEd Eisenhower Regional Consortium. Muench collaborates with key state and district personnel to provide technical assistance and staff development in mathematics education, assessment, and using data to effect change. She also works with individual school sites in California to support middle school mathematics improvement efforts. Muench will lead the development of AIMA's intervention curriculum as well as implement the district field tests for the research study.

Thomas L. Hanson (Ph.D., Sociology, University of Wisconsin, Madison) is currently a Senior Research Associate at WestEd where he is director of the Race/Ethnicity and Student Tobacco Use study (USC/NIH), the Analysis of California Adolescent Data Study (California TRDRP), and the Risk/Resilience and Student Academic Performance Study (California Department of Education/Stuart Foundation). Hanson serves as statistician for the Evaluation of the California In-School Tobacco Use Prevention Education Program (California Department of Health and Human Services). Hanson will serve as a psychometrician for AIMA.

Jerry Bailey (M.A., Sociology, California State University, Los Angeles) is Senior Statistician at WestEd and provides statistical expertise to numerous projects. He is responsible for sampling on the California Healthy Kids Survey for the California Department of Education and had a major role in data analysis for the Evaluation of Programs to Prevent and Reduce Drug, Alcohol, and Tobacco Use Among In-School Youth. Bailey will serve as a psychometrician for AIMA.

ADVISORY BOARD MEMBERS

AIMA's advisory board (see full vitas in section f) will review materials and evaluation plans, and make recommendations to inform the mathematics content development and the research study. The following educators will lend their expertise to this project: ***Ruth Ann Costanzo*** — Assistant Superintendent Santa Clara Unified School District, advise group of school implementation; ***David Foster*** – curriculum and assessment developer; ***Martha Hanisch*** – National Board Certified mathematics teacher; ***Edward M. Landesman*** – mathematician and curriculum development expert; ***Miriam Landesman*** – mathematician, teacher educator, and curriculum development expert; ***Judith E. Mumme*** – mathematics educator, curriculum development and implementation expert, and national policy advisor; ***Richard J. Shavelson*** – professor Stanford University and measurement expert, ***Mark R. Wilson*** – professor University of California–Berkeley and measurement expert.

Section D(4) Resources

Over the past 37 years, **WestEd** (formerly Far West Laboratory for Educational Research and SWRL) has carried out more than 1,600 successful projects, many of them on the cutting edge, and some representing major contributions to the nation's R&D resources. We have earned a reputation as a leader in moving research into practice. In these years of helping to develop significant R&D resources, and in applying the best available R&D to improve schooling, we have built solid working relationships with education-related agencies at all levels, playing key roles in facilitating the efforts of others and in initiating important new improvement ventures. WestEd has vast experience and expertise in Mathematics, Science, and Technology (MST) education — including curriculum development, teacher professional development, technical assistance and research and evaluation. The proposed staff collectively brings over 100 years of educational experience. This expertise includes curriculum development, research and evaluation and implementation of innovative programs. The selected school districts have an established working relationship with WestEd. This relationship will enable the development team to work closely with teachers and administrators to pilot test the materials and improve the final product in advance of the randomized field test.

Carnegie Learning products draw upon twenty years of basic research in cognitive psychology and artificial intelligence at Carnegie Mellon University (Anderson, Corbett, Koedinger, & Pelletier, 1995) and have been shown to dramatically improve student learning as compared to traditional approaches of instruction (Koedinger, Anderson, Hadley, & Mark, 1997; Carnegie Learning, 2002a). Their mathematics products are currently used in over 1,500 schools internationally.

Dissemination of AIMA will benefit from WestEd's public information services as well as the sales and support divisions at Carnegie Learning. WestEd, for example, actively engages an audience of education practitioners and policy makers with a comprehensive catalog of its products and services. This catalog features professional development services ranging from whole-school improvement programs to curriculum-specific interventions. Products include teacher resources and classroom materials. The catalog is mailed to every school district superintendent in the United States, to every principal in the twelve states where WestEd's work is most concentrated, and to mailing lists of curriculum directors, teacher professional developers, and current WestEd customers and clients. In addition, publications and products are prominently featured in exhibit booths and presentations at national professional conferences (e.g., AERA, ASCD, NSDC, and NCTM). Educators and policy makers made over two million visits in 2003 to WestEd's Web site [www.wested.org] for education information and solutions. A new online initiative, Schools Moving Up [wested.schoolsmovingup.net], is targeted specifically at under-performing schools, with resources and tools to help schools meet their improvement goals. WestEd leadership in the federally funded RTEC and Eisenhower Mathematics and Science Consortium provide further outlets for news about innovative mathematics curricula.

The sales and support staff at Carnegie Learning will also be involved in getting word out about AIMA. In addition to the support they offer to current customers of the *Cognitive Tutors*™ software, Carnegie Learning staff talks with hundreds of prospective customers annually and undertake focused pilot studies to understand how the Carnegie curricula can support local instructional programs.

Section C Project Abstract

ALGEBRAIC INTERVENTIONS FOR MEASURED ACHIEVEMENT

A MATHEMATICS AND SCIENCE RESEARCH GRANT GOAL ONE PROPOSAL

Learning algebra is a difficult task for many students, yet it is quickly becoming the gateway to high school graduation, as well as economic access. Learning algebra is not necessarily similar to learning arithmetic, but the textbooks used in many American classrooms are likely to focus on the procedural rules one needs to follow to solve an algebraic equation rather than the underlying concepts that help one *understand* how to approach problems. The challenge for many teachers, as they try to help struggling algebra students understand the underlying concepts, has been in finding interventions that are grounded in a cognitive framework of how students actually learn.

WestEd and Carnegie Learning have partnered to develop and research the effectiveness of an intervention curriculum that targets particular trouble spots in school algebra. The ALGEBRAIC INTERVENTIONS FOR MEASURED ACHIEVEMENT (AIMA) modules will help a teacher provide the "3 R's" of student learning experiences that — based on student needs– *reinforce*, *refresh*, and *re-teach* algebra concepts. These intervention lessons will reinforce current learning for students who understand the particular concepts, building their fluency and confidence in the subject. The interventions will refresh students' knowledge of concepts they may have already learned, but which need reinforcement. And they will re-teach concepts that students may have misunderstood or never learned. AIMA will develop such an intervention curriculum by pairing portions of Carnegie Learning's successful *Cognitive Tutor*™ software with WestEd developed print-based curriculum materials that reflect the research on how people learn mathematics.

The impact of the AIMA materials will be determined and the efficacy of the development process will be validated through a rigorous scientific study on two of the six modules. The basic effectiveness evaluations will take the form of randomized controlled studies with pre- and post-tests. The formative studies on mathematical skill will take the form of analyses of the underlying skills involved in curricular activities and in exam items. These analyses will be used to revise the curricular unit, which will then be evaluated in a second implementation.

A diverse mix of middle and high school algebra students from six school districts in California will participate in the pilot- and field-testing of AIMA's intervention materials. In these districts with enrollments ranging from 7,000 to 140,000 students, approximately 37.8% (range: 20.6% to 56.8%) of the students participate in the free or reduced lunch programs, 28.5% (range: 16.2% to 50.6%) are English language learners, 7% (range: 2.6% to 15%) are African American, and 43% (range: 40.9% to 63.2%) are Hispanic/Latino. Failure rates in algebra courses within these schools are very high.

When AIMA has been proven as a way to provide a viable solution for students who are struggling to learn algebra and the educators who are struggling to assist them, the materials can be incorporated into an existing curriculum (either replacing or supplementing targeted lessons) or augment/replace curricula of extended classes where students are given additional time for mathematics learning.