

Project Description

I. INTRODUCTION

Our nation is failing to prepare millions of young people for meaningful and productive participation in an information-based society. The target population of this proposal is those young people who are performing in the bottom quartile on state and national tests, and many of these are children of color living in under resourced communities. Today, many of these young people end up diverted into an underground economy, gangs, and prisons.

Our project addresses this failure by pilot implementation and research on an approach we are developing for high school mathematics, in which students form a cohort that takes mathematics every day using our instructional materials (developed with two IMD awards), and are enabled to stay together for all four years of high school. The promise of this approach to accelerate, rather than remediate, student learning was indicated by our work from 2002-2006 with a cohort of students at the lowest performing high school in Jackson, MS. Entering freshmen were assigned by counselors to Algebra Project or nonAlgebra Project Algebra I classes based on scheduling (not as volunteers). Four years later, seniors taking college prep math courses were five times as likely to be Algebra Project cohort students than students from other math classes. Many are now in college taking college math courses.

Since then, we have developed two more cohorts in order to research and develop this model further. We have developed and piloted instructional materials for a one- or two-year course (depending on the local implementation) in beginning algebra, as well as teacher guides and institutes to enable teachers to use the materials. We have pre-piloted materials for high school geometry, and this work positions us to finish a full four years of high school materials within this program. Our young people and their peers have formed their own project, been awarded an NSF ISE grant to develop “mathematics literacy workers” who serve after school and in summer activities. The combination of our classroom and professional development work, innovative curriculum materials, and community organizing experience creates an intervention that can significantly influence the peer culture, even in the face of negative forces.

In this proposal we seek to study key elements of design in existing cohorts, to revise and extend materials and professional development accordingly, and to implement demonstration cohorts in four new sites. Using organizing strategies, we will also create a network that enables communications among interested sites and disseminates ongoing research and development activities and findings.

We believe that, with an implementation of a cohort program that satisfies most of the cohort model characteristics listed in Section III.A below, cohort students will pass the state and district mandated tests in mathematics, pass the mathematics portions of any graduation test, and score well enough on the SAT or ACT to meet college admissions standards. We aim to prepare students *not only* to gain admission to college, but also to place out of remedial courses and to qualify for mathematics courses for college credit.

Our approach is to stimulate a demand for math literacy in those most affected by its absence -- the young people themselves. This approach, which places a high value on the importance of peer culture, is an outgrowth of our experience in the Civil Rights Movement of the 1960s, as well as the emergence of our own Algebra Project graduates into a group with their own perspectives and initiatives. In the 60s, we learned how to use the meeting place as a tool to engage and empower the people that the meeting was intended to serve. In the proposed project, we have two meeting places: the Algebra Project high school mathematics classroom; and a

network of member sites that are supporting cohorts of students similar to those in the NSF study. The role of the young people in both of these settings is the key to creating the motivation and commitment needed for student success.

Project goals:

1. To determine whether and how the cohort model can enable initially low performing students to enter college and qualify to take mathematics courses for college credit; and to stimulate national interest in this model as a way to achieve the above.
2. To study key features of the design of our materials and professional development, and of peer group development, in certain sites that have already started cohorts;
3. To develop the additional curriculum materials and professional development necessary for a four-year cohort implementation;
4. To conduct formative research and summative evaluation on the core characteristics of the model and their implementation in four new sites in areas of the country where the project has not previously worked. These cohorts will be tracked from Grade 9 into the first semester of college. Data collection will include students' mathematics achievement, learning and thinking (on state or national tests and on project-designed assessments); the development of a positive peer culture in the cohort; students' identities as math learners; their education and career planning; their progress in applying to and entering college; and their actual placement into and success in first year college math courses.

II. RESULTS OF PRIOR NSF SUPPORT

With three prior and two current awards, the Algebra Project has been evaluated by an interdisciplinary panel of experts, has developed relationships with university mathematicians and math educators to strengthen teacher professional development, and has begun developing a four-year high school mathematics sequence and teacher professional development for students performing in the lowest quartile. These grants have also leveraged additional funding from private foundations and individual donors.

In 1995 (#ESIE9459258, \$605,612; 2/15/94-7/31/95), an expert panel visiting Algebra Project sixth grades in Mississippi observed “positive outcomes in teaching, in students’ attitudes and engagement around mathematical ideas, in community involvement, and in movement toward systemic reform (Cazden et al., 1995). With #ESIE9630116; \$2,503,748; 4/1/97-3/31/02), the project formed teams of teachers and university math and science specialists that facilitated professional development for over 700 teachers in southern states, New York City area, and district-wide in Cambridge, MA. The facilitators in Cambridge were hired to lead professional development in any of several optional math programs, not only the Algebra Project. The potential of the project to engage teachers was indicated in that, across sites, 31% of teachers committed more than the minimum hours recommended by NSF, and 17% participated voluntarily for 2-4 times the minimum. Students who graduated from middle schools where a majority of students participated in the Algebra Project enrolled in (and passed) college preparatory math courses in high school at about twice the rate of their peers from non-Algebra Project middle schools in the same districts (Davis & West, 2000; West & Davis, 2005).

Recently, two IMD awards have enabled Bob Moses and colleagues to develop high school materials. With #IMD0137855 (\$575,337; 12/16/02-11/30/05), several mathematicians collaborated with Moses at Lanier High School, Jackson, MS, resulting in two modules for Grade 9 Algebra I that were fully piloted in Proviso, IL, near Chicago, and partially piloted in Irvington, NJ, and Rochester, NY. Moses and colleagues also supported one cohort of students

from 9th through 12th grade. Students were assigned to Algebra Project or nonAP teachers based on scheduling -- neither students nor parents were volunteers. At the end of 9th Grade, 56% of the Algebra Project students (n=108) passed the state Algebra I exam on first attempt, compared to 38% of nonAP students (n=85) in the school. By Grade 12, only 41% of the original Grade 9 Algebra I students at Lanier were still taking math, but 85% of these were Algebra Project students.

With #IMD0628132 (\$2,749,760; 10/01/06 - 09/30/09), we are developing seven curriculum modules with accompanying teacher guides and professional development. By June 2008, we will have piloted three modules in Petersburg VA and Summerton SC, and will have produced drafts of the other four modules based on development work in high schools in Bronx, NY, Miami, New Orleans, and Jackson, MS.

Finally, with an SGER award (#0600793, \$199,866; 11/01/05 – 6/30/08), the Algebra Project is collaborating with Students at the Center in New Orleans to produce a database of students' stories of their experiences in the aftermath of Hurricane Katrina, and a pedagogical process that teachers can use to create mathematics lessons from students' stories.

III. PROJECT ACTIVITIES

To reach our goals, we will study key elements of design in established cohorts, revise and extend our materials and professional development, and implement and study cohorts in four new sites, as described below.

A. Cohort Characteristics and Predicted Outcomes for Students. Based on our past experience, we have identified features of the cohort model that will enable students who enter high school performing in the bottom quartile on national or state tests to become prepared for college work. These features we call the Cohort Characteristics:

1. Each Cohort school commits for four years to reduced class size of 20 students and providing math class every day for 90 minutes, and a common planning period if there is more than one Algebra Project teacher; and
2. Cohort students commit to take math classes every day for 90 minutes with Algebra Project teachers for all four years and to participate in summer institutes as well as other aspects of the program listed below; and
3. Students use the Algebra Project's experientially-based classroom materials for all four years; and
4. The students' teachers are prepared and supported in the use of these materials by 2-3 weeks of summer and winter Professional Development (PD) institutes annually, as well as at least two classroom visits by experienced Algebra Project professional developers during the school year; and
5. Cohort students attend summer institutes (that are locally developed and designed) to enhance their learning.

We have identified additional characteristics that we recommend as important for cohort sites, but the forms in which these characteristics are implemented will have to vary from site to site. These additional characteristics include: having community groups develop a local network of parents, school personnel, community activists, and leaders, who focus on sustaining the above intervention; Cohort students receiving some form of support for improving English and language arts achievement; Cohort students having support from counselors who can work with them individually and/or in groups; Cohort students being exposed to the wider culture in some

way that overcomes their isolation from the larger society; and Cohort students receiving some form of support for college entry and an introduction to various careers and job opportunities.

Predicted Results of a Cohort Implementation: If the five Cohort Characteristics are implemented, we predict the following outcomes for cohort students, which will be the focus of research:

1. A large majority of the cohort students will chose to remain in the program for all four years;
2. Virtually all the cohort students who remain will pass state mathematics tests and mathematics sections of graduation exams;
3. Virtually all cohort students who remain will perform sufficiently well on college entrance exams (SAT or ACT) to gain admission into college; and
4. A large majority of the cohort students who remain will place out of remedial math in college and will be qualified to enroll in mathematics courses for college credit; and
5. Cohort students will exhibit positive attitudes toward mathematics and confidence in their own mathematical thinking; a desire and capacity to engage in deep mathematical thinking about various concepts; a willingness to demand engagement from their peers, and to take responsibility for the classroom environment; an insistence on support from adults, including teachers, parents, administrators, and government officials.

B. Cohort Sites

The research sites are of two types: (1) **R&D Cohorts**: two cohorts now in Grade 10 in Miami and Jackson, MS, and the two other schools now using our curriculum materials under the current IMD grant; and (2) **Demonstration Cohorts**: four new cohorts that will begin in Fall 2009, who will be tracked until their first semester of college at the end of the grant. In addition, we will work with (3) **“Incubator” Cohort Sites**.

1. R&D Cohorts

Edison HS, Miami, FL. The Center for Urban Education & Innovation at Florida International University (FIU) partnered with the Algebra Project in 2004 to prepare for forming a Cohort of students. The cohort model was designed to support 24 students through four years of high school. The Cohort, formed in August, 2006, is the first Algebra Project school-based/university affiliated educational reform effort. In this reform, the university comes to the school house. Professors and visiting scholars are in the classroom working with the students alongside the high school teacher. At present, the students are studying algebra and geometry using curriculum material developed by the Algebra Project Materials Development Team. For the 11th grade, modules of the proposed trigonometry material will be piloted in the classroom, and the 12th grade course schedule will be comprised of the proposed discrete math and classical function modules.

Lanier HS, Jackson, MS. Lanier High School in Jackson, MS represents the longest running high school affiliation of the Algebra Project. It is the site of the first high school cohort which was established in 2002 and graduated in 2006. At present, 36 10th students are taking 90 minutes of math a day using pieces of the NSF IMD curriculum. For the 11th grade, modules of the proposed geometry/trigonometry curriculum will be piloted in the classroom. As with Edison, the 12th grade course schedule will be comprised of the proposed discrete math and classical function modules.

Scotts Branch High School, Summerton, SC, and Petersburg, VA, High School: These two sites are part of our current IMD award and are funded through September 2009. Two classes of roughly 20 students each are now in the midst of the first year of the Algebra Project high school curriculum. Formative and summative evaluation here will contribute to our R&D effort.

2. Demonstration Cohorts

Los Angeles. One LA is a community organization operating in Los Angeles County on health, welfare and education for over 30 years. One LA is an outgrowth of the Industrial Areas Foundation (IAF). Their efforts have involved securing resources for gang prevention and intervention, youth jobs, after school programs and training parents to be advocates for their children. It has also worked with Los Angeles Unified School District (LAUSD) on passing school construction bond measures. One LA will take responsibility for developing a Cohort satisfying all of the Cohort Characteristics described above in at least three high school feeder patterns: Crenshaw, Franklin and Fremont. They are also working to develop university affiliation at colleges such as Occidental College.

Southern Illinois. Southern Illinois University Carbondale (SIUC) will identify and develop one cohort in the region. SIUC has a working relationship with a considerable number of school systems in the region, and candidates include East St. Louis, Cairo, and Carbondale. After a selection process that will include discerning community interest and commitment by school officials and prospective teachers to the Cohort Characteristics, a school in the region will be chosen to participate as a Demonstration Cohort starting in Fall 2009. An experienced mathematics education researcher will lead site research.

Southeastern Michigan. The School of Education in the University of Michigan agrees to take responsibility for the initiation, oversight, follow up, and evaluation of one Algebra Project cohort in southeastern Michigan. The funds requested in this proposal will allow the SOE to mobilize students, parents, teachers, school officials, and the larger community to conceive and carry out the successful implementation of a cohort in southeastern Michigan in line with the Cohort Characteristics detailed in IIIA; to design, garner additional funding, and implement 2-week summer institutes for cohort students in each summer of the project; to financially support the cohort teacher to attend professional development institutes for teachers sponsored by the Algebra Project; to design and implement a case study of the cohort intervention in relation to the Cohort Characteristics.

Mansfield, OH. Ohio State University-Mansfield (OSU-M) will develop a relationship with a group of current 7th graders, who will be 8th graders in Fall 2008. Working with personnel of the Mansfield City Schools they will recruit a group of twenty-five of these students to participate in an already-existing summer program on the OSU-M campus, an academically oriented non-residential summer camp for middle school kids.

OSU-M will fund a faculty member to participate in Algebra Project sponsored professional development sessions in calendar year 2008. We will begin immediately to navigate the local school system in search of teachers interested in participating in the Algebra Project Cohort program, beginning in 2009. The result of these efforts will be to have all the elements in place to begin a cohort of 25 9th graders in Fall 2009.

Communication among sites. While this proposal is pending, the Mansfield, OH, group has volunteered to coordinate communications among the demonstration cohort sites. Shared communication between the sites will become important as the project proceeds (see Section III E).

for a description of internet tools that will be developed to foster this communication).

3. “Incubator” Cohort Sites

The Algebra Project is either in contact with or currently working in many other places around the country. A number of these locations have expressed interest in establishing Cohorts. A partial list includes New Orleans, LA, Philadelphia, PA, Minneapolis/St. Paul, MN, Asheville, NC, Petersburg, VA, Baltimore, MD, and Teaneck, NJ. While these sites will not be directly funded through this proposal, the Algebra Project will continue to stay in communication with them and disseminate products and findings that aid in their development toward true Cohort sites. These sites will be given access, at their own expense, to the global functions of the program including professional development and curriculum materials. The distribution of this information and material will be facilitated through an online format that includes an open source network that allows sharing and customizing the instructional materials (see also III E below).

C. Development of Experientially Based Curriculum Materials

Based on the fundamental principle that the nature of knowledge and the processes by which it develops in the mind of an individual are inextricably interrelated (Piaget, 1970), all Algebra Project curriculum units begin with mathematically-rich experiences. The pedagogical strategy involves Moses’ five-step process (Moses & Cobb, 2001) which has proved successful in middle schools in changing teachers’ classroom practice and improving student achievement (West et al., 1995, 1998; Davis & West, 2000; Currell & West, 2003; West & Davis, 2004, 2005, 2006; Davis et al, 2006. (1) Mathematically-rich physical experiences; (2) Pictorial representations/ Modeling of the events; (3) Intuitive language about the events – “People Talk”; (4) Structured language about the events – “Feature Talk”; (5) Symbolic representation of the events. Student work proceeds first individually, then in small groups and finally in whole class discussions.

The mathematics material for the cohorts will include the seven algebra modules being completed and piloted under our current IMD project. In addition, we will develop new modules in geometry/trigonometry, discrete mathematics, and classical functions. These materials are designed to prepare students to enter college ready to take mathematics courses for credit.

Geometry/Trigonometry. These materials will connect discrete algebraic material to continuous geometric notions and integrate geometric ideas with algebraic ideas. The practical nature of geometry and its connections to physical events provides numerous opportunities for mathematically rich activities. For example: (a) experiences with marks on a line, such as possible heights on a height chart, which leads to coordinate-free vectors, linear coordinates, real numbers as points on a line that can be approximated by rationals and decimals; (b) making a map of the school yard or similar area, which leads to coordinate systems, measurement, units, approximations, orders of magnitude, scale, simple spherical coordinates; (c) relationships between objects and their shadows, which leads to scalar multiplication, parallel/perpendicular, similar triangles, trigonometric ratios, slope, ratios, proportions; (d) measuring areas and volumes, leading to Pythagorean Theorem, some geometric algebra, trig functions and identities; (e) symmetry in art and physical world, leading to symmetry arguments in geometry, groups, transformations; (f) using a stick and string attached to determine unknown heights (which leads to trigonometric functions and applications, similar triangles, ratios; circular motion of wheels or other mechanisms (angles, trigonometric circular functions, arcs, chords).

We will also introduce local deductions from simple to complex asking “why is this true and what are we assuming in saying it is true” – for example, comparing rectangular planar coordinates to spherical coordinates will motivate the need for a parallel postulate.

Discrete Mathematics. In 1989, the NCTM elevated discrete mathematics to the high school curricular status of algebra, geometry, and calculus by including a separate discrete mathematics standard in their Standards document. Today, it is a core component of mathematics at the undergraduate level. In a society with a complex social structure, grounded in computer technology and digital communication, discrete mathematics has an essential role to play in the development of students’ mathematical power.

Few high school students in the bottom quartile are provided the opportunity to study this material, yet discrete mathematics topics flow naturally from our algebra modules (for example, set theory and propositional/predicate calculus in the Trip Line module, functions on finite sets and matrices in Road Coloring, combinatorics and probability in Random Walks). With this award, we will develop a one semester course for 12th grade that will introduce several discrete mathematics topics and provide a bridge to college-level discrete mathematics. The motivating experiences include students constructing physical switching circuits, writing computer programs, designing secret codes, and investigating the spread of a rumor in their classroom.

Classical Functions. Trigonometric functions, exponential and logarithmic functions, polynomial, rational and other power functions all lie at the heart of science and engineering. We will create a one-semester course for 12th grade that builds on previous modules. Students will have seen various trigonometric, polynomial, and power functions. This module will help the students move toward seeing functions as objects in themselves by analyzing the effect of transformations on the functions, especially in the trigonometric setting. Simple devices such as pendulums for discovering periodic motion and thermometers for studying temperature gradients will provide some of the motivating experiences. Population growth studies will help model exponentials. Students can produce and modify sounds and visualize their waveforms using inexpensive oscilloscope simulators aiding the development of sinusoidal functions.

Effects on Students. Will our students be willing to do the regimen of work necessary to be prepared for college-level non-remedial mathematics? Past work demonstrates that our materials, presented in a cohort model, motivate students’ interest and commitment. We attribute this to: the teaching of math through mathematically rich physical experiences, that often requires students to use their own bodies to describe space, as well as trips or games that engage them fully; dialogues about mathematics that they act out in class; classroom process that involves attention and respect to individuals (Davis et al., 2006). A transformation occurs that fuels students’ desire to take the necessary mathematics to prepare themselves for college.

Another issue we face is mandatory high-stakes tests of traditional material. We have developed a Phase1/Phase2 strategy for test preparation. This strategy applies to any school period that ends with a mandated exam -- benchmark exam, exit exam or college entrance exam. The focus of Phase 1 is entirely on building students’ basic understanding of mathematics concepts and helping them believe in their potential success in mathematics using Algebra Project material and pedagogy. The goal is that mathematics they study in Phase 1 will be learned with a deep level of understanding. This phase will also include some, but not all, of the specific material that they will need for the test and the set of required topics for the course in question.

Then, at a predetermined time that will vary with the particular situation, the class moves over to Phase 2 in which students are prepared for the test through developing procedural knowledge, learning methods of solving problems, and learning test-taking strategies. Required material not studied in Phase 1 will be covered rapidly during Phase 2. The basis for this strategy is that because of their deep understanding, ability to think, and confidence in doing mathematics that they developed in Phase 1, students will be able to prepare for the exam in Phase 2 efficiently and effectively.

We have seen indications of the effectiveness of this strategy in past years at Lanier High School, and currently at Petersburg VA, Summerton SC and in the new Lanier High School pilot. In all of these cases, some version of the Phase1/Phase2 strategy was used and our students did as well or better on the test as students in the traditional classes, and in some cases much better.

D. Professional Development and Support for Teachers

The Algebra Project's approach to professional development for high school cohort teachers is consistent with the current literature (e.g. Darling-Hammond & Bransford, 2005; Hoban, 2002; Loucks-Horsley et al., 2003), and has four specific goals: (1) foster collaboration among mathematicians/math educators and high school educators in order to strengthen the quality of mathematics content and knowledge for teaching of this mathematics (e.g. Hill, Rowan & Ball, 2005); (2) provide opportunities for teachers to explore and become familiar with the new modules, including professional development institutes, follow-up support, and teacher resource materials for each module; (3) support teachers' work with cohorts of students by exploring how students learn, collaborate, and communicate in mathematics; and (4) assist teachers to build their own professional learning communities.

In using our materials, teachers are required to provide learning experiences where students construct conceptual and procedural understanding of high school mathematics concepts. This combination of content and process presents unique demands upon both the teachers who will implement Algebra Project curricula and the university mathematicians and Algebra Project PD specialists working with and supporting these teachers. It requires teachers to re-conceptualize the mathematics they have been teaching at a much deeper conceptual level than they previously have. It requires university mathematicians and Algebra Project PD specialists to aid and support teachers in this process.

Teachers who use our materials will attend a 2-week Summer Institute, and a 2-day winter meeting, and participate in classroom visits and Saturday workshops at their schools. Schools are also required to provide common planning periods at least three times a week for Algebra Project teachers to debrief and share lessons and experiences. Further, Algebra Project PD personnel, including PD specialists, university mathematicians, and math educators, will participate in specialized facilitator professional development to prepare them to co-facilitate the summer teacher PD sessions, and the follow up work at the schools during the school year, which are being developed with a pending supplement to our current IMD award.

E. Fostering a National Network

We are assembling a network of schools, universities, community organizations, and educational leaders interested in the use of Cohorts and to sharing ideas and knowledge gained from their experiences. An important part of this national network will be "Algebra Project affiliated universities" (APAU) which are committed to support several of the following: PD of teachers and summer institutes for students, supplemental language arts education tied to the project activities, after school programs with students to work with the high school students,

support mathematicians to work with the local Cohort program, support faculty research on the Cohort project and on Algebra Project pedagogy.

In addition to beginning to establish a national network of APAU's, we are looking to aggressively use the latest technology to create a more effective learning community. Learning communities need effective mechanisms for creating community specific materials, sharing existing materials and allowing for the free flow of ideas and concepts. We believe that by making our materials more open and accessible we will build a richer and more effective national community of math enthusiasts in our target population. The "Incubator" Cohort sites described above can be directed to this "open source" material to enhance their development. The center of this program is adopting open source software approaches and concepts. Our initial adoption of an open approach will be to create mechanisms and tools to allow others to customize the materials that we provide.

In this proposal, we seek support to create a website which will allow all members of our Learning Community to access, customize and share the key curricular components. For instance, with the Trip Line the following are envisioned: (1) Make available PDF's and editable versions of the curricular documents; (2) Allow for the classroom input pieces to be done online and then printed out; (3) Allow for input Cohort classroom pieces to be preserved and shared with other classrooms; (4) Allow for students to import or connect to videos of their Trips; (5) Create Flash versions of the Dialogues that individual users can customize and share across the network; (6) Allow for users to review and comment on the material that others create.

Each member of our learning community including the mathematicians, teachers, students and administrators would be able to independently help create a version of the materials that is highly specific to their community. As the materials grow, different communities would be able to share and reference the materials that other communities used. Learners could also see the comments and ratings that other learners have given different sets of materials so that the community would learn about the most effective methods. The information stored in the database would be critical for researchers wanting to learn about linguistic and cultural differences that may contribute to effective understanding of fundamental topics in math education.

IV. RESEARCH

We have formed a research team with expertise in mathematics, math education, mathematics teaching and learning, engineering, psychology and adolescent development, anthropology, language arts, and psychometrics. Members will collaborate throughout the five years to conduct research that falls in Phases 4 and 6-8 of Clements' (2007) framework for curriculum research. The existing cohorts are the context for two years of research to inform details of design of the student activities, classroom and teacher materials, and professional development that will be implemented in the four new sites, and to develop constructs and indicators needed for some of the outcomes.

While the existing cohorts have significant direct involvement of the Algebra Project materials developers, the new sites provide a test for the cohort model and components as they are implemented in a variety of contexts where students are performing in the lowest quartile nationally or statewide. The new sites will implement the Core Characteristics; but aspects of implementation are bound to vary, due to the type of community, local configuration of schools and districts, the state testing programs and how they influence district and school policies, the nature of support from the affiliated university, and other local resources. The nature of out-of-school student institutes or activities will also vary and may affect the emergence of youth

leaders and the development of peer culture.

These variations and their impact on the student outcomes summarized on page 2 and specified further on page 4 are the subject of the research in the new sites, using mixed methods (Johnson & Onwuegbuzie, 2004) that include measures of students' mathematics achievement and attitudes, interpreted in the light of case studies of the implementations, and cross-case analysis (NRC, 2001; 2004; Stake, 1995; Patton, 1997; Patton & Patrizi, 2005). We are especially interested two themes: the formation of positive peer group culture and how it may affect eventual student academic achievement; and students' and others' role in the "scaling up" of local interest in the cohort model to leverage additional resources.

The team's work will be facilitated by a researcher with experience studying Algebra Project classrooms (with ROLE#0087664) and in formative and summative evaluation of the Algebra Project and other math education projects. Data and interpretations will be shared with the external evaluators who will conduct an independent analysis of project data, collect some additional data on their own, and prepare a summative evaluation (see section VI). All sites will participate in the online network that will include researchers, teachers, and developers.

Initial Formative Research

Beginning in Year 1, a team at Florida International University will conduct five studies within the cohort at Edison High School, Miami, which serves many students of Haitian backgrounds, and some Latino/a students. These studies will examine the development of students' concept of function, the design of embedded assessments given state mandated testing, the impact of the project on teachers' classroom practices and beliefs as they adopt the new materials, change in students' learning identities, and the impact of the dialogues in the Algebra Project materials on the development of mathematical discourse in the classroom. All of these studies will inform revisions of the materials, PD process and recommendations for implementation.

1. Research on the Concept of Function (team led by Dubinsky). This research will examine the effects of particular learning activities on students' progress in developing rich and useful concepts of function. The function concept is fundamental to mathematics, and a deep understanding of this concept is essential for success in college math, science, and engineering. A major content goal of high school mathematics is to send students to college with at least an understanding of function as an input/output process that has a myriad of important representations and applications in mathematics, science, technology and engineering and in everyday life, and we seek to do better.

The function concept permeates the Algebra Project high school material. For example, our 9th grade Road Coloring unit introduces functions with finite domains leading directly to function-theoretic notions of single-valued, onto, inverse and composition. This unit also considers a variety of representations of functions including arrows, sets of ordered pairs, and incidence matrices. Other 9th and 10th materials lead to simple algebraic expressions that represent linear functions with multiple representations, a thorough exploration of polynomial functions, probability functions, and continuous mechanically-defined multivariable functions. In our 11th grade materials we will have: geometric transformations, transformations of vectors, translations as motions, and trigonometric circular functions. Our 12th grade materials will include the classical functions in addition to varieties of functions in discrete mathematics.

One of us (Dubinsky) has summarized the research and curriculum development literature

related to functions and have added to this literature. An understanding of Calculus requires a progression that many students never make: from an action conception, to a process conception, to an object conception of function. We will make use of existing theoretical analyses, including the action-process-object-schema model, and instruments previously developed (Breidenbach et al., 1992; Carlson, 1998), to study how Algebra Project students construct their understanding of the function concept. In addition, we will investigate the interrelationships between discrete approaches to function, continuous versions, and geometric transformations. For example, if students see geometric transformations as functions does this help them to understand the geometric transformation? – and vice-versa. Also, how do these complementary approaches help students develop concepts such as domain, range, one-to-one, onto, addition of functions, composition of functions?

The study will use the methodological framework described in Asiala et al. (1996) and methods similar to those in Breidenbach et al. (1992), in which students are pre- and post- tested with instruments that reveal their ability to work with functions as processes. This approach has proven to be powerful for investigating how students learn mathematics (Weller et al., 2003). Although the emphasis in this work was on mathematics at the beginning college level, it is based on ideas of Piaget related to learning mathematics from ages 6 months to 16 years. Some of the design and instruments will be taken from the literature; others will be created in our work.

2. The Social Aspects of Learning Mathematics. Some of the newest research on raising academic achievement for underperforming students has indicated that attending to academics alone is not enough, and, at best, creates only short term gains. This research suggests that our target population needs attention to social and emotional learning skills (Raggozino, 2003; Zins, 2004). Believing that learning, for students of color, is primarily relationship centered, many researchers have documented the impact of teacher attitudes on students' academic achievement (Delpit, 1997; Perry et al., 2003; Wynne, 2003). As important, though, is the impact of students' attitudes on student achievement (Perry et al., 2003; Raggozino, 2003; Steele, 1997; Zins, 2004). Part of the Algebra Project philosophy is that while offering world-class mathematical instruction to under-achieving students, there is a concurrent need to raise students' expectations of their capacity to achieve excellence in math. In addition, the Algebra Project is concerned about creating a classroom culture where students develop the self-discipline to achieve at high levels so that they can demand quality education for themselves and others. Moses explains this student demand as "earned insurgence," which he perceives as imperative to the work of whole school reform (PBS, 2007).

To explore this theme, we will observe classrooms and work with students to learn: What is the relationship between students' self perception, engagement and math learning and what effect does the Algebra Project have on the relationship over time? What are the attitudes of the cohort about their capacity to excel in mathematics when they come into the program? What are their attitudes after each year of the AP program? How does student engagement change over time? What are the manifestations of that engagement? How do we shift students' attitudes from accepting mediocrity in mathematics achievement to an attitude of self-disciplined demand for achieving excellence in math? How important is that shift to their improvement in math? What particular activities seem to cause that shift? To what extent do students recognize the academic and social goals of the Algebra Project? When and how do they begin to connect their academic achievement in math with quality education as a civil right? This work will inform development of constructs and indicators for studying student motivation and the development of positive peer group culture.

3. Mathematical Thinking and Dialogues. The National Council of Teachers of Mathematics' *Principles and Standards for School Mathematics* (2000) highlights communication as an "essential part of mathematics and mathematics education" (p. 60). Across the grade levels, students should be able to organize and consolidate their mathematical thinking through communication, communicate their mathematical thinking coherently and clearly to peers, teachers, and others, analyze and evaluate the mathematical thinking and strategies of others, and use the language of mathematics to express mathematical ideas precisely."

AP materials contain dialogues that students act out in class. These Dialogues provide students with opportunities to gain confidence in their mathematical abilities and to communicate mathematically. The Dialogues contain roles as mathematicians and students. The goal is to have students go beyond the Dialogues and begin to read mathematical content, engage in mathematical conversations amongst themselves, as well as between the students and teachers. To assess the effectiveness of the Dialogues in attaining this goal, the following questions will be considered: What role do the Dialogues play in creating more mathematical conversations among the students and between the students and teachers? What is the content and context of the mathematical conversations of students? What are the characteristics of the Dialogue that contribute to mathematical conversation outside of the Dialogue-related situation? Do the Dialogues have the same effect for English Language Learners and non-English Language Learner students? The structure, format, and content of the Dialogues and classroom interactions will be examined using content analysis.

4. Algebra Project Assessment and State-Mandated Standardized Tests. Researchers have debated about the consequences (both positive and negative) of high stakes testing (Camilli, 2003; Cizek, 2001; Guskey, 2007; Lane & Stone, 2002; Mehrens, 2002; Rich, 2003; Smith & Rottenberg, 1991). However, these assessments should not negatively affect the teaching and learning that takes place in classrooms. To this end, two questions will be explored: (1) What is the relationship between the assessments developed by the Algebra Project for use in the classroom and the external state-mandated standardized assessments taken by the student? and (2) How can students be prepared for taking standardized tests without degrading conceptual understanding? Results will inform the Phase 1-2 sequence described above on page 7.

5. The Effect of the Algebra Project on Professional Development. Teachers play an important role in what students have an opportunity to learn (Hiebert, 2003; Mewborn, 2003). Three important contributors framing, at least in part, the opportunities for learning granted students in their classrooms are teachers' knowledge, beliefs and actions with respect to mathematics, students, and curriculum (both intended and enacted). Research suggests that teachers' knowledge and beliefs about mathematics have been found to influence their practice (Ma, 1999; Sowder, Phillip, Armstrong, & Shappelle, 1998; Swafford, Jones, & Thornton, 1997; Thompson, 1992). Similarly, teachers' knowledge of students' thinking has been found to have effects on their instructional decisions (Even, 1993; Even & Tirosh, 2002; Fennema & Franke, 1992). Thirdly, teachers' appropriation of curriculum suggests ways in which they use curriculum in teaching that in turn enhances or limits what students have an opportunity to learn (Remillard & Bryans, 2004; Brown & Edelson, 2003).

We will investigate changes in these three interrelated areas as teachers participate in the project. Interpretive case studies (Stake, 1995) will be used to develop understandings of cohort teachers' appropriations of Algebra Project materials and the effect of this appropriation on their knowledge and beliefs of mathematics and students' thinking. Questions will include the following: Through what processes and to what degree do cohort teachers appropriate project

materials? How does this appropriation effect change in their knowledge and beliefs about mathematics and students thinking, if at all? Answers to these questions will inform the project's developing PD program for cohort teachers, as well as benefit the mathematics education field through greater understanding of the impact of teachers' professional development experiences on their learning about and use of curriculum, knowledge of mathematics, and understanding of students' thinking, particularly when working with students typically underrepresented in mathematics-related fields.

Formative & Summative Research on Four Demonstration Cohorts

These four cohorts provide a context to study implementations in a variety of contexts, and to interpret their impact on the student outcomes presented on page 2 and further specified on page 4. Sites are located in four different states with different configurations of high school testing, and in schools in small and large districts with different practices of monitoring student progress on tested objectives. The sites will vary in how they use existing community and university resources, which will affect the extent and nature of their summer programs and after school programs for students, the role of youth leaders, counseling, support for college admissions, and other details. These differences may affect the ability of students to form a supportive peer group that is motivated to learn – which we see as a key intermediate objective that mediates student achievement outcomes.

Using a common framework, site researchers will document the implementations in enough detail that other sites could learn from these examples. The four cohorts will be observed from Grade 9 through first year of college, and their mathematics achievement and learning will be tracked through Algebra Project classroom assessments, scores on all mandated tests, ACT or SAT on each attempt, the development of career and college interests, actual applications, college entry, and placement into college courses. Scores of cohort students on state-mandated tests or national tests will be compared with non Algebra Project students in the same school or district who are demographically similar. Sites will use constructs and instruments generated by the first two years of research to study particular topics. All of these data will be assembled into case studies that are updated annually, with annual cross-site analysis to generate recommendations and lessons learned. Researchers will share their work on line as well as in two conferences in Year 1, and in annual project meetings.

V. EXTERNAL EVALUATION

Inverness Research Inc. will serve as the external evaluator and conduct the summative evaluation. The purpose of the summative evaluation is twofold: to assess the project's overall success in meeting its goals related to improving motivation and achievement in mathematics for students scoring in the lower quartile in the development and demonstration sites; and to provide an independent perspective on the feasibility and efficacy of the cohort model, including its Cohort Characteristics. The focal questions guiding the summative evaluation are:

- 1) As a result of the project's work, what are the ways in which and degree to which students in the targeted population experienced greater success in mathematics?*

Inverness Research will examine student learning outcomes using achievement data collected by the project and will review these data and draw independent conclusions about the cohort model and the progress the project made towards its goals. They will look at other indicators of success as listed in Section III.A. In addition, the summative evaluation will document what capacities contributed to student success. It will consider what capacities are built by the project

that school districts and communities can continue to utilize when the grant funding ends.

2) *What are the lessons learned from the cohort model and what new knowledge do they contribute about successful strategies for addressing the needs of low performing students?*

A critical component of the project's outcomes is the generation of research and knowledge based on its work. The summative evaluation will look closely at the cohort model as the centerpiece of the work, asking the following questions of it: What does it take to do this model successfully? How does each of the project's key components contribute to the overall success? What is the efficacy of the teaching and learning? Do cohorts make a difference? What evidence is there to support these claims? Based on the data, the summative evaluation will address the question of feasibility and transferability to other school districts. In addition, it is important that the effort must so contribute to a broader knowledge and research base. With this in mind, another essential piece of the summative evaluation will be to glean more general lessons learned from the project that will inform the funder and others interested in similar efforts.

Summative Evaluation Activities. The summative evaluation will monitor the project's work throughout the funding period. However, given its summative nature, the most intensive period of data collection will occur in the final two years. Below we list the major strands of work.

Communication and coordination with the AP: Inverness Research will maintain ongoing communication with the Management Team to communicate our work and stay abreast of project activities. We will attend key meetings to learn about the project's yearly progress.

Communication with the research coordinator: IR will be in contact with the research coordinator of the project to stay informed of the progress and activities of the various research efforts. We will establish communication with local research early in the project so we know what data they are collecting and the extent to which they may inform the summative evaluation.

Site visits: IR will conduct site visits to the 4 demonstration sites in years three and four. The site visits will include classroom observations and after school support programs, interviews with teachers, interviews and/or surveys of students, and interviews with participating university faculty and students. We will use these data together with data collected by other research efforts, such as the site case studies, to assess the project's progress towards its goals.

Phone interviews: The summative evaluation will include interviews with key support people who may not be present at the site visits, including PD people and mathematicians.

Independent review of other data: The summative evaluation will independently review data gathered by other research efforts within the project and draw conclusions.

Products: Inverness Research will produce a final report of findings at the completion of the project to communicate the achievements, knowledge and lessons learned. The audience for the report will be the field at large and the NSF. The report will incorporate an independent analysis of student achievement data as required.

VI. DISSEMINATION

Our model for dissemination that stresses communities dedicated to particular missions who can communicate at national local levels. This communication will be aided by our development of open source software. In each site, students, teachers, parents, administrators, school boards, affiliated university personnel, community organizations and individuals will work together and with the Algebra Project. With assistance from Algebra Project staff via workshops, visits and electronic communication, members of the local project will study the Cohort Characteristics, the classroom and teacher materials, and our pedagogical strategies for using then materials and implementing cohorts.

Part of the work will be to “incubate” new sites in and near their local regions. At least until the end of this proposed project, the Algebra Project will play a central role of coordination, communication and support. Eventually, successful dissemination will consist of a large number of autonomous projects serving a substantial portion of our target population and providing evidence of effectiveness in terms of students graduating from high school, being accepted into college and succeeding in their college careers. Development of new sites will extend this dissemination and lead to truly raising the floor of mathematics literacy in our country.

VII. ORGANIZATION

The project has both “global” and “local” layers. The global layer includes a Management Team that provides overall direction and facilitates cross-team and cross-site communications and meetings, including the open source software and online communications. This team includes the PI and coPIs, and Ben Moynihan, director of operations for Algebra Project Inc. The teams for global functions include the Materials Development, Professional Development, and Research teams, which each have their own internal coordination. Locally, there are site-based teams supporting each of the Demonstration Cohorts. These site-based teams involve local community personnel, and the local affiliated universities and their faculty and graduate students. Site point persons are: Southern Illinois (Greg Budzban), Mansfield, OH (Lee McEwan), Southeastern Michigan (Mark Thames), Los Angeles, CA (Ken Fujimoto).

VIII. TIMELINE

Summer 2008: (Pre-Award, funding from current IMD award and local sources) PD for 9th and 10th grade modules for piloting in R&D Cohort sites; Summer institutes for students in R&D cohorts; PD for teachers of 11th grade materials at R&D cohort sites.

2008-09: Pilot test 10th grade modules at Summerton and Petersburg; Revise piloted 9th and 10th grade materials. (DRK-12 funding starting January 2009) Assist Demonstration Cohorts in final development stage; R&D 11th grade materials at Lanier and Edison; Initial writing of 12th grade materials. **Summer 2009:** PD workshops for piloting of 11th grade at Petersburg and Summerton; PD workshops for 9th grade modules for new Demonstration Cohort teachers; PD workshops for R&D of 12th grade materials.

2009-10: Demonstration Cohorts starting with 9th grade modules; R&D of 12th grade materials at Lanier and Edison; Piloting of 11th grade materials at Summerton and Petersburg; Revising 10th and 11th grade modules. **Summer 2010:** PD workshops for Demonstration Cohort teachers (10th grade modules); PD workshops for piloting of 12th grade materials at Summerton and Petersburg; Summer institutes for students in Demonstration Cohorts.

2010-11: Demonstration Cohorts with 10th grade modules; Piloting of 12th grade materials in Summerton & Petersburg; Revising 11th and 12th grade materials; Follow-up on Lanier & Edison students (1st year) attending college. **Summer 2011:** PD workshops for Demonstration Cohort teachers (11th grade materials); Summer institutes for Demonstration Cohort students.

2011-12: Demonstration Cohorts with 11th grade materials; Revising 12th grade materials; Follow-up on R&D Cohort in college. **Summer 2012:** PD workshops for Demonstration Cohort teachers (12th grade materials); Summer institutes for Demonstration Cohort students

2012-13: Develop a continuing structure of national coalition of cohort sites; Demonstration Cohorts with 12th grade materials; Follow up on R&D students in college. **Summer 2013:** Summer institutes for Demonstration Cohort students.

Fall 2013: Follow-up on Demonstration Cohort students attending college. Final Report.

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