Abstract Title Page

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Title:
Democratizing Access to Core Mathematics Across Grades 9-12

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Abstract Body

Background / Context

Our proposed work builds upon 12+ years of research collectively known as the "SimCalc Projects." SimCalc Connected MathWorlds (SCM) combines two innovative technological ingredients to address core mathematical ideas in deep and sustainable ways for mathematics learners. Software that addresses content issues through dynamic representations and wireless networks that enhance student participation in the classroom. We have begun to develop materials that fuse these two important ingredients in mathematically meaningful ways and aim to revise and develop new curriculum materials to replace core mathematical units in Algebra 1 & 2 at high school for the purpose of transforming students' experiences in deep and sustainable ways. We are measuring the impact of implementing these materials on student learning, and high-stakes State examinations in local districts in Massachusetts.

Purpose / Objective / Research Question / Focus of Study

Our proposed work addresses many needs: the Algebra Problem (RAND, 2002), the related problem of student motivation and alienation in the nation's high schools, especially urban high schools (National Research Council, 2003), and the widely acknowledged unfulfilled promise of technology in education, especially mathematics education (e.g., Cuban, 2001). We also address the need to retain more students in mathematics past algebra, which increasingly means past high-stakes State examinations, into fundamental courses such as Pre-Calculus and Calculus, to help prepare them for higher education and careers in STEM programs. Our materials aim to address these needs in two dimensions: (i) deepening core ideas within significant sections of particular courses (Algebra 1 & 2) and (ii) connecting and sustaining the development of mathematical ideas across the grades (e.g., slope as rate can be examined in Algebra 1 to lay the foundation for examining links between rate and accumulation graphs in Calculus). So, we not only seek to implement significant sets of activities in each grade but measure the impact on numbers of students, particularly underrepresented groups, who continue into other junior and senior mathematics courses, relative to historic figures in the districts we shall work with.

We have revised and extended our present materials to create a connected curricular strand through the predominant existing modular set-up of mathematics in high school curriculum (i.e., Algebra 1 & Algebra 2). We have implemented these materials, into mainstream curriculum in local districts some of which have been partners with our projects for several years. We have aimed to observe gains in students' learning based upon content and process strands in the NCTM Principles and Standards (2000), both specifically across each subject as well as longitudinally, across the grades. Our main research questions are:

- Do we see learning gains following an implementation of an 8 to 12-week set of materials in Algebra 1?
- Do we see learning gains following an implementation of a 6 to 8-week set of materials in Algebra 2?
- Does exposure to our materials increase students' motivation to do mathematics and help retain more students in mathematics post 10^{th} grade vs. historic numbers in our local districts?
- Do our materials support a deeper, more longitudinal, development of mathematical growth, particularly with respect to problem solving and modeling?

We have begun to answer these questions with empirical data collected via various cluster randomized trials, assigning a few teachers in our participant schools to classrooms with our materials and collect data from a similar number of classrooms in each school as a control.

We have also collected data on what types of professional development are needed to support effective faithful implementation that integrates the designers' original intentions (Borko, 2004).

Setting

Our work has been conducted in a wide variety of school settings. Eight school districts agreed to participate in the study, a mix of urban and smaller town schools in the South Coast Region of Massachusetts.

Population / Participants / Subjects

Our main interventions primarily took part in eight main districts (Dartmouth, Fairhaven, New Bedford, Rochester, Westport, Wareham, Dighton-Rehoboth), a mix of urban and smaller town schools in the South Coast Region of MA. This sample incorporates a wide and diverse mixture of SES and performance levels. One of our partnering districts is New Bedford—a major city in MA with low achievement scores. Algebra failure rates, especially urban districts, continue to disappoint (RAND, 2002), as do achievement shortfalls among African American/Black (AA) and Hispanic (H) students in MA (NCES, 1994a; 1994b; 2001); 90% of African American (11.2% of State) and 92% (8.8%) are not proficient at 10^{th} grade mathematics. The figures are only slightly less for 8^{th} grade. In New Bedford, 34.2% of the students are AA/H with 58% not proficient at the 10^{th} grade level. But of course, the role of algebra as a gateway to all the opportunity that mathematics makes possible greatly multiplies its impact on the lives of students, especially those who are least advantaged in our society (Moses, 1995; Moses & Cobb, 2001).

Intervention / Program / Practice

We have systematically tested SCM across a series of mathematical topics and have begun to produce a set of curriculum materials that build on research and experimentation. Such materials exploit the power of both parallel software and the new, classroom-based communication infrastructure, to facilitate rich inquiry-based classrooms, fuelled by group-based or whole-class collaborative efforts. Our technology also binds representation, connectivity, curriculum and pedagogical techniques in mathematically significant and relevant ways. We exploited these affordances to create several new Connected Algebra activity structures:

1. **Mathematical Performances**. These activities emphasize individual student creations, small group constructions, or constructions that involve coordinated interactions across groups that are then uploaded and displayed, with some narration by the originator(s) of the construction.
2. **Participatory Aggregation to a Common Public Display.** These activities involve systematic variation, either within small groups, across groups, or both, where students produce functions that are uploaded and then systematically displayed and discussed to reveal patterns, elicit generalizations, expose or contextualize special cases, and help raise student attention from individual objects to *families* of objects.
3. **Project Work**. Here students individually or in groups collaboratively, produce some mathematical construction, usually to be displayed and discussed by the whole class.

Table 1 includes a summary of content areas for our intervention materials. Our Algebra 1 & 2 materials cover about 60%/40% respectively of traditional curriculum. Our intervention is unique compared to traditional methods of instruction as it connects core mathematical ideas, for example slope as rate, vs. separating these as two individual concepts as traditional textbooks tend to address them. Our materials engage students to reason, and justify their reasoning. We have also developed a suite of modeling problems that attend to systems of linear and piecewise linear functions (e.g., varying rate cell-phone plans) that are prevalent on many state examinations. In such activities, the idea of simultaneity is not only described as intersecting graphs but also the place where two moving actors meet at the same time.

Research Design

We have conducted 5 studies over 4 years including one Algebra 1 Pilot (yr 1), one Algebra 2 Pilot (yr 2), one Algebra 1 Main study (yr 2), one Algebra 2 Main study (yr 3) and a final Algebra 2 Main Study (yr 4). This design aimed to complete an iterative design based model to revise Algebra 1 and 2 materials as well as follow cohorts of high school students from 9^{th} to 11^{th} grade and subsequently in 12^{th} grade (see figure 1).

For our pilot studies, we have collected data in 8 clusters (classrooms), 4 treatment and 4 control. In the main studies, we collect data in 28 clusters (classrooms), 14 treatment and 14 control. This equates to approximately, 200 students for each pilot study (100 treatment; 100 control), and 700 students for each main study (350 treatment; 350 control). Exact numbers deviate only slightly from these expected numbers. We report here on our Algebra 1 studies (Pilot and Main).

Data Collection and Analysis

We use two outcome measures of student achievement in mathematics. The first assesses students' mathematical ability and problem solving before and after using our Algebra 1 materials. The second assesses ability and problem-solving before and after using our Algebra 2 materials.

The first is a researcher-developed instrument that has been devised and used in our present work. The test is composed of standardized test items from high-Stakes examinations, items from textbooks, past State examinations (including MCAS), research literature and NAEP items.

The second test was developed during Year 1 and piloted in Year 2 as a pre-post test around our Algebra 2 intervention. To construct the test, we followed the principled assessment design approach (Mislevy, Steinberg, Almond, Haertel, & Penuel, 2003).

We have used an attitude survey we have developed in present projects to assess changes in attitude towards mathematics and other factors related to the interventions (e.g., working in groups, using technology).

Findings / Results

We will present preliminary findings that builds on previous quasi-experimental work that concluded that SimCalc, under certain classroom conditions, can have a significant effect on student outcome measures related to core algebra 1 skills such as linear functions but extended concepts such as understanding slope as rate, working across representations productively and developing skills in conceptual as well as procedural skills in functions and modeling. In addition these skills deeply intersect in statistically meaningful as well as design based methodologies with motivation through mathematically meaningful curriculum designs to structure participation.

Such purposeful design configurations can impact the related impact of learning and motivation as repeatedly measured by our attitude surveys. Our preliminary results in the context of a longitudinal 4-year dataset has the ground to substantiate claims that curriculum established on participatory framework that enhance mathematically meaningful engagement as outlined earlier can impact more latent desires in high school students across various performance backgrounds such as attitude and motivation to want to learn mathematics.

We present how the intervention effect of SimCalc is distributed over initial conditions. We have discovered how even though there is an intervention effect over a wide variety of students differentiated by SES, the initial conditions are significant. In analyzing students' self-reports of their confidence (as they entered 9th grade) on pre-algebra and algebra 1 concepts our results illustrated significant differences in terms of their means scores.

We will present disaggregations of our data to show various slices of the hierarchical structure in order to unpack the broader motivational factors (as delimited through various factor analyses) and the nature of the mathematical activities in a collaborative, and representational-rich mathematics classroom. We also wish to comment on methodological lessons learned by our Algebra 1 Pilot study on things to be aware of in cluster-randomized trials with small samples (n=250).

In addition to student outcome data, we have used classroom observation tools, to monitor and get information on how the teachers are using the materials and software and associated feedback in their pedagogy, and their ability in instantiating and facilitating activities for networked classrooms.

We discuss some preliminary analyses that utilize regular daily log data in the form of sparklines (Tufte, 2006) to illustrate how teachers in our experimental conditions differ over time in terms of their self-explained preponderance to focus on procedural vs. conceptual tasks (for example) through high-density data maps.

Conclusions

In time, we aim to produce reports that compare difference gains in students' mathematical ability and attitude scores between treatment and control at scale across our five studies. Our classroom observation data and other qualitative methods will help us develop a detailed description of what is occurring in SCM classrooms, particularly forms of participation, and pedagogical strategies, which will form a series of case studies. We will contrast this with descriptions of traditional practice in our control classrooms. The results of this Research & Development process will be an integrated set of software and curriculum materials with empirical data of the impact they have on students learning and motivation. A secondary source of data (less experimental) will be good insights into professional development on pedagogical practices necessary to implement these materials into mainstream curriculum.

Appendices

Appendix A. References

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Appendix B. Tables and Figures

Existing Materials	Planned Material Development
Algebra 1 - Functions and Their Graphs: Relating Graphs to Events, - Linking Graphs to Tables, and interactive motions, & imported motions - Functions & Families of Functions, Y=MX+B, - Parametric Variation, Slope, Modeling and Solving Equations, Equations and Interpreting Solutions - Modeling and Systems of Equations - Exponential Functions: Growth and Decay - Quadratic Functions, Equations and Graphs	*Algebra 2* - Functions, Equations and Graphs: Direct Variation, Linear Models - Linear Systems: Solving Systems Algebraically, Graphically - Quadratic Functions: Properties of Parabolas, - Translating Parabolas, Factoring - Exponential Functions: Properties, Modeling

Table 1: Materials

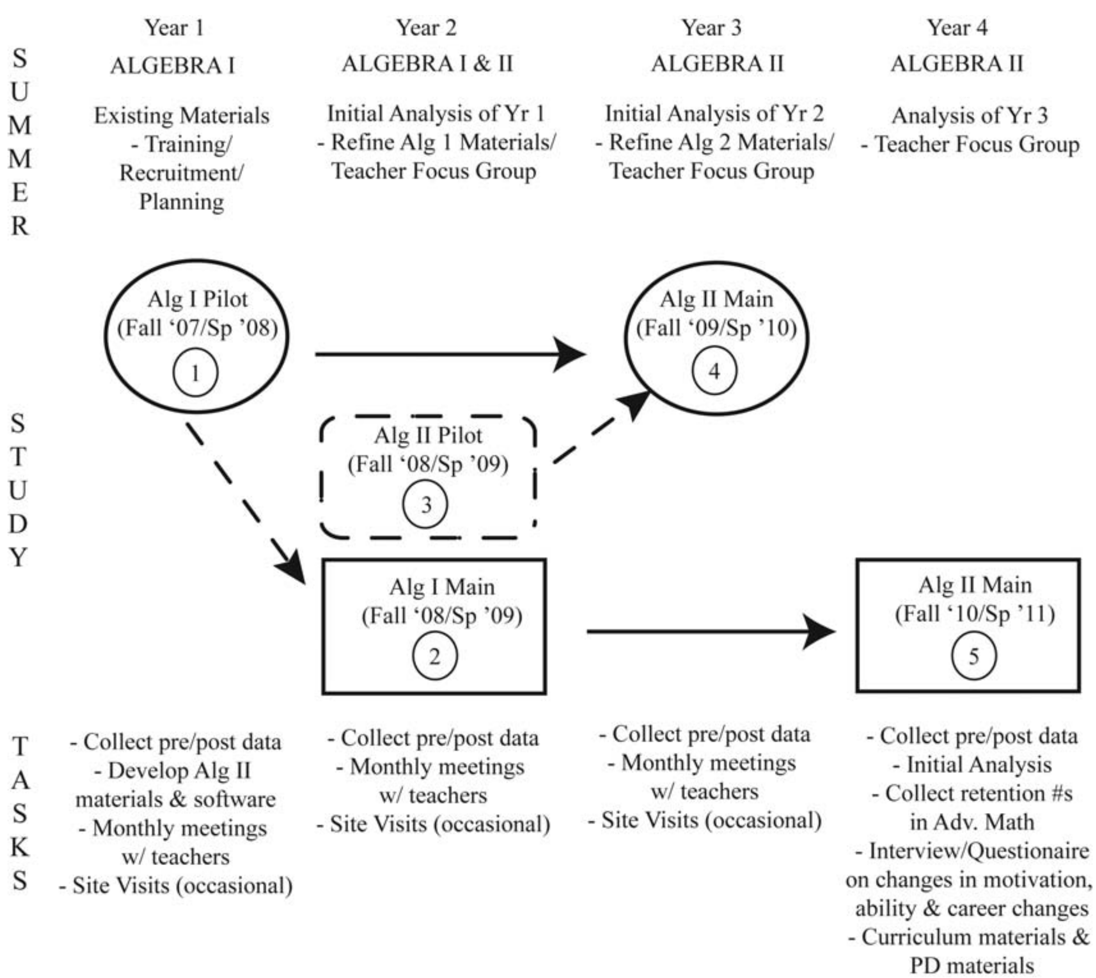

Figure 1. Program of work over the 4 years of the project