Title: Results from a Randomized Trial of Two Algebra Sequences for Underprepared Freshmen

Authors: Ruth Curran Neild, Vaughan Byrnes, and Tracy Morrison Sweet
Abstract

Background/context

One of the aims of the education standards movement is to make intellectually demanding course work the norm in high school. In the area of mathematics, a growing number of states and districts now require that students not only earn an Algebra 1 credit to graduate, but that they take Algebra 1 - or a more advanced mathematics course - during their freshman year. In addition, some large school districts have made earning an Algebra 1 credit a requirement for promotion to 10th grade. There are compelling arguments for enrolling most – if not all – freshmen in Algebra 1. Successful completion of Algebra 1 in the first year of high school places all students on an equal footing, credit-wise, to reap the benefits of advanced mathematics courses in high school.

The painful reality associated with such mandates, however, is that Algebra 1 course failure rates among freshman are typically very high. When Los Angeles required all freshmen to take Algebra 1 in Fall 2004, only 39% of the students earned a C or better in the course and 44% failed (Helfand, 2006). Milwaukee’s “algebra for all” policy resulted in about half of the freshmen failing algebra, on average, over a 7 year period (Ham and Walker, 1999). These and other data suggest that mandates alone – without a more effective instructional approach - will not produce substantially higher percentages of disadvantaged students who are “college ready” and may actually accelerate the high school dropout rate as numerous students become discouraged over their prospects of earning the credits needed for graduation.

A large part of the reason for the dismal Algebra 1 results in cities like Los Angeles is that most first-time freshmen in public schools in these districts are seriously under-prepared to succeed in a rigorous Algebra 1 curriculum if additional supports are not provided. The traditional Algebra 1 course assumes that students have mastered basic and intermediate math skills, including multiplication and division of fractions, decimals, and signed numbers. Students who are below grade level in mathematics, however, struggle to perform operations with rational numbers and integers (National Research Council, 2001; National Mathematics Advisory Panel, 2008). A second area in which many students need extra help is with the transition from arithmetic to mathematics. One of the central TIMSS findings is that the mathematics curriculum in U.S. schools is highly repetitive and remains strongly focused on arithmetic between the 4th and 8th grades. Students in the US are taught fewer advanced mathematical topics in 7th and 8th grade than are students in higher achieving nations (Schmidt et al., 1999). As a result, the learning curve in high school mathematics can be very steep. A perusal of the leading algebra textbooks used in the 9th grade, for example, indicates that many of the texts begin with a rapid “review” of probability, proportional reasoning, measurement, data, and geometry - topics that large numbers of students, according to TIMSS data, have had limited opportunity to learn in middle school.

One of the strategies used by districts with large percentages of freshmen who are underprepared for Algebra 1 is “double dosing.” Double-dose classes allow for approximately 70-90 minutes of instruction in a subject per day, throughout the school year. The idea behind the double dose is that additional time spent on mathematics in the ninth grade provides an opportunity for students to catch up on intermediate skills and/or to proceed through algebra at a slower pace, allowing time for extra practice and the clearing up of misconceptions.

Additional class time allowed by the double dose opens the question of what to do with that extra time. There are two primary theories about the sequence of the curriculum. The first
theory, sometimes called “Stretch Algebra” or “Algebra 1A/1B,” is that students should begin to study algebra from the beginning of the course, stopping throughout the course to backfill on intermediate skills as when the teacher observes that review is needed. The second theory is that students should take a structured “catch up class” during the first semester, followed by Algebra 1 during the second semester.

Research questions
The research compared the impacts on student achievement and credit accumulation of the two curriculum sequences described above (“Stretch Algebra” v. “catch up/Algebra 1”), for freshmen who entered high school between 1 and 4 years below grade level. The “catch up/Algebra 1” strategy was operationalized as a sequence of the Transition to Advanced Mathematics (TAM) curriculum, developed by the Johns Hopkins University Center for Social Organization of Schools, followed by an Algebra 1 curriculum of the school’s choosing. The TAM curriculum is described in more detail in a subsequent section of this abstract. No specific curriculum was specified for the “Stretch Algebra” strategy; schools were allowed to choose their own scope and sequence as well as materials.

The key research questions were:

1) Are there end-of-course differences in Algebra 1 proficiency between a) those 9th graders who spend time building intermediate skills before taking an Algebra 1, in comparison to b) those who are placed directly into an Algebra 1 class that has additional instructional time built-in? If differences exist, are they large enough to be educationally significant?

2) Are there mid-year differences in growth in intermediate mathematics skills and mathematical reasoning between students in the two conditions? To what extent can end-of-course Algebra 1 proficiency be attributed to gains in intermediate skills and reasoning acquired during the first semester?

3) Are there differences between students in the two conditions in credit accumulation in Algebra 1 and in course grades (of C or better) that would indicate potential for success in future mathematics classes?

Setting
A multi-district randomized trial took place in eight school districts during the 2008-2009 school year and five additional districts during the 2009-2010 school year. These districts are medium to large districts with at least two high schools each serving a minimum of 75 first-time freshmen who are taking Algebra 1 but are underprepared in mathematics. The districts are located in the Northeast, South, Southwest, Midwest, and West.

Participants
Forty-eight schools in thirteen districts have participated in the study. Overall, 133 teachers and about 5,000 students participated in either 2008-2009 or 2009-2010.

Intervention
Within each district, schools were randomly assigned to implement either the Stretch
Algebra or the TAM/Algebra 1 sequence. Districts with two participating schools had one Stretch Algebra school and one TAM/Algebra 1 school; districts with four participating schools had two Stretch Algebra schools and two TAM/Algebra 1 schools; and so on. Each participating district had at least two schools in the study; the maximum number of schools was six. As part of the study, each school implemented their assigned condition for a single year.

Each district selected its own Algebra 1 text, materials, and scope and sequence for Stretch Algebra. The relative emphasis of the Algebra 1 courses varied in part as a result of state standards and the specificity of Algebra 1 courses of study.

Each TAM/Algebra 1 school received all curriculum and classroom materials necessary for implementing the TAM course (Algebra materials were of the district’s choosing). The TAM curriculum contains a sequence of lessons, and each lesson is tightly outlined, though not scripted. The 90 minute class period is broken into a consistent series of routines that include segments of teacher directed instruction, partner and small group interaction, and individual work and practice.

The curriculum was developed by teachers and others who have deep, firsthand knowledge of the conditions for teaching mathematics in urban high schools. The curriculum is tightly scripted because many experienced teachers do not have a good sense of how to make the best use of classes of 70-90 minutes, and because it is not uncommon for the most inexperienced teachers to be assigned to the ninth grade. In addition, TAM students receive consumable workbooks that contain all the problems and exercises and explorations they are asked to do, as well as explanatory text and examples. This is because copiers and copy paper are often in short supply in urban schools. Each TAM/Algebra 1 teacher receives a complete set of teaching materials, including a teacher manual, all of the materials needed for the course (ranging from paperclips to string to algebra tiles), and a class set of white boards for students, because teachers cannot assume that resources will be available to purchase classroom supplies.

The TAM curriculum was developed and field tested over a period of ten years prior to the start of this randomized field trial. The recognition for the need for such a “catch-up” curriculum came from the developers’ deep experience with struggling urban high schools and on-the-ground work with teachers at these schools who were charged with helping students to master algebra. Preliminary data, using less rigorous methods, had suggested that there might be a positive impact of the TAM curriculum on student achievement. For example, MDRC’s evaluation of the Talent Development program found impacts in 9th grade credit accumulation that were especially striking in Algebra. The impacts, in terms of differences in percent passing Algebra 1 between the Talent Development and demographically similar control schools, ranged between 17 and 30 percentage points. In Talent Development schools, the percentage of students passing Algebra 1 approximately doubled (to over 60%) between the baseline (pre-implementation) period and the implementation phase (Kemple, Herlihy, and Smith, 2005). A small-scale, non-randomized study in Baltimore found an effect size for TAM of .18; a similar comparison in Philadelphia showed an effect size of .52 (Balfanz, Legters, and Jordan, 2004).

Teachers implementing the TAM/Algebra 1 condition received several days of professional development on the curriculum, prior to the start of school. Teachers also met four additional times each semester to preview the upcoming course sub-units. The study provided a classroom coach for the entire year, whose responsibility was to interact with each TAM/Algebra 1 teacher for the equivalent of two class periods per week.

Stretch Algebra teachers also received study-provided professional development (on curriculum mapping) at the beginning of the school year, as well as professional development on
instructional strategies throughout the year, as requested by the district. The study did not support a coach for the Stretch Algebra condition.

**Research Design**

The overall research design is a multi-site cluster randomized trial. Within districts, schools were randomly assigned to implement either the Stretch Algebra or the TAM/Algebra 1 condition. Each district participates in the study for a single year, during which relevant data are collected.

**Data Collection and Analysis**

There are four key sources of data. First, student achievement data that provide outcomes for research questions #1 and #2, described above, were obtained from nationally normed achievement tests in mathematics. At the beginning of the school year, students took the CTBS Terra Nova test in mathematics (Level 19), as a pre-test of their knowledge of intermediate mathematics. The same test was given again in January, at the end of the first semester, to assess academic growth in intermediate math. To assess their Algebra knowledge, students take the CTB Algebra 1 assessment at the end of their freshman year. As a covariate control for prior Algebra knowledge, we use students’ scores on the Orleans-Hanna Algebra Prognosis Assessment, given at the beginning of the school year.

Second, teacher and student surveys given at the beginning and end of the school year provide important information about students’ motivation and experiences in math class, as well as teachers’ prior experience in teaching mathematics, their beliefs about mathematics, and opinions about the usability of the curricula.

Third, classroom observations conducted for each Stretch Algebra and TAM/Algebra 1 teacher twice during implementation (once during the fall semester and once in the spring). These observations provide quantitative and qualitative information about basic fidelity and instructional quality that allow us to conduct exploratory analysis of the context(s) in which one or the other of the curricula produced strong effects.

Fourth, student administrative records provide data on student demographics, prior achievement, and grades in ninth grade mathematics courses.

Missing covariates are imputed using multiple imputation. We fit multi-level models to estimate the impacts of the two conditions on the student outcomes described above. We present our uncontrolled results; results from a two level model with students at Level 1 and school variables (including the treatment variable) at Level 2; and a three level model with students at Level 1, teacher variables at Level 2, and school variables at Level 3. The magnitude and precision of the effects is compared for each of these models.

**Findings / Results**

At the 2011 SREE conference, we will present results from our confirmatory analyses for the thirteen districts that participated in the study. (At the SREE 2010 conference, we presented results for just the initial cohort of 8 districts; this paper will cover all 13 districts). Our analyses of first-year data from the 8 districts indicated that students in the TAM condition had greater gains in intermediate mathematics skills (as measured by the CTBS mathematics assessment) than students in the Stretch Algebra condition. These differences were statistically significant, with an effect size of between .16 and .17, depending on model specification. However, for the first group of 8 districts, we failed to find a statistically significant difference between the
conditions in end-of-year algebra achievement. Moreover, we find that the districts were evenly divided in terms of whether TAM or Stretch students had superior algebra outcomes.

With the addition of a second cohort of 5 districts (so that we can conduct the analysis on our fully-powered set of 13 districts), we find that the unadjusted mean difference between the conditions in intermediate mathematics skills is larger than that of the first 8 districts (with the advantage continuing to the TAM condition). We also observe that the unadjusted mean difference in algebra achievement (for the total group of 13 districts) between the conditions is larger than that of the first group of 8 districts, although possibly not statistically significant and probably not large enough to be educationally meaningful.

We also observe that first semester grades in mathematics for TAM students are statistically significantly higher than those of Stretch Algebra students, and second semester grades in mathematics are somewhat higher for TAM students. There also are small differences in attitudes toward mathematics, although the statistical significance and magnitude of the difference fluctuates depending on the model specification.

We are in the process of modeling these five outcomes for the full group of districts with proper specifications so that we can present the definitive results at the SREE conference.

Conclusions

This study involved a large-scale randomized trial of a curriculum that had been developed and field tested over a period of ten years. Revisions were made based on teacher input about the organization of the curriculum and success of particular lessons and activities. The recognition for the need for such a “catch-up” curriculum came from the developers’ deep experience with struggling urban high schools and on-the-ground work with teachers at these schools who were charged with helping students to master algebra.

Our conclusions from initial analysis of the first year of data from the randomized trial are that students in the TAM/Algebra 1 sequence substantially outgained the Stretch Algebra students in intermediate mathematics and performed as well on a test of Algebra knowledge. Our initial analyses from the full set of districts suggests similar outcomes, with a slightly greater advantage accruing to the TAM condition when we use the full data set as opposed to the first 8 districts only.

These findings suggest that there are impacts of the TAM curriculum on intermediate mathematics, but that there are no clear-cut algebra impacts from using one curricular strategy or another. If time permits, we will highlight classroom, school, and district conditions under which there were differences in algebra achievement.
Appendices

Appendix A. References


