Algebra for All? An Evaluation of Academic Achievement of College and Tech Prep Students

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Paper presented at the annual meeting of the American Educational Research Association, Chicago, IL., April 10, 2007.

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Abstract

"Algebra for everyone" has been a popular reform, though not commonly implemented and not fully evaluated. Through investigation, one might be able to determine whether courses deemed equivalent to a traditional college preparatory algebra course provide an equitable understanding of algebra concepts and skills, while controlling for variables that have an impact on learning like prior mathematics achievement. No matter what algebra course was attempted, the State of Georgia required all students to sit for the same state-mandated assessment at the end of their course sequence. Results showed that tech prep students taking applied algebra slightly outperformed college prep students taking the traditional algebra one year course, controlling for prior mathematics skills and demographic variables (ethnicity and gender).

Algebra for All? An Evaluation of Academic Achievement of College and Tech Prep Students

In their Agenda for Action, the National Council of Teachers of Mathematics (1980) recommended “more mathematics study be required for all students and a flexible curriculum with a greater range of options be designed to accommodate the diverse needs of the student population.” (p. 1) A few years later, the National Commission on Excellence in Education (1983), published A Nation at Risk, in which they reported a nation-wide decline in academic achievement scores, an increase in college remedial mathematics courses, and demands by employers for more highly skilled employees. To provide guidance for increasing mathematics achievement, the National Council of Teachers of Mathematics (2000) claimed all students should learn algebra, "Algebraic competence is important in adult life, both on the job and as preparation for postsecondary education" (NCTM, 2000, p. 37).

One goal of this study is to research the effect of algebra course taking on students’ achievement. Gamoran and Hannigan (2000) claimed that "algebra for everyone" has been a popular reform, though not commonly implemented and not fully evaluated. Through investigation, one might be able to determine whether courses deemed equivalent to a traditional college preparatory algebra course provide an equitable understanding of algebra concepts and skills, while controlling for variables that have an impact on learning like prior mathematics achievement.

The importance of learning algebra

Silver (1995) considered algebra a “gatekeeper course”, which opens or closes doors of opportunity for many students. This conceptualization supported Taylor’s (1989)

belief that a lack of algebra knowledge limits one's choices for further education and careers. Researchers (Finn, 1997; Goycochea, 2000) and reporters (Fields, 1997; Kollars, 2000) viewed algebra knowledge as necessary for the opportunity to attend college and to attain more than marginal employment. Checkley (2001) talked with Civil Rights activist Robert P. Moses, who has been involved with the development of the Algebra Project. Moses, like Ladson-Billings (1997), asserted that algebra knowledge provides access to higher-level mathematics, which can mean increased educational and economic opportunities for students.

Colleges and universities have expected students to have algebraic knowledge, beginning with Harvard demanding algebra course taking as a requirement for admission in 1820 (Rachlin, 1989; Willoughby, 2000). Fey (1989) stated, "The most convincing reason for making algebra the core of high school math is because of its contribution to problem solving in nearly every scientific discipline" (p. 207).

Alternatives to Algebra One

The federal government gave support for the development and implementation of Technical preparatory (tech prep) programs in secondary schools by passing of the *Carl D. Perkins Vocational and Technology Act Amendments of 1990*. Tech-prep programs of study combine academic and vocational training through the application of skills. Application courses are available for students in the areas of mathematics, social studies, science, and language arts.

In the early 1990's, Georgia's curriculum leaders designed and implemented two Applied Mathematics courses, described as hands-on laboratory courses. The Georgia Board of Education (GBOE) deemed completion of the two courses as equivalent to

traditional Algebra One. For the two-year sequence, teachers used materials developed by the Center for Occupational Research and Development (CORD).

The CORD materials were intended to provide students with the same or greater skills than students completing a traditional college prep algebra course (Tanner & Chism, 1996, p. 316). CORD designed their materials for students performing in the middle 50% (mathematics performance in the 26^{th}-75^{th} percentile), emphasizing the application of mathematics and problem solving skills.

The Equity Principle

To address the need for all students to achieve, the NCTM claimed, "The social injustices of past schooling practices can no longer be tolerated". (NCTM, 1989, p. 4) Due to the under-representation of women and minorities in mathematical and technological careers, they stressed the equity of mathematical knowledge as an economic necessity. (p. 4) The NCTM's proposal of a core curriculum (Standards) for all students intended to provide equal access to the same curricular topics. (p. 131) The NCTM explained further that they were not suggesting,

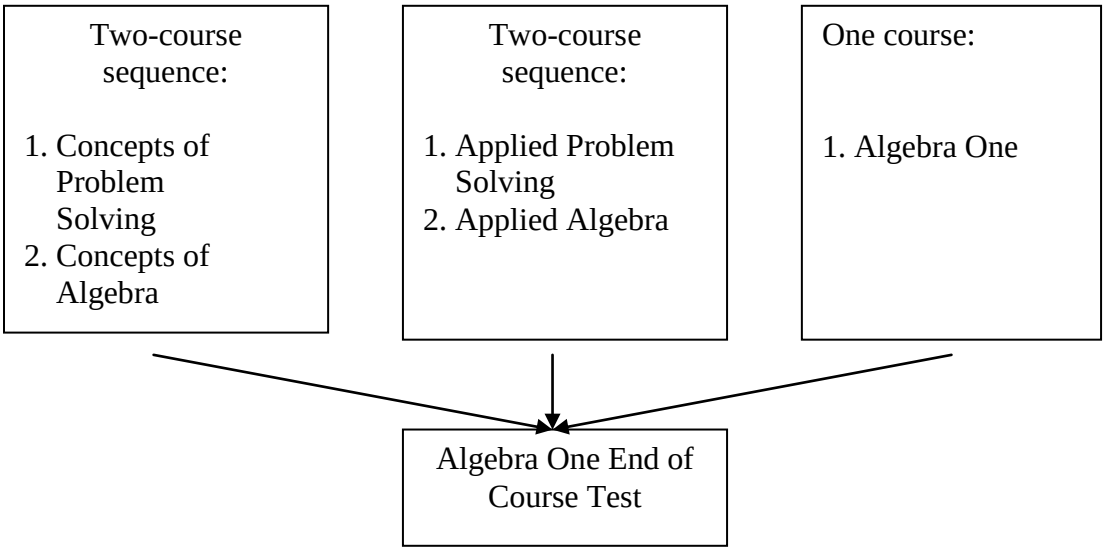
> that all students should explore the content to the same depth or at the same level of formalism. The curricular topics we propose may each be further and quite naturally subdivided and their associated content developed at several levels, consistent with students' ability to abstract." (p. 131)

The *No Child Left Behind Act of 2001*, the Equity Principle in the NCTM's *Principles and Standards for School Mathematics* (2000), and the Principle of Academic Integrity of the *Georgia Framework for Learning Mathematics and Science* continue the call for the equity of educational opportunities for all students. In 1987, Oakes claimed,

"If the low track placements served to prepare disadvantaged students for success in higher tracks and lead them to future educational or post-secondary opportunities, we would not likely question the need for them." (p. 137).

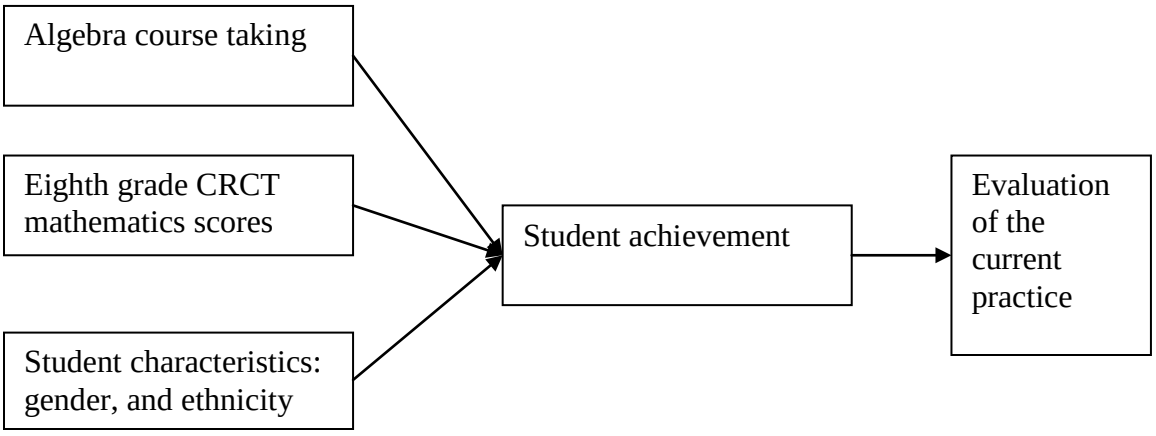
Figure 1 shows the possible ways for Georgia's students to earn algebra credit toward graduation.

Figure 1. *Course sequences for meeting Georgia's algebra requirement for graduation.*



Source: Terry (2005)

Figure 2. *Conceptual framework.*



Source: Terry (2005)

Should all students take the Algebra One, the college preparatory course?

Chambers (1994) called for the elimination of tracking, thereby forcing all students to take college preparatory courses as a way to respond to the inequity of academic opportunities for all students. However, Gamoran (1987) said, "One cannot simply thrust all students into advanced courses and expect their achievement to rise" (p. 152). If students are placed into advanced courses, there could be negative side effects, especially if rates of failure in courses increase. Failing courses have negative impacts for students such as delaying or preventing graduation, to mention two pertinent possibilities.

The acquisition of algebra knowledge has been investigated due to claims of high failure rates. Silver (1995) claimed that failure rates in algebra courses were commonly 40% to 50%; however, Peele (1998) suggested the failure rate in beginning algebra was consistently 25% to 45%. Clopton and Evers (2003) speculated whether a lack of mathematics prerequisites was the strongest predictor of algebra failure. Other mathematics educators and researchers (Kieran & Wagner, 1989) wondered if the problem with learning algebra was due to the content, the learning, or the instruction. Studies have shown that, although not all students pass courses in algebra, most or all seem to benefit by the exposure to an algebraic way of thinking (Chaney, Burgdorf, & Atash, 1997; Clement & Green, 1999; Gamoran & Hannigan, 2000; Goodlad & Oakes, 1988; Roth, Crans, Carter, Ariet, & Resnick, 2000/2001).

A concern of Gamoran and Hannigan (2000) was that special versions of algebra classes would be dead-end courses and would not transition students to other college prep courses (p. 257). Whitmire (1997) claimed that algebra-equivalent courses replaced the remedial and general mathematics courses previously taken by the lower-achieving

students, and that teachers perceived the courses to be an improvement although they were not as rigorous as the college preparatory courses.

Fourteen years after the implementation of the algebra equivalent courses, we believed that the following questions were important:

1. Did students at XYZ High School achieve Georgia's goal of algebra knowledge for all students?

- Was there a difference in algebra achievement on the Algebra One EOCT attributable to students' taking the various algebra course tracks?
- If such a difference was found, did the effect for algebra course taking hold up with statistical controls for ethnicity, gender and prior mathematics knowledge?

Methods

Participants

Participants came from one rural school district in south Georgia. The district has one high school. Students completing an algebra course sequence at the high school in May 2006 constituted the population of students meeting the eligibility requirements for participation in the study. An estimated 463 students were eligible to participate. Data was collected on 448 of those students (97%). The main reason for non participation in the study was lack of information on the required end-of-course test (EOCT). Data on the 8^{th} grade mathematics component of the state mandated assessment was available on 340 students.

Quantitative methods were used to test the hypotheses. Administrative data was collected on the algebra course taken (concepts of algebra, applied algebra [the tech prep

courses] or algebra one [the college preparatory course]), performance on the state-mandated required algebra EOCT, prior knowledge of mathematics (the state mandated assessment in 8th grade mathematics) and demographic variables (ethnicity and gender).

Course taking was considered a treatment in a quasi-experimental design (Cook & Campbell, 1979; Shadish, Cook & Campbell, 2002). The outcome variable was performance on the state mandated EOCT. Covariates for prior mathematics knowledge, ethnicity, and gender were introduced to control for differences between participants independent of the particular algebra course taken.

To test these hypotheses a one-way ANOVA was estimated for a simple model and multiple regression equations for multivariate models. Eighth grade Criterion Referenced Competency Test (CRCT, Georgia's 8th grade state mandated assessment) scores were used as a covariate to control for prior mathematics knowledge. The researchers chose the conventional $\alpha = .05$ level of significance as the criterion to establish support or lack of support for the hypotheses tested (Huck, 2000, p. 187). The study was approved by the home institution's Institutional Review Board (IRB), and the school district.

Unstandardized regression coefficients were presented in all multivariate tables for the convenience of the reader. Unstandardized regression coefficients were calculated in the metric of the dependent variable (scaled score for EOCT). We thought that some less technically inclined readers might have a more intuitive understanding of the size of the estimated regression coefficients with points than standard deviation units, the metric of standardized beta coefficients.

End of Course Test scale. For this study, performance on the Algebra One EOCT is reported as a score ranging from 0 to 100. A score of 70 or higher indicated that a student met the EOCT standard and passed the test.

Results

Univariate results

One hundred and six students were enrolled in Concepts of Algebra, 130 in Applied Algebra, and 212 in Algebra One. The mean score on the Algebra One EOCT was 76.6 with a standard deviation of 12.8. Scores on the EOCT ranged from 44 to 94, with the lowest quartile including scores from 44 to 66. Scores in the second quartile ranged from 67 to 76, while the third quartile contained scores from 77 to 89, and the fourth quartile included scores from 90 to 94.

The univariate distribution of the sample is described in Table 1, which shows the distribution of the sample with regard to the dependent and independent variables.

Table 1.

Univariate distribution of variables in model.

	Score distributions		
	Mean	Std. Dev.	N
EOCT scores	76.7	12.8	448
CRCT scores	313.2	33.1	340

	Course Enrollment			
Course	Concepts of Algebra	Applied Algebra	Algebra One	Total
	106	130	212	448

	N	Percent
Gender		
Male	226	50.4%
Female	222	49.6%
Ethnicity		
African American	137	30.9%
Hispanic	44	9.8%
White, non-Hispanic	263	52.2%

Table 2 shows the relationship between type of algebra course taken and whether the student passed the EOCT. Sixty-five percent of the students passed the EOCT, as shown in Table 2. Fifteen percent of those students taking the concepts of algebra course passed the ECOT, compared to 84% of those students taking the algebra one course, a 69% difference. These differences were statistically significant ($\chi^2 = 151.4$, df = 2,

p<.001). The effect size, w, equaled .34, a moderate effect size per Cohen's (1988) criterion. We note here that there was a considerable difference in the pass rate on the EOCT between the two Tech Prep courses. Students taking Applied Algebra passed the EOCT at a higher percentage (74) than students taking the Concepts course (15).

Table 2

Did student pass Math EOCT by algebra course taken

			Course Title Taken			
			Algebra I	Applied Algebra	Concepts Algebra	Total
Did student pass Math EOCT	Failed	Count	35	34	90	159
		% within Course Title Taken	16.5%	26.2%	84.9%	35.5%
	Passed	Count	177	96	16	289
		% within Course Title Taken	83.5%	73.8%	15.1%	64.5%
Total		Count	212	130	106	448
		% within Course Title Taken	100.0%	100.0%	100.0%	100.0%

Table 3 presents the performance of students on the EOCT by the three different algebra courses. The dependent variable is the student score on the ECOT. Two dummy variables account for the Algebra One and Applied Algebra sequence. Student performance in the concepts of algebra course is the reference category and estimated by the constant term. Students in the concepts of algebra course averaged a 62.6 on the EOCT. Students taking the Applied Algebra course averaged a 79.1, and students taking the Algebra One sequence averaged an 82.2. The differences between the type of algebra course taken and performance on the EOCT were statistically significant at the p <.001 level and the overall equation explained 39 percent of the variance.

Table 3

Performance of students in the Algebra EOCT course by three different types of classes

Coefficients(a)

Model	Unstandardized Coefficients		t	Sig.
	B	Std. Error		
(Constant)	62.594	.977	64.041	.000
Took algebra1	19.599	1.197	16.372	.000
Took applied algebra	16.529	1.317	12.551	.000

Table 4 includes the variables in Table 3 (the Algebra One and Applied Algebra course), plus statistical controls for; gender [coded such that "1" indicates female and "0" indicates male], ethnicity of student [two dummy variables coded such that a code of "1" indicates African-American and "0" indicates not African-American, and a code of "1" indicates a person identifying as Hispanic, and "0" indicates a person not identifying as Hispanic.] Lastly, a student's performance on the state mandated 8th grade mathematics assessment accounted for subject knowledge prior to taking an algebra sequence.

Algebra Course Taking Variables

Table 4 shows that students taking algebra one sequence scored, on average, 11.1 points higher on the EOCT test than those taking the concepts course, and students who took the Tech Prep applied algebra course scored, on average, 12.4 points higher than those taking the concepts course, when controlling for the other variables in the model and those differences were statistically significant.

Background Variables

Table 4 also shows that females performed slightly worse than males, and Hispanics performed slightly better (1.9 points) than White, non-Hispanics, controlling for the other

variables in the model. However, neither of these two variables had a statistically significant relationship with performance on the EOCT. African-Americans on average scored 3.8 points lower than White, non-Hispanics, a statistically significant difference controlling for the other variables in the model. Additionally, there was a strong, positive and statistically significant effect between score on the 8th grade state mandated mathematics assessment (CRCT) and EOCT. For every ten point increase on the 8th grade state mandated assessment in mathematics, performance on the EOCT was predicted to increase by 1.37 points. R-squared, a measure of overall effect size for the equation was .49.

Table 4

Performance of students in the Algebra EOCT exam by three different types of courses, controlling for gender, ethnicity, and prior mathematics knowledge.

Model	Unstandardized Coefficients		t	Sig.
	B	Std. Error		
(Constant)	26.668	5.973	4.465	.000
Took algebra1	11.139	1.747	6.376	.000
Took applied algebra	12.429	1.563	7.950	.000
Gender	-.821	.983	-.835	.404
African-American	-3.770	1.181	-3.194	.002
Hispanic	1.923	1.819	1.058	.291
CRCT Math	.137	.020	6.710	.000

Matched Pairs Design

In an attempt to highlight the relationship between prior mathematics knowledge, course taking, and passing the algebra EOCT, a matched pairs design was estimated. Students scoring 300 or above on the 8th grade state mandated mathematics test were said to have met expectations in math by the State of Georgia. Students scoring 299 or below on the 8th grade state mandated mathematics test were said to have not met expectations in math by the State of Georgia. Table 5 showed the results for students between course taking and passing the EOCT

for those students not meeting expectations on the 8th grade mathematics assessment. Overall 25% of students not meeting expectations on the 8th grade mathematics assessment passed the algebra EOCT, but 53% of students taking the applied algebra course did pass the algebra EOCT. Only five students not meeting expectations on the 8th grade mathematics assessment took the algebra one course. Most students not meeting expectations on the 8th grade mathematics assessment took the concepts course, and only 12% of those students passed the algebra EOCT. The overall relationship was statistically significant (χ^2=18.47, df=2, p<.001). The effect size, w, equaled .44, a moderate effect size per Cohen (1988).

Table 5

Students whose eighth grade mathematics skills were below state standards by type of algebra course taken

			Course Title Taken			
			Algebra I	Applied Algebra	Concepts Algebra	Total
Did student pass algebra EOCT	Failed	Count	4	14	53	71
		% within Course Title Taken	80.0%	46.7%	88.3%	74.7%
	Passed	Count	1	16	7	24
		% within Course Title Taken	20.0%	53.3%	11.7%	25.3%
Total		Count	5	30	60	95
		% within Course Title Taken	100.0%	100.0%	100.0%	100.0%

Table 6 showed the results for students meeting expectations on the 8th grade mathematics assessment. Only 33% of the students taking the concepts course passed the algebra EOCT when their prior mathematics skills prior mathematics skills met state standards, albeit with a small number of cases (n=6). However, an equal percentage of students in algebra one and applied algebra (86%) passed the EOCT when their prior mathematics skills met state standards. The

overall relationship was statistically significant (χ^2=12.29, df=2, p<.01). The effect size, w, equaled 0.22, a small effect size by Cohen's (1988) criterion.

Table 6

Students whose eighth grade mathematics skills were above state standards by type of algebra course taken

			Course Title Taken			
			Algebra I	Applied Algebra	Concepts Algebra	Total
Did student pass algebra EOCT	Failed	Count	25	9	4	38
		% within Course Title Taken	14.1%	14.5%	66.7%	15.5%
	Passed	Count	152	53	2	207
		% within Course Title Taken	85.9%	85.5%	33.3%	84.5%
Total		Count	177	62	6	245
		% within Course Title Taken	100.0%	100.0%	100.0%	100.0%

Discussion

As adjustments are made for course-specific testing, the question of how teachers and students prepare for the assessments, as well as how students perform on them is of interest to stakeholders. For the first time, teachers and students knew whether the implementation of different algebra curricula is meeting the goal of algebra for all students in Georgia. The results show the algebra curriculum fell short of the goal of algebra for all. The gap in passing rates on the EOCT between the Concepts of Algebra Course and Algebra One was 69%. However, the gap in passing rates on the EOCT between the Applied Algebra and Algebra One was narrower, only 10%. Even after controlling for prior knowledge in mathematics and background variables (ethnicity and gender), we find that students taking Algebra One score 11 points better than their

counterparts taking the Concepts sequence but one point worse than tech prep students taking the applied algebra sequence. The disparities in the performance of the applied algebra and concepts tech prep courses can be partially explained by the recommendations by the State of Georgia that students in the bottom quartile were recommended to take the Concepts course (1st-25th percentiles), students in the two middle quartiles were recommended to take the Applied Algebra course (26th-75th percentiles), and students in the top quartile were recommended to take the college prep course (76th-99th percentiles). After controlling for prior math knowledge, we find that those students taking the applied algebra course were able achieve at slightly higher level than the college prep courses. The applied algebra results show that students taking a two year tech prep course can achieve algebra knowledge at about the same level as the college prep course, especially when differences in prior mathematics knowledge is controlled. The concepts of algebra tech prep results show that students taking this tech prep course don't achieve algebra knowledge at near the same level as the college prep course or the applied algebra tech prep course, even after controlling for prior mathematics knowledge. One recommendation from this research would be to consolidate the two tech prep courses into one, and eliminate the concepts course.

Our analysis shows that it is not necessary for all students to take the college preparatory algebra course to learn algebra. The tech prep applied algebra students learned the same amount of algebra, when prior mathematics skills were controlled. Granted, it took the applied algebra tech prep students two years to learn what the college preparatory students learned in one year, but they were able to achieve at about the same level as their college prep peers.

Based on Gamoran's analysis, we would recommend an analysis of student grades before recommending all students take the college preparatory algebra course. A failing grade has negative consequences to a student; the student may need to make up the lost credit in summer school, or be forced to delay graduation. An analysis of failure rates in algebra courses would help shed some light on an important potential negative side effect of putting all students in advanced classes.

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