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The Core Plus Mathematics Project and High School Students' Mathematics Achievement

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THE CORE PLUS MATHEMATICS PROJECT
AND HIGH SCHOOL STUDENTS' MATHEMATICS ACHIEVEMENT

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AND HIGH SCHOOL STUDENTS' MATHEMATICS ACHIEVEMENT

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ABSTRACT

The purpose of this study was to investigate the effects of the Core Plus Mathematics Project in terms of raising students' mathematics achievement. The study utilized Iowa Test of Educational Development (ITED) mathematics score data for 454 minority and low-income students. An Individual Growth Model revealed that Core Plus participants' initial status was statistically significantly higher than their traditional counterparts. Over a three-year period, Core Plus participants' total ITED mathematics score growth decelerated significantly. However, the Core Plus participants remained slightly higher than the traditional students at the end of the three-year period. The study recommends use of other measures of student learning outcomes beyond the ITED to determine the effectiveness of Core Plus among diverse groups of students.

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CHAPTER I

INTRODUCTION

Introduction

In recent years there has been a call for mathematics education reform. Primary to this reform has been the National Council of Teachers of Mathematics (NCTM). They have advocated a standards-based approach to mathematics education, focusing on a core of study for all students. This approach highlights the connectedness between mathematics concepts and emphasizes the process of thinking and doing mathematics rather than following a set procedure. After NCTM released its *Standards* document (NCTM, 1989), the National Science Foundation gave out several grants to develop curricula that reflect the intent of the standards. One such curriculum is the Core Plus Mathematics Project.

Core Plus focuses on conceptual understanding, using an integrated approach over three or four years. Instead of the traditional progression of Algebra 1, Geometry, Algebra 2, Core Plus Mathematics simply has Course 1, Course 2, and Course 3, which each incorporate strands of algebra, geometry, statistics and discrete mathematics. Core Plus also has an optional Course 4, aimed at college-bound students, rather than a traditional pre-calculus class. The Core Plus curriculum is taught with a goal of active student engagement, where the teacher acts mainly as a guide and coach, not as the sole provider of knowledge. The

students acquire knowledge by solving mathematical problems set in real-world contexts. Through their exploration, students construct their own interpretations and knowledge of fundamental mathematics concepts.

Problem Statement

This research seeks to understand whether the standards-based, Core Plus approach to mathematics education can foster mathematics achievement as well as, or better than traditional methods. The developers of Core Plus at Western Michigan University have field-tested the Core Plus curriculum in 36 high schools across the country with positive results (Schoen, Hirsch, and Ziebarth, 1998). While they claim to have covered a diverse group of schools (urban, rural, and suburban), the majority of the schools studied do not have a large percentage of minority or low-income students. Therefore, it is unclear if Core Plus will have the same effects on mathematics achievement in all school contexts.

Purpose of the Study

The primary purpose of this study is to look at the impact of using Core Plus in a private, urban high school with a very high percentage of minority and low-income students. The goal of this research is to evaluate the effectiveness of the Core Plus curriculum, in terms of improving students' mathematics achievement. The following research questions will be addressed:

1. To what extent does the initial status of students' mathematics score vary by grade level, gender, ethnicity, or Core Plus involvement?
2. To what extent does the growth rate of students' mathematics score vary by grade level, gender, ethnicity, or Core Plus involvement?

Significance of this Study

Many researchers have begun the task of evaluating the effectiveness of standards-based curricula (Briars & Resnick, 2000; Hill & Parker, 2006; Huntley, Rasmussen, Villarubi, Sangtong, & Fey, 2000; Mayer, 1998; Riordan & Noyce, 2001; Schoen & Hirsch, 2003; Schoen, Cebulla, Finn & Fi, 2003; Schoen, Hirsch, Ziebarth, 1998; Schoen & Pritchett, 1998). Evidence exists that students taught using standards-based methods, including Core Plus, score as well as or better than traditional students in many settings. However, there is also research that suggests they do not fare as well on certain measures. Because of this, more research is needed in specified settings, particularly with urban, minority, and low-income students. This thesis seeks to add another study to the emerging body of research indicating how, when, and where Core Plus is effective.

Delimitations

This study considers mainly minority students – African American and Hispanic – who are of low socio-economic status. It cannot be interpreted as extending to other populations. This study also only considers the effect of the mathematics curriculum on students' mathematics achievement. It does not consider other factors that may affect student learning, such as student motivation. In addition, this study considers only one method of measuring students' mathematical ability, a traditional achievement test. It is necessary to note that one test cannot capture all aspects of students' mathematical growth and a nontraditional, authentic assessment may produce different results.

Limitations

All students at the Core Plus participating school follow the same mathematics track, so it was impossible to randomly assign students to either Core Plus or traditional.

Therefore, comparisons had to be drawn using similar schools. The study was carried out in four small private schools. Hence, the students may not be representative of all low-income, minority students.

CHAPTER II

LITERATURE REVIEW

Both quantitative and qualitative research exists on the Core Plus curriculum. The quantitative research primarily compares student achievement by method of mathematics instruction using standardized tests. The qualitative research has focused on describing student and teacher experiences with Core Plus, particularly their attitude toward and implementation of Core Plus

Measures on Standardized Tests

In order for any mathematics curriculum to be deemed effective, it must be able to show that it helps students acquire higher levels of achievement. This is typically measured on objective, standardized tests. Therefore, the bulk of research done about Core Plus has used one or more of these measures to compare Core Plus to other, more traditional programs (Huntley, et. al, 2000; Hill & Parker, 2006; Schoen & Pritchett, 1998; Schoen & Hirsch, 2003; Schoen, Cebulla, Finn & Fi, 2003; Schoen, Hirsch, Ziebarth, 1998).

National Achievement Tests. Much of the field-testing of the Core Plus curriculum is related to measuring student achievement on a subsection of the Iowa Test of Educational Development, the ITED-Q. This section is a 40-question, multiple-choice test, known as the

Ability to Do Quantitative Thinking. In a study of nearly 1500 students, it was found that “The CPMP [Core Plus Mathematics Project] curriculum appears to have a positive effect on quantitative thinking, as measured by the ITED-Q, with the greatest effect occurring in the first year of CPMP use” (Schoen & Hirsch, 2003, p. 14). This effect held true for all racial groups except African Americans, who showed little growth in year one, but then showed progress. Growth on the ITED-Q was also consistent among locations (rural, urban or suburban), but again with one exception: urban students in Course 1. The apparent lack of progress with urban and African American students in year one may be an anomaly but more likely is due to students dropping out of math classes. “According to teachers in urban schools, the students who did not continue beyond Course 1 were those with the most problems” (p. 13). Therefore it is unclear if urban and African American students have actually made progress in later years or if the lowest achieving students have simply dropped from the data pool.

The National Assessment of Educational Progress (NAEP) has also been used to compare Core Plus students with other students across the country. The NAEP, often referred to as “The Nations Report Card,” is a continuous assessment given to students across the country in grades 4, 8 and 12. Using the twelfth grade data, Schoen, Hirsch (1998) found that Core Plus students scored significantly higher in all areas of the NAEP. However, it is important to note that the control sample included a representative sample of over 8000 students from across the United States. The Core Plus sample is much smaller and may not be comparable in terms of background, especially with urban and minority students.

Researcher-developed tests. Researchers have sought to develop their own tests to pinpoint exactly where the differences in mathematical knowledge lie between Core Plus and

traditional students. Huntley et. al. (2000) looked specifically at students' algebra skills and found that "CPMP students perform better than control students when setting up models and solving algebraic problems presented in meaningful contexts while having access to calculators, but CPMP students do not perform as well on formal symbol-manipulation tasks without access to context clues or calculators" (p. 349). Schoen and Hirsch (2003) found similar results using a different instrument, again underscoring that while conceptual understanding is better with Core Plus students, procedural competency is the same or worse than with traditional methods.

College Entrance Examinations. The Scholastic Aptitude Test (SAT) and American College Testing Assessment (ACT) are two tests generally used by colleges as one factor in college acceptance. These tests are typically taken in a students' junior year. Schoen and Hirsch (2003) found that Core Plus students' scores on the ACT and SAT did not differ significantly from those in traditional settings.

College Placement Tests. An effective high school mathematics curriculum must promote student success beyond high school. Schoen and Hirsch (2003) gave students a college placement test from a major university. In terms of algebra, they found the Core Plus students to be essentially the same as traditional students. However, in terms of calculus readiness questions, Core Plus students scored significantly higher. These results are in contrast to a study conducted at Michigan State University. There it was found that all but the very top Core Plus students scored lower on placement tests, took fewer math classes, and earned poorer grades than their counterparts from traditional high school curricula (Hill & Parker, 2006). It is crucial to point out that the study at Michigan State does not differentiate between students who completed Core Plus Courses 1 through 3 versus those

who completed Courses 1 through 4. The Schoen and Hirsch study takes into consideration only students who have completed all four courses, as is recommended for college preparation. Therefore, the differences between the studies may be due in part to the amount of high school math completed by the participants.

Student Perceptions

Beyond test scores, it is also important for the success of a program that students embrace it. Schoen and Pritchett (1998) surveyed current high school students in Core Plus and found that they were generally more positive about their math experiences than their traditional counterparts. They had more confidence, felt they were better able to reason mathematically and talk and write about math. They also found their courses to be just as challenging as traditional college-prep classes, but more interesting.

Implementation

Because Core Plus is not yet widely used, all of the aforementioned studies have a limited number of participants and therefore the conclusions present may be influenced by the quality of the teaching that is taking place at the school rather than the method of the teaching. Using Core Plus books does not guarantee adherence to its credos. Teachers' adherence to the curriculum materials has been shown to correlate with high students' achievement (Arbaugh, Lannin, Jones, & Park-Rogers, 2006; Briars & Renick, 2000; Schoen & Hirsch, 2003). Schoen and Hirsch also found that high quality reform teachers use "more small-group work, much less teacher presentation, somewhat less whole-group discussion, and somewhat more students presentation than teachers with lower achieving students" (p. 247).

CHAPTER III

RESEARCH METHOD

Subjects

The students in this study came from four high schools, each in a major Northeastern or Midwestern, urban city. The schools are all a part of the same network, which specifically recruits low-income, minority students who are college-bound. In order to qualify for admission, students must have demonstrated financial need. Each of the schools has at least 70% of the students on free or reduced lunch and their populations are over 80% minorities. For the purposes of this study, only students in the eleventh and twelfth grade from each school were used. One of the schools uses the Core Plus mathematics curriculum with the integrated Course 1, Course 2, Course 3 progression. The other schools use traditional textbooks with the class progression Algebra 1, Geometry, and Algebra 2.

Instruments

The Iowa Test of Educational Development was used to measure students' mathematics achievement. The mathematics portion of the ITED can be broken down into two subsections, Concepts and Problem Solving, and Computation. The ITED was

administered to all students at these high schools each fall and was used to measure their academic growth.

Institutional Review Board Approval

The study was submitted to the Cleveland State University Institutional Review Board. Approval was granted to collect the data in March, 2008.

Data Collection

The data were obtained anonymously from a database maintained by the school network. The information accessed included mathematics test scores, grade, gender, and ethnicity. ITED score data for three years, Fall 2005, Fall 2006, and Fall 2007, were secured for each student in the study.

Data Analysis

Ethnicity data was demi-coded into African American and Other. The ITED scores were standardized into z-scores. Hierarchical Linear Modeling was employed to analyze the students' scores. An Individual Growth Model (Raudenbush & Bryk, 2002) allowed for students' yearly test scores to vary independently from other students, while at the same time yielding comparisons based on method of instruction.

Model Specification

Level-1 (Within Subjects) Model. At level-1 each student's growth trajectory was modeled using his or her standardized ITED mathematics score data. The following equation shows the growth trajectory for student i at time t , where time is in years.

$$MATH_{it} = \pi_{0i} + \pi_{1i}(YEAR_t) + e_{it}$$

$MATH_{it}$ represents the ITED score at time t , for the i^{th} student as a function of his or her growth trajectory plus the random error. π_{1i} is the growth rate per year for the i^{th} student.

π_{0i} is the initial status for the i^{th} student. Three such equations were utilized, one for the total score and one for each of the two ITED sub-scores, Concepts and Problem Solving, and Computation.

Level-2 (Between Subjects) Model. At level-2, the students' mathematics achievement growth is nested within mathematics instruction techniques. This equation models the y-intercept of the level-1 equation as a function of the level-2 characteristics.

$$\pi_{0i} = \beta_{00} + \beta_{01}(Grade_i) + \beta_{02}(Gender_i) + \beta_{03}(Ethnicity_i) + \beta_{04}(CPlus_i) + r_{0i}$$

Here, π_{0i} , the initial status of student i is indicated by grade level, gender, ethnicity and the Core Plus treatment. The regression coefficient β_{00} is the predicted initial status for a typical child. The regression coefficients, β_{01} , β_{02} , β_{03} , and β_{04} , represent the effect of the contribution of grade level, gender, ethnicity, and Core Plus treatment, respectively.

The second level-2 equation models the growth rate per year of each student in terms of the level-2 characteristics. The regression coefficients represent the contribution of grade level, gender, ethnicity and Core Plus treatment on the students' growth.

$$\pi_{1i} = \beta_{10} + \beta_{11}(Grade_i) + \beta_{12}(Gender_i) + \beta_{13}(Ethnicity_i) + \beta_{14}(CPlus_i) + r_{1i}$$

Like the level-1 equations, each of these level-2 equations exists for the three components of the students ITED mathematics scores.

CHAPTER IV

RESULTS

Descriptive Statistics

Subjects were chosen from four urban high schools serving low income, minority students. There were a total of 454 subjects consisting of 285 (63%) female and 169 (37%) males; 102 (23%) were African American students, 252 (55%) were Hispanic students, 57 (13%) were Multi-racial students and 37 (8%) were White students. The subjects included 275 (60%) eleventh graders and 179 (40%) twelfth graders. Of these 454 students, 137 were taught using the Core Plus curriculum, while the other 317 were taught using traditional methods.

Research Question 1

To what extent does the initial status of students' mathematics score vary by grade level, gender, ethnicity, or Core Plus involvement?

Table I shows the results for the initial status (π_{0i}) from the individual growth model. The table shows the regression coefficients for the contributions of grade level, gender, minority status, and Core Plus involvement, for the ITED Total Mathematics score, as well as the subsections of Concepts and Problem Solving, and Computation.

Table I. Individual Growth Model Results for the Prediction of Initial Status (π_{0i})

Predictor	Total ITED Score	Concepts and Problem Solving	Computation
Grade (11 th = 0, 12 th = 1)	0.176	0.137	0.101
Gender (Male = 0, Female = 1)	-0.193	-0.231*	-0.040
Minority Status (Black = 1, Other = 0)	-0.360**	-0.327*	-0.289
Core Plus (Core Plus = 1, Traditional = 0)	0.360**	0.428**	0.062

* p < .05 ** p < .01

Only ethnicity and curriculum were found to have a significant effect ($p < .01$) on the initial status of students on the ITED Total Mathematics score. African American students on average started 0.36 standard deviations below their counterparts. Students using the Core Plus curriculum started on average 0.36 standard deviations above their counterparts in traditional curricula.

For the ITED Concepts and Problem Solving subsection, gender, ethnicity and participation in the Core Plus curriculum were all significant ($p < .05$) predictors of students' initial status. Females started on average 0.231 standard deviations below males. African American students started on average 0.327 standard deviations below their counterparts. Students taught using the Core Plus curriculum started on average 0.428 standard deviations above students in traditional curricula.

In terms of students' initial status on the Computation portion of the ITED, none of the predictors had a significant effect ($p > .05$).

Research Question 2

To what extent does the growth rate of students' mathematics score vary by grade level, gender, ethnicity, and Core Plus involvement?

Table II shows the results for the yearly growth rate (π_{1i}) from the individual growth model. The table shows the regression coefficients for the contributions of grade level, gender, minority status, and Core Plus involvement, for the ITED Total Mathematics score, as well as the subsections of Concepts and Problem Solving, and Computation

Table II. Individual Growth Model Results for the Prediction of Growth Rate (π_{1i})

Predictor	Total ITED Score	Concepts and Problem Solving	Computation
Grade (11 th = 0, 12 th = 1)	-0.066	-0.033	-0.058
Gender (Male = 0, Female = 1)	-0.081	-0.050	-0.129*
Minority Status (Black = 1, Other = 0)	0.002	-0.045	0.046
Core Plus (Core Plus = 1, Traditional = 0)	-0.149**	-0.126	-0.115

* $p < .05$ ** $p < .01$

In terms of students' ITED Total Mathematics score growth, only the use of the Core Plus curriculum factored significantly ($p < .01$). The growth rate of students in Core Plus was decelerated by 0.149 standard deviations per year relative to their counterparts in traditional mathematics curricula.

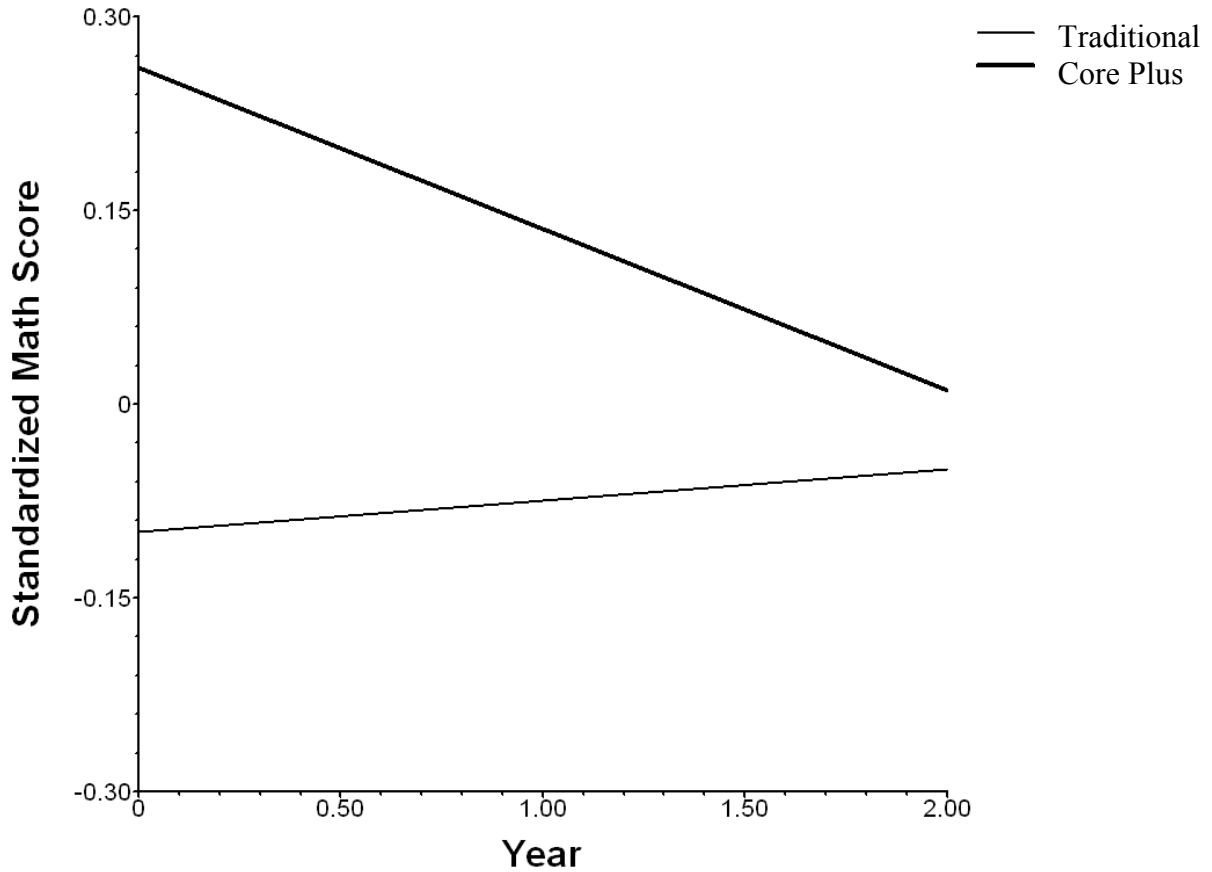
In terms of students' growth rate in the Concepts and Problem Solving subsection, none of the predictors factored significantly. However, the Core Plus curriculum did have the greatest effect, decelerating students' growth by 0.126 standard deviations per year, but this difference was not found to be statistically significant ($p = .062$).

In terms of the Computation subsection, only gender was found to be a significant predictor of growth rate, with female's growth rate decelerating at 0.129 standard deviations per year relative to males. Similar to Concepts and Problem solving, Core Plus did cause a deceleration in students' growth in Computation. Again, however, this deceleration of 0.115 standard deviations per year was not significant ($p = .081$).

Growth Trajectory

Figure 1 shows the initial status and growth trajectories for Core Plus and traditional students in their ITED Total Mathematics score. It can be seen the figure that Core Plus students initially begin higher and then decelerate, while the traditional students initially begin lower and then accelerate. However, it can be seen that at the end of the three-year period, Core Plus students still remain slightly higher than their counterparts.

Figure 1. Growth Trajectories of ITED Total Mathematics Score by Curriculum



Adequacy of the Model.

The adequacy of this model needed to be tested to determine the extent to which the independent variables of grade level, gender, ethnicity, and Core Plus involvement, predict the dependent variable of mathematics achievement on the ITED. The adequacy of the model was determined by looking at the unconditional models, or empty models. This is the variability that exists in the model before considering any independent variables. Table III shows the variation for both the unconditional and conditional models. The within-student variation (σ^2) represents the variance in ITED mathematics achievement of the student from

year to year. The between-student variation (τ) represents the variation in mathematics achievement from student to student. The intra-student correlation (ρ) represents the proportion of variance in the students' ITED scores that can be attributed to the independent variables (Grade, Gender, Ethnicity, and Core Plus involvement).

Table III. Unconditional and Conditional Model Variation

ITED Section	Variation	Unconditional (empty model)	Conditional
Total	within student (σ^2)	.30	.30
	between student (τ)	.68	.66
	intra-student correlation (ρ)	.69	.69
Concepts and Problem Solving	within student (σ^2)	.39	.39
	between student (τ)	.60	.57
	intra-student correlation (ρ)	.60	.59
Computation	within student (σ^2)	.45	.44
	between student (τ)	.55	.53
	intra-student correlation (ρ)	.55	.55

As shown in Table III, the intra-student correlation remains unchanged between the unconditional and conditional model. This suggests that the independent variables alone (Grade, Gender, Ethnicity, and Core Plus involvement) are not adequate at predicting the differences in students' mathematics achievement growth.

CHAPTER V

SUMMARY, DISCUSSION & RECOMMENDATIONS

Summary

The purpose of this study was to investigate the impact of the Core Plus Mathematics Project in terms of raising students' mathematics achievement. An Individual Growth Model was used to determine to what extent students' participation in Core Plus, as well as demographic characteristics, predicted their mathematics growth as measured on the Iowa Test of Educational Development (ITED).

Research Question 1. To what extent does the initial status of students' mathematics score vary by grade level, gender, ethnicity, or Core Plus involvement?

Core Plus was found to have a significant effect ($p < .01$) on students' initial status on ITED Total and the Concepts and Problem Solving subsection. Students in Core Plus started significantly higher than their traditional counterparts. Ethnicity was the only demographic characteristic to make a statistically significant difference, with African American students starting lower than others.

Research Question 2. To what extent does the growth rate of students' mathematics score vary by grade level, gender, ethnicity, and Core Plus involvement?

The growth rate of students in Core Plus on the Total ITED score was statistically significantly decelerated over the three-year period compared to their counterparts in traditional math courses. Gender was the only demographic characteristic to have a significant effect with girls Computation subsection score being decelerated relative to boys.

Discussion

Core Plus Growth. While Core Plus students start higher, their mathematics growth declines while traditional students improve modestly. This decline in growth may have happened for a variety of reasons. First, it could be attributed to the ceiling effect. Because the Core Plus students start higher, they have less reason to grow. Although this is possible, no student maxed out of the ITED score, and thus all could have displayed growth.

Another reason could be because Core Plus does not use a traditional progression, students' eighth grade mathematics coursework may not lead coherently into Core Plus Course 1. This lack of coherence in method or material may leave students with gaps in their mathematical understanding and not address incoming disparities. Alternatively, the lack of cohesiveness could have students repeating knowledge they have already mastered.

Another factor that may affect Core Plus students' growth is a lack of repetition, both within units and within the course as a whole. Core Plus does not believe in repetitious practice problems. Also, because of the integrated nature of the curriculum, a topic may be touched upon in Course 1, but not returned to again until a later course. As a result of this lack of repetition, skills at which students were once proficient may become rusty over time and thus contribute to the decline in growth.

Another reason for the decline in Core Plus students' achievement may be due to the amount of reading required in the textbook. The Core Plus text utilizes a discovery-based

approach, which requires working problems in context and thus requires more reading for the students. Course 1 is designed primarily for ninth grade students and thus it can be assumed that the reading level of the text is appropriate for ninth grade students. However, students may not be at grade level in reading and thus their reading level may prohibit them from succeeding in mathematics.

Model Adequacy. The independent variables investigated in this study were grade-level, gender, ethnicity, and Core Plus involvement. The intra-student correlations did not vary from the unconditional to the conditional model, suggesting that the variance in students' mathematics scores cannot be adequately predicted by the independent variables. Thus the main causes of the variances in mathematics scores between students have yet to be identified.

It is possible that grades students earn in math class play a role in predicting their mathematics growth. Students who excel in classes might be expected to grow more per year than those who do not earn as high of grades, regardless of method of mathematics instruction.

Another factor that could predict students' mathematics achievement would be the special services or level of instruction that students are receiving. Students whose schools track mathematics classes may grow at a faster rate because their classes are tailored more closely the students' needs. Likewise, students who are receiving special services such as an extra remediation class or individual tutoring may see more growth in their mathematics achievement because their individual deficiencies are caught and addressed.

Recommendations for Further Research

The current research indicates that Core Plus is not effective in raising student achievement as compared to other traditional methods. Further research is needed in minority and low-income populations to determine if Core Plus can yield positive results.

Research is suggested in the following areas:

1. Students' reading level. Students who are at or above grade level in reading may find more success with the Core Plus program because they are able to more fully comprehend the contextual math problems.
2. Grades and Attitude. Students who are earning higher grades may be growing faster than their counterparts. Attitude may also play a key role. Schoen and Pritchett (1998) found that Core Plus students tended to be positive about Core Plus. It is possible that students who have more positive attitudes toward Core Plus will exhibit more growth than those who do not value the Core Plus method.
3. Other achievement measures. The current research considered only mathematics achievement as measured by the ITED. Other instruments may be able to identify more specific areas where Core Plus students excel or are deficient. These instruments should include specific mathematics areas and college preparedness measures.

Further research is needed to understand and assess the effectiveness of Core Plus and other reform mathematics curricula in urban and minority populations.

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