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## Reformed and Traditional Mathematics Teaching Approaches: Are They Related to the Mathematics Achievements of U.S. Students across Racial Groups?

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REFORMED AND TRADITIONAL MATHEMATICS TEACHING APPROACHES:  
ARE THEY RELATED TO THE MATHEMATICS ACHIEVEMENTS OF U.S.  
STUDENTS ACROSS RACIAL GROUPS?

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A dissertation submitted in partial fulfillment  
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**Doctor of Philosophy in Teacher Education**

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## THE GRADUATE COLLEGE

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**Qiang Cheng**

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## **ABSTRACT**

### **Reformed and Traditional Mathematics Teaching Approaches: Are They Related to the Mathematics Achievements of U.S. Students across Racial Groups?**

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Promoting problem-solving and reasoning among all U.S. students and closing mathematics achievement gaps across different racial groups have become important foci in the current U.S. mathematics education reform. Framed through three contentious theoretical assumptions underlying reformed teaching, traditional teaching, and culturally relevant pedagogy, this dissertation investigates the relationship between the two kinds of teaching and the relevant mathematics achievements of students across racial/ethnic groups. The study examines specifically such a relationship drawing on U.S. eighth grade data set from the Trend in International Mathematics and Science Study (TIMSS) 2007 and using a two-level hierarchical linear modeling (HLM) approach. Results from the study indicated that reformed teaching is positively and significantly related to Caucasian, African-American, and Hispanic students' overall mathematics achievement, problem-solving and basic skills achievement, but is not related to Asian-American students' three mathematics performance measures. In addition, this study found that the

traditional teaching approach is also positively and significantly related to Caucasian and Hispanic students' overall mathematics achievement, problem-solving and basic skills achievement, but is not related to African-American and Asian-American students' three mathematics performance measures. Results from this study help support the theoretical assumptions in culturally relevant pedagogy and pose challenges to the assumptions underlying reform-minded and traditional instructions about the impacts of different teaching approaches on the mathematics performance of students across different racial/ethnic groups. Implications for how to improve teaching and teacher education practices and future directions of research were also discussed.

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## **CHAPTER ONE: INTRODUCTION**

U.S. educational policy makers often maintain that in order for the US remain as a global economic leader in the 21<sup>st</sup> century depends, in large part, on whether American students can be well educated in mathematics (National Commission on Mathematics and Science Teaching for the 21<sup>st</sup> Century, 2000; U.S. Department of Education, 1991). In the post-industrial age, problem-solving and reasoning, which is seen as higher order mathematics thinking capabilities, tend to be valued more than the basic mathematics knowledge and skills, such as memorizing facts and concepts, conducting basic calculations, and applying rules to solve simple problems (Carnoy, 1998; Lappan & Ferrini-Mundy, 1990; National Center for Research in Vocational Education, 1998; Romberg, 1990).

However, according to two large scale international assessments, the Trend in International Mathematics and Science Study (TIMSS) and the Program for International Student Assessment (PISA), U.S. students' overall mathematics performance, performance on the problem-solving and reasoning, and on the basic mathematics knowledge and skills have been lower than their counterparts in many European and East Asian countries and regions, although U.S. students' performance has improved slightly over the past two decades (Aud et al., 2010; Fleischman, Hopstock, Pelczar, & Shelley, 2010; Gonzales et al., 2009). In addition, the achievement gap in mathematics performance has been persistent

among U.S. students of different racial groups<sup>1</sup>, especially African-American, Hispanic, and Native American students have scored substantially lower than Asian-American and Caucasian students (Aud et al., 2010; National Center for Education Statistics, 2009). The latest results from the National Assessment of Educational Progress (NAEP) showed that the racial achievement gaps remained largely the same (about 20 points for Caucasian-Hispanic gap and 30 points Caucasian-Black gap) without substantial improvement from 1990 to 2009 (Aud et al., 2010; National Center for Education Statistics, 2009). The achievement gaps among the racial groups not only influenced the overall lower ranking of U.S. students' performance in the international comparisons, but also presented an equity problem for U.S. education (U.S. Department of Education, 2005). Therefore, the large racial achievement gaps need to be narrowed "at a steeper rate" (National Mathematics Advisory Panel, 2008b, p. 4-92) in order to maintain U.S. competitiveness as an economic and political leader in the 21<sup>st</sup> century and to pursue the ideal of a democratic and just society.

Researchers and policy makers realize that teaching quality is important in improving students' learning outcomes and helping close the achievement gaps (Floden et al., 2011). The importance of teaching quality lies in the fact that it is in the classrooms that

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<sup>1</sup> In this dissertation, the categorization of racial and ethnic groups follows the 1997 Office of Management and Budget (OMB) standard classification scheme, which is used by TIMSS 2007 and the U.S. 2010 Census. "Hispanic or Latino" is an ethnicity category instead of a racial category in OMB. For simplicity, the term "racial groups" is used in this dissertation to refer to the major racial and ethnic groups in the US.

teachers translate their knowledge and belief into teaching practice, and impact students' learning directly as compared with other mediating factors and proxy measures of teacher quality such as teacher degree, certificate, or subject matter knowledge, which often have to exert their influences on student learning through the teaching process (Wallace, 2009).

Thus, for educational policy makers, improving the teaching quality of K-12 teachers is a priority in addressing the issues of U.S. students' lower mathematics performance and persistent achievement gaps. To do so, National Council of Teachers of Mathematics (1989, 1991, 2000) established a series of teaching standards to guide teachers in adopting new ways of teaching mathematics that focuses on helping students develop, communicate, and justify their own answers to non-routine, complex mathematics problems with proper representational devices and meaningful connections to real life context. These expected changes to teaching were assumed to foster students' mathematics problem-solving and reasoning skills that are much needed in the post-industrial age, as well as basic mathematics knowledge and skills for all students regardless of their racial and cultural background (Lappan & Ferrini-Mundy, 1990; Romberg, 1990). This kind of teaching differs from the more traditional mathematics teaching that emphasizes solid memorization of algorithms, facts and rules, routine computational drill, procedural skill practice, and using algorithms, facts, rules and concepts to solve simple, routine problems (Romberg, 1992).

The policies formulated on the basis of the above assumptions influenced teaching and teacher education programs, and practice at the state and district level as well. NCTM's standards had considerable national influence on both pre-service and in-service teacher training programs in that they followed the recommendations of NCTM to produce high quality teachers as suggested in the standards documents (Ross, 2000). Meanwhile, most states in the US have used the NCTM standards as a guide to develop their own mathematics standards; schools and districts have used the NCTM standards to guide the adoption of useful curriculum for their students (Blank & Dalkilie, 1992; Blank & Pechman, 1995; Council of Chief State School Officers, 1997).

However, the above assumption held by NCTM is conceptually controversial (Apple, 1992). It has inspired intense criticism from supporters of traditional instructional approach who assume that the teaching of basic mathematics knowledge and skills is primary as it can lay solid foundations for students to learn how to use reasoning and solve complex problems (Gamoran, 2001; Geary, 1994; Greeno, Collins & Resnick, 1996; Wu, 1999). Moreover, reform-minded teaching also lacked sufficient empirical support as it was developed on the basis of what is not working in traditional teaching, what is most valued in mathematics learning (Hiebert, 1999), and the influence of some educational leaders who see traditional teaching not working (Hirsch, 1996).

The conceptual debates about the effects of these two kinds of teaching were often



conducted without sufficient attention to the racially diverse nature of U.S. students (e.g., Brewer & Goldhaber, 1997; Carpenter, Fennema, Peterson, Chiang, & Loef, 1989; Hiebert et al., 1997; Wood & Sellers, 1996). Advocates for the teaching of problem-solving and reasoning often implied that this kind of teaching would be effective for all U.S. students, regardless of their racial backgrounds (National Council of Teachers of Mathematics, 1989, 1991, 2000). However, this assumption differs from that of culturally relevant pedagogy theory, which emphasizes that students across racial groups have different needs, norms, and ways of mathematics learning, and their teachers thus need to use different and culturally relevant pedagogies to address these racial and ethnical differences in order to improve their mathematics learning (Ladson-Billings, 1994, 1995; Nelson, 1995; Oxford & Anderson, 1995).

Moreover, most studies examining the effects of the different kinds of teaching on students' mathematics performance have focused on U.S. students as a racially homogeneous group (e.g., Brewer & Goldhaber, 1997; Carpenter et al., 1989; Hiebert et al., 1997; Wood & Sellers, 1996). The findings thus cannot help identify the effects of reformed teaching and traditional teaching on the mathematics achievement of students across racial groups, and help examine the assumptions of cultural relevant pedagogy theory. Such seemingly conflicting theoretical assumptions need to be examined to verify their validity in U.S. school environment as both assumptions exert strong impact on the

current mathematics education policy-making and practice (National Mathematics Advisory Panel, 2008a).

### **Research Questions**

This study investigated the relationship between the two types of mathematics teaching approaches (reformed and traditional) and the mathematics achievement of students from four major racial groups, i.e., Caucasian, African-American, Hispanic, and Asian-American. Specifically, the study aimed at investigating the following research questions:

- 1) Is reformed teaching positively and significantly related to the problem-solving, basic skills, and overall mathematics achievements of students from four racial groups respectively?
- 2) Is traditional teaching positively and significantly related to the problem-solving, basic skills, and overall mathematics achievements of students from four racial groups respectively?
- 3) Controlling for traditional teaching, does students' problem-solving score significantly predict their basic mathematics knowledge and skills score when they are exposed to more or less reformed teaching?
- 4) Controlling for reformed teaching, does students' basic mathematics knowledge and skills score significantly predict their problem-solving score

when they are exposed to more or less traditional teaching?

### **Significance of the Study**

The answers to the above questions are important for researchers, policy makers, and practitioners in mathematics education and teacher education in several ways. First, they will help to determine whether the theoretical assumptions underlying the reformed teaching, traditional teaching, and culturally relevant pedagogy are supported by providing necessary empirical evidences. As I explained in the above, the assumption of reformed teaching has been used as one of the important conceptual bases for the mathematics instruction reform policy (National Mathematics Advisory Panel, 2008a; Ross, 2000).

Second, these answers will help strengthen, modify, and change mathematics education policy recommendations that help improve mathematics learning of different racial groups of students. These empirical bases are especially necessary considering those policy recommendations regarding how to teach mathematics effectively and how to address the needs of racially diverse students are exerting important influences on mathematics teaching practices in many classrooms (Banks, 2006; Lappan & Ferrini-Mundy, 1990; Ross, 2000).

Third, these answers will help provide necessary information for teacher educators and professional development personnel in mathematics teacher education to

develop, modify, and change their curriculum that prepares teachers to teach mathematics for learners across different racial groups.

### **Definition of Terms**

*Reformed Teaching* is a term used to refer to the type of teaching that is advocated by NCTM through a series of its published reform documents. This type of teaching focuses on fostering students' higher order mathematics thinking skills and emphasizes the developing, communicating, and justifying students' own answers to non-routine, complex mathematics problems with proper representational devices and meaningful connections to real life context (National Council of Teachers of Mathematics, 1989, 1991, 2000). Other scholars also called this type of teaching as reform-oriented teaching (Le, Lockwood, Stecher, Hamilton, & Martinez, 2009), "standards-based instruction" (Hamilton et al., 2003), "conceptual teaching" (Hiebert et al., 1996), "higher-order instruction," "teaching for understanding" (e.g., Carpenter et al., 1989). These terms commonly refer to the type of teaching practices that are consistent with the teaching and assessment guidelines published by the National Council of Teachers of Mathematics (1989, 1991, 2000).

*Traditional Teaching* is a term used to refer to the type of teaching that focuses on fostering students' lower order mathematics thinking skills as its priority. In this type of teaching, basic mathematics knowledge and skills is primary because of its foundational role in students' learning to use reasoning and solve complex problems (Gamoran, 2001;

Geary, 1994; Greeno et al., 1996; Wu, 1999).

*Culturally Relevant Pedagogy* was originally proposed by Ladson-Billings (1994) and it acknowledges that students from different racial and ethnic backgrounds have different cultural characteristics, learning styles, and learning habits. It argues that the same type of teaching might not be equally effective for students from diverse backgrounds. Teachers thus need to adjust their teaching approaches to accommodate students' cultural and racial differences.

### **Organization of the Dissertation**

This dissertation is organized in six chapters. In chapter one, I provide an overview and introduction to the study, along with its research questions and its significance. In Chapter two, I specifically elaborate on the theoretical framework that informed the design of the study. Chapter three includes a review of the relevant studies about the effects of two teaching approaches on students' mathematics achievement. In Chapter four, I present an in-depth discussion of the methodology, including the data sources, participants and sampling, instruments, and data analysis to be used for the investigation of the research questions. In Chapter five, I present the results of the study. Lastly, I present the limitations of the study, discussion of the results and the implications and future directions of study in Chapter six.

## **CHAPTER TWO: THEORETICAL FRAMEWORK**

Two lines of theoretical debate frame the foci, design, and data analysis of this study. The first line of theoretical debate is between proponents of problem-solving and reasoning focused teaching, which I define as reformed teaching, and those of teaching that focuses on basic mathematics knowledge and skills, which I define as traditional teaching. The second contention is between the proponents of reformed teaching and those of culturally relevant pedagogy. In this chapter, I review each line of the theoretical debate, identify its central issues, and the ways in which this study can help enrich and contribute to each line of debate.

### **Debate between Proponents of Reformed and Traditional Teaching**

The first line of theoretical debate center around which type of teaching is more effective for improving U.S. students' mathematics achievement in light of problem-solving and reasoning skills, basic mathematics knowledge and skills as well as the relationship between problem-solving and reasoning skills, and basic mathematics knowledge and skills in each kind of teaching.

On the one hand, proponents of reformed teaching believed that U.S. students' low mathematics performance on both problem-solving, reasoning skills, and on basic mathematics knowledge and skills is partly due to the inefficiency of traditional mathematics teaching prevailing in U.S. schools (Darling-Hammond, 2001; Hiebert &

Stigler, 2000; Hirsch, 2001; Stigler & Hiebert, 2004).

Following the above assumption, the published standards documents for mathematics content and teaching (National Council of Teachers of Mathematics, 1989, 1991, 2000, 2006) projected a new image of mathematics teaching that focuses on problem-solving and reasoning, and encouraged teachers to a new direction of teaching mathematics that differed from the traditional ways. Underlying these standards is a constructivist philosophy of mathematics learning that emphasizes the active role of the students in the construction of their own mathematical knowledge and skills that are needed in the new century (Thompson, 2001). The problem-solving and reasoning were seen as primary goals of all mathematics instruction as well as the means of mathematics learning (National Council of Teachers of Mathematics, 2000). They were considered a process that should be integrated into the entire mathematics teaching and learning. According to these standards documents, problem-solving is considered as the process that students engage in to find a solution to a task by drawing on mathematical knowledge they have learned, especially, those non-routine, complex ones that require students to make bold conjectures, propose multiple approaches and solutions (Hiebert et al., 1996; National Council of Teachers of Mathematics, 1991). This point was emphasized again in NCTM 2000 standards document by stating that “students should have frequent opportunities to formulate, grapple with, and solve complex problems that

require a significant amount of effort” (p. 52). In addition, it continues to encourage students to properly justify their solution to a problem and their thinking processes in solving a problem and see the engagement of students in the reasoning process as critical in improving students’ conceptual understanding of mathematics ideas and concepts (Hiebert et al., 1997; National Council of Teachers of Mathematics, 2000).

To improve students’ problem-solving and reasoning ability, NCTM (1989,1991, 2000) advocated that teachers need to resort to *communication*, *representation*, and *connection* that focus respectively on encouraging students to share their mathematical ideas and clarify their understanding of problems solving process, demonstrate mathematical ideas, concepts, relationships, and problems solving approaches “mentally, symbolically, graphically, and by using physical materials,” and relate problem-solving to their real life experience (National Council of Teachers of Mathematics, 2000, p. 67).

Moreover, these standards documents and its proponents assume that the process of training the students to become better problem solvers with reasoning skills in mathematics will enable them to become better problem solvers with better conceptual understanding in their daily lives and in their future careers (Hiebert et al., 1996, 1997; National Council of Teachers of Mathematics, 2000).

For example, the NCTM standards in 1989, 1991, and 2000 all state that by giving students more opportunities to develop, communicate, and justify their own answers



to non-routine, complex mathematics problems with proper representational devices and meaningful connections to real life context, U.S. students will be able to learn school mathematics with deeper conceptual understanding and fluent basic mathematics skills, and that all U.S. students' mathematics achievement will be improved. Many proponents of the NCTM standards (Hiebert, et al., 2004; Romberg, 1992; Schoenfeld, 2004; Thompson & Senk, 2001) argue that by encouraging problem-solving and reasoning to be permeated in the teaching of specific mathematics content knowledge at all grade levels in K-12 classrooms, not only would U.S. students' problem-solving skills but also their basic mathematics knowledge and skills be improved, along with their overall mathematics achievement. Following this line of thinking is a top-down approach to raising U.S. students' overall mathematics achievement, which assumes that by focusing on the teaching and learning of students' higher-level thinking capacity such as problems solving and reasoning, reformed teaching will be able to raise students' lower-level thinking capacity such as basic mathematics knowledge and skills.

However, these assumptions were conceptually contentious. Some scholars challenge the above assumption by arguing that traditional teaching approach has an irreplaceable role in helping all students develop high level conceptual understanding of mathematics ideas and concepts, and gain better mathematics problem-solving skills (Gamoran, 2001; Geary, 1994; Wu, 1999). They claimed that the traditional approach of

teaching played an important role in developing students' problem-solving and reasoning skills through laying down sound foundation of basic mathematics knowledge and skills, such as well-retained basic mathematical concepts and fluent use of mathematical procedures, algorithms, facts and rules (Greeno et al., 1996). These basic mathematics knowledge and skills could be well developed through traditional mathematics teaching that focuses on solid memorization of algorithms, facts and rules, routine computational drill, procedural skill practice, and using algorithms, facts, rules and concepts to solve simple, routine problems (Gamoran, 2001; Geary, 1994; Greeno et al., 1996; Wu, 1999).

In contrast to the "top-down" approach of the reformed teaching, these scholars suggests a "bottom-up" approach to raising U.S. students' overall mathematics achievement by stressing that traditional teaching will be able to raise students' higher-level thinking capacity such as problems solving and reasoning through developing students' solid lower-level thinking capacity such as basic computational skills.

In sum, proponents of reformed teaching assumed that, by emphasizing problem-solving and reasoning focused instruction, students' overall mathematics achievement and achievement on basic mathematics skills will be improved. In contrary, proponents of traditional teaching assumed the opposite is true. They held that by emphasizing the teaching of basic mathematics knowledge and skills, students' overall mathematics achievement and achievement on problem-solving skills will be improved.

This study will help determine whether and to what extent which side of this line of debate is right by examining the relationship between the two teaching approaches and students' three mathematics achievement measures, i.e., overall mathematics achievement, achievement on problem-solving and on basic skills.

## **Debate over Effective Mathematics Teaching and Learning of Diverse Student**

### **Population**

The second line of theoretical debate occurs between those supporting reformed teaching focusing on problem-solving and reasoning, and those advocating culturally relevant pedagogy. The different theoretical assumptions of each side regarding how to effectively teach students of different racial and cultural backgrounds are exerting important influences on the current policy and practice of mathematics teaching (National Mathematics Advisory Panel, 2008b).

On the one hand, those proponents for reformed teaching assumed that the teaching focusing on problem-solving and reasoning would be effective for all kinds of students regardless of their racial backgrounds. In NCTM's earlier reform document (1989), the reformed teaching strategy is seen as an important effort to challenge the historically pervasive belief that only a small number of students can learn mathematics. It stresses that the reformed teaching could contribute to "a just society in which ... various ethnic groups enjoy equal opportunities and equitable treatment" (1989, p. 8). Underlying

this position statement is an assumption that the reformed teaching would meet the needs of all students and improve their mathematics achievement (Lubienski, Camburn, & Shelley, 2004; Meyer, 1991).

In its 2000 standards document, NCTM further formulated an *equity* principle as one of the core elements of its vision by stressing that “[e]quity does not mean that every student should receive identical instruction; instead, it demands that reasonable and appropriate accommodations be made as needed to promote access and attainment for all students” (p. 12). However, what these “accommodations” look like was not clearly articulated in NCTM’s 2000 standards document. In the meantime, NCTM continued to promote its advocated problem-solving and reasoning focused teaching to improve the mathematics learning of students across different racial groups, which, as pointed out by some scholars (Lubienski et al., 2004; Meyer, 1991), leaves an impression that the needs of all students across racial/ethnic groups would be satisfied through one single teaching approach as NCTM recommended.

Such an assumption is in contrast with the assumption underlying culturally relevant pedagogy that clearly focuses on addressing the racial and cultural differences of students from various racial groups. The goal of the culturally relevant pedagogy is to help students from particular racial groups to improve their performance, develop critical consciousness of their social situation while nurturing their own cultural competence

(Ladson-Billings, 1995). It was developed on the basis of several related assumptions.

First, individuals learn by their preferred style of learning, norms, and habits (Kolb, 1981), which are developed in the cultural contexts in which they live and grow up (e.g., De Vita, 2001; Hayes & Allinson, 1988; Katz, 1988; Pewewardy, 2002). The value, belief system, and ways of perceiving things in a culture were shared among its members, which influence the learning style, norms, habits, and needs of students in the culture in similar ways (Heredia, 1999; Irvine & York, 1995; Guion & Diehl, 2010). In the US, cultural and racial influences were often overlapped to a large extent, which led to the fact that students' way of thinking and behaving as well as their norms, habits, and needs tend to be similar with his or her peers from the same cultural and racial group (Betancourt & Lopez, 1993; Guion & Diehl, 2010).

Second, effective teaching approach for different groups of students needs to be developed with proper attention to students' special learning needs, styles, and habits (Ladson-Billings, 1994, 1995, 1997; Nelson, 1995; Oxford & Anderson, 1995). Students' learning outcome will not be enhanced if their teachers' instruction fails to address the cultural or racial needs, habits, norms, and learning styles of students from different cultural and racial groups (Irvine & York, 1995; Moran, 1991). Therefore, teachers need to be well aware of the cultural and racial characteristics of their students and strive to develop teaching strategies based on their learning about students' cultural heritage (Banks,

2006; Irvine, 2009; Irvine & York, 1995).

Third, considering that students from different racial and cultural backgrounds are exposed to different values, beliefs systems, and ways of perceiving things, accordingly, the needs, norms and learning styles of one group of students can be quite different from those of another group (Guion & Diehl, 2010). This naturally leads to the assumption that the type of teaching approach that is effective for a particular racial group of students may not be equally effective for another racial group of students (Banks, 2006; Irvine & York, 1995; Pewewardy, 2008).

Supporters of culturally relevant pedagogy criticize the one-size-fits-all instructional approach as it blurs the difference among different racial groups and ignores students' different cultural learning styles (Tomlinson & Kalbfleisch, 1998). They argue that just as content knowledge and pedagogical content knowledge are important for teaching mathematics, equally important is the type of pedagogical content knowledge associated with students' racial and cultural background that most teachers ignore (Brewley-Kennedy, 2005).

In sum, proponents for reformed teaching assumed that problem-solving and reasoning focused teaching would work effectively for all students across different racial groups. Thus, teaching focusing on problem-solving and reasoning will be valued. In contrast, proponents for culturally relevant pedagogy assumed that one universal teaching

approach might not be equally effective for students of different racial groups. Focusing on examining the relationship between reformed teaching and the mathematics achievements of students across racial groups, my dissertation will help-determine whether and to what extent the assumptions maintained by proponents of NCTM and culturally relevant pedagogy hold true.

### **CHAPTER THREE: LITERATURE REVIEW**

To develop an understanding about how well the research questions examined in the dissertation have been addressed in the existing relevant empirical literature, this chapter reviews previous studies that examine the effects of reformed and traditional teaching on students' mathematics achievement including their overall mathematics performance, and performance on problem-solving skills, and on basic mathematics knowledge and skills across different racial groups. Through this review, I identify the gaps and limitations in the existing understanding about my research questions and situate my research questions in these limitations and gaps.

To complete this task, I searched five databases including ERIC, Academic Search Premier, Professional Development Collection, PsycINFO, and PsycARTICLES using the terms "math instruction," "student achievement" and "NCTM". In addition, a separate search was conducted in all the volumes of the *Journal for Research in Mathematics Education* from 1989 to 2011. This search process led to 97 articles that are empirical studies or position papers. Some articles were eliminated either because they were non-empirical studies or were not related to the research questions of this dissertation. A further reading of the references in the selected articles led to more related studies that were not listed in the database searches. This process located a total of 19 empirical studies for this review.



In the following, I will firstly review, critique, and present my review results of these studies that were grouped into two broad categories. The first category includes empirical studies that focus specifically on the effect of reformed and traditional teaching on the problem-solving, basic mathematics knowledge and skills, and overall mathematics achievements of students without distinction of their racial backgrounds. The second category includes those empirical studies focusing on the effect of reformed and traditional teaching on the problem-solving, basic mathematics knowledge and skills, and overall mathematics achievements of U.S. students from a racially heterogeneous population perspective. Additionally, a summary of the findings, gaps in the literature, and implications for future study will be discussed in relation to my research questions.

### **Studies with Racially Homogeneous Student Population Perspective**

#### **On students' overall mathematics achievement.**

It is the expectation of reform documents and their proponents that reformed teaching focusing on problem-solving and reasoning can help improve U.S. students' overall achievement than the traditional teaching that focuses on basic mathematics knowledge and skills (National Council of Teachers of Mathematics, 1989, 1991, 2000; Hiebert et al., 2004; Romberg, 1992). Several studies have investigated this assumption and provided mixed findings about the relationship between the reformed and traditional teaching and students' overall mathematics performance.

First, some studies showed somewhat positive relationship between reformed teaching and student performance. One study (Mayer, 1998) involved 2,369 middle and high school students in 94 classes from 40 schools in a large school district. It surveyed teachers' use of reformed teaching that emphasizes writing about problems solving, explaining problems solving, and discussing alternative way of solving problems and measured their students' performances with three criterion referenced standardized algebra assessments. Using Hierarchical Linear Modeling (HLM), the study found that more reformed teaching that teachers reported to use contributed to students' higher growth rate on traditional tests, with students of higher academic levels benefited more from reformed teaching.

Three studies conducted by the RAND Corporation also showed similar findings. In the first one, Klein and colleagues (2000) examined the effect of reformed teaching on students' mathematics achievement in about 100 elementary and middle schools from six sites during the 1996-97 and 1997-1998 school years. Researchers surveyed teachers about their instructional practices. Using exploratory factor analyses, they identified two factors that indicated reformed and traditional approach of instruction from a multitude of questionnaire items. The reformed teaching factor had 22 items that included solving real world problems, asking students to describe their reasoning when explaining an answer and students' making formal presentations, etc. The items that loaded on the traditional

teaching factor included practicing computational skills, memorizing mathematics facts, rules, or formulas, and monitoring traditional tests. The researchers used students' mathematics test scores at district or state level as control measures and assess students' achievement on both standardized assessment and open-ended assessment. Using linear regression analysis while controlling for student background characteristics and previous test scores, the researchers found that across all sites, reformed teaching was positively associated with students' mathematics achievement but the effect was weak and much smaller than that of students' background characteristics. In addition, it was found that traditional teaching was negatively related to students' achievement. A follow-up non-experimental study (Hamilton et al., 2003) using a much larger sample size (more than 13,000 mathematics students from 11 sites in the springs of 1997 and 1998) confirmed the above finding using Ordinary Least Square regression.

Suspecting the weak effect was due to shorter duration of implementation of these new practices (one year), a 3-year longitudinal study (Le et al., 2009) was conducted to explore the relationship between reformed teaching and students' mathematics achievement. The initial participants were from the third, sixth, and seventh grade from the identified districts, and they were followed up in the study for an additional 2 years. The researchers controlled for students' prior achievement using their achievement scores on state tests and locally administered district tests and then measured students' test

scores on the Stanford Achievement Test Series, Ninth Edition (SAT-9). The study found that reformed teaching was weakly related to higher student achievement in mathematics but this relationship tends to be stronger when these practices were implemented for longer time duration.

In addition, Wenglinsky (2000, 2002) conducted two studies using data set from the NAEP 1996. Using multilevel structural equation modeling (MSEM) in both studies, Wenglinsky found in one study (2000) that, after controlling for student background and prior performance factors, when teachers focused on solving real world problems and hands-on learning activities, their eighth graders showed higher mathematics achievement. In the other study, Wenglinsky (2002) found that solving unique mathematics problems was related to higher student achievement.

Second, other studies, nevertheless, found contrary results that challenged the positive relationship between reformed teaching and students' overall achievement. Brewer and Goldhaber (1997) used a sample of 5,149 tenth-grade public school students, 2,245 mathematics teachers in 638 schools from the National Educational Longitudinal Study of 1988 (NELS: 88) to examine this relationship. The reformed teaching was defined and measured as focusing on problem-solving and small group work. Using Ordinary Least Square regression approach, the study indicated that reformed teaching was related to lower scores of the tenth grade students on traditional mathematics standardized

test, after controlling for the effects of student background, prior achievement and teacher characteristics.

Schwerdt and Wuppermann (2011) obtained a similar conclusion in their study using the eighth grade sample from TIMSS 2003 that includes 6,310 students taught by 639 teachers (303 mathematics and 355 science teachers, while 19 teachers teach both subjects) in 205 schools in the US. Using working on problems solving with or without teachers' guidance as reformed teaching and time spent on listening to lecture style presentation as traditional teaching, Schwerdt and Wuppermann (2011) conducted the Ordinary Least Square regression estimation with their data and found that, after controlling for student and family background variables, school, teacher and class characteristics, the more time spent on reformed teaching is not associated significantly with higher student achievement, while the more time teachers spent on traditional teaching, the more likely their students demonstrate higher mathematics performance.

In summary, the existing literature on the relationship between the reformed and traditional teaching, and students' mathematics performance is not able to yield solid evidence to sustain a strong relationship between reformed or traditional teaching and students' overall mathematics performance. These mixed results call for further investigation of the reasons for the inconsistent findings.

Among all the possible reasons for such mixed results, the fact that all these

studies used their student participants as a racially homogeneous group might have compromised their results in different directions as suggested by the assumption underlying culturally relevant pedagogy (Ladson-Billings, 1994, 1995) and the gaps of students' performances across racial groups. The fact that all the studies reviewed above failed to distinguish student performance in problems solving, basic mathematics knowledge and skills in their measurement can be another reason, which leads to mixed findings as suggested in the assumption of the relationship between problem-solving and basic mathematics knowledge and skills by the proponents of reformed teaching (Hiebert et al., 2004; Romberg, 1992; Schoenfeld, 2004) and traditional teaching (Gamoran, 2001; Geary, 1994; Wu, 1999).

Thus, it is important and necessary to consider both factors in the research design so that more discriminated understanding can be developed about the mixed results. My dissertation will help contribute to addressing the gaps and limitations in this part of the literature by examining the relationship between the two types of teaching and the overall mathematics achievement, problem-solving, basic mathematics knowledge and skills achievement of students from different racial groups.

#### **On students' problem-solving and basic skills achievement.**

One of the important assumptions underlying reformed teaching is that, by focusing on the teaching of problem-solving and reasoning, students' achievement on

problem-solving will be improved along with their basic skills and overall mathematics achievements (National Council of Teachers of Mathematics, 1989, 1991, 2000; Romberg, 1992). This assumption is problematic as supporters of traditional teaching hold that the teaching of basic mathematics knowledge and skills provide an important and necessary basis for developing students' problem-solving skills and thus, their overall mathematics achievement (Gamoran, 2001; Geary, 1994; Wu, 1999). Several studies have investigated such contentious assumptions regarding the relationship between students' problem-solving skills, and their basic mathematics knowledge and skills.

First, some studies showed that reformed teaching that focuses on problem-solving and reasoning help students perform better on problem-solving, basic mathematics knowledge and skills assessment than the traditional teaching. Ginsburg-Block and Fantuzzo (1998) conducted an experimental study with a sample of 104 third and fourth grade low-achieving urban school kids. In one experiment group, students were taught using problem-solving teaching while in the control group, students did not receive either problem-solving, peer collaboration or combination of the two. A Pre-test before and a post-test after the 7-week program showed that students in the problem-solving group significantly outperformed the control group on word problem-solving test and on computation skills test.

Wood and Sellers (1996) investigated the prolonged effect of reformed teaching

emphasizing problems solving on the arithmetic achievement of 417 students from five schools. In the first grade, all the sampled students were taught using traditional approach to obtain the baseline achievement data at the end of the first grade. In the second as well as the third grade, the experimental group taught by problems-centered instruction for two years. Control group one was taught traditionally and textbook-based, control group two was taught using problem-centered teaching for one year and traditional teaching for another year. At the end of the third grade, ANOVA analysis with Scheffe follow-up test showed the experimental group receiving problem-centered instruction for two years achieved significantly higher on computational skills test than students who were taught by problem-centered method for one year and students who were taught using traditional teaching.

This finding is confirmed by the study of Carpenter et al. (1989), who found that first-grade students taught by teachers that received training on emphasizing students' thinking process in problem-solving outperformed those students in the control group taught by teachers who did not receive such training on addition and subtraction problem-solving. Another study (Peterson, Fennema, Carpenter, & Loef, 1989) also found that students taught by teachers with training emphasizing students' thinking process in problem-solving scored higher on word problem-solving test than the traditionally taught students.



Second, other studies showed that, although reformed teaching that focuses on problem-solving and reasoning help students perform better in problem-solving skills than the traditional teaching, it is not so helpful on basic mathematics knowledge and skills. The experimental study conducted by Brenner et al. (1997) investigated whether or not reformed teaching focusing on multiple representations of concepts and problem-solving in cooperative groups had an effect on regular and ELL students' achievement in junior high school. Students in the experiment group were exposed to a 20-day function learning program using reformed teaching while the control groups were exposed to traditional, direct instructional approach from a textbook. They found that the experiment groups scored significantly higher on solving function word problems but underperformed on more basic skills such as solving routine equation problems than those in the control group.

Peterson et al. (1989) also found that students taught by teachers with training on emphasizing students' thinking process in solving problems did not surpass traditionally taught students on addition and subtraction fact. This finding was confirmed by Saxe, Gearhart, and Selzer (1999) who found reformed teaching that focuses on problem-solving and students' higher level of thinking such as reasoning was not positively related to students' computation scores, and by Cobb et al.'s study (1991), which found that second graders whose teachers used reformed teaching focusing on problem-solving showed similar competence in computational skills in arithmetic with students in the control group

taught by traditional approach. In addition, Thompson and Senk (2001) found that, although students taught by reformed teaching (emphasizing explanations of problem-solving process) performed better than students taught by traditional approach on measures of multistep problems, problem applications, and problems involving applications or graphical representations, no difference was found between the two groups on basic algebraic skills test.

The existing studies also suggested that there seemed to be a complex and inconsistent picture for the effects of reformed teaching and traditional teaching on students' basic mathematics knowledge and skills, in spite of the stronger effects of reformed teaching over the traditional teaching on student problem-solving skills. Thus, these studies were unable to provide sufficient empirical data to help resolve the contentious debate over the relationship between problems solving and basic skills argued by the proponents of reformed teaching and traditional teaching. Furthermore, these studies failed to consider student learning differences across different racial groups, which may lead to possible different effects of either reformed teaching or traditional teaching on student problem-solving skills as well as on their basic mathematics knowledge and skills. In addition, in many studies, the traditional teaching was not clearly and consistently defined and controlled so that the results can be made comparable. This dissertation will help contribute to addressing the gaps and limitations

in this part of the literature by considering U.S. student population racially heterogeneous and examining the relationship between the two types of teaching and the problem-solving, and basic mathematics knowledge and skills achievement of students from different racial groups.

### **Studies with Racially Heterogeneous Student Population Perspective**

Research that focused on the effects of the two types of teaching on students' problems solving, basic skills, and overall mathematics achievement across different racial groups has not been well developed in the existing literature. A small number of available studies often involved fewer minority groups and were unable to track the performance differences of students across different racial groups in problem-solving, and basic mathematics knowledge and skills.

Manswell-Butty (2001) used a subsample of 190 African-American and 174 Hispanic tenth and 12th grade students from the two follow-up studies of the National Educational Longitudinal Study of 1988 (NELS: 88) to examine the differential effects of reformed teaching and traditional instruction on these two groups of students' mathematics performance as measured by standardized tests. The reformed and traditional teaching measures were based on teachers' degree of emphasis in seven areas including analyzing problem-solving strategies and connecting mathematics learning to students' daily life. Manswell-Butty constructed two indexes to represent the two teaching approaches by

computing the above items so that lower scores in the indexes would reflect a traditional teaching while higher score would indicate the reformed teaching approach. The first follow-up study was conducted in 1990 when the sampled students were in the 10<sup>th</sup> grade and second follow-up study was in 1992 when the students were in the 12<sup>th</sup> grade. The dependent measure was students' overall mathematics achievement score. The researcher conducted ANOVA with their data and found that the relationship between the two types of teaching and the mathematics achievement was non-significant for the sample of the 10<sup>th</sup> grade African-American and Hispanic students, but significant for the sample of the 12<sup>th</sup> grade African-American and Hispanic students. Moreover, the 12<sup>th</sup> grade students receiving reformed instruction significantly outperformed students receiving traditional instruction.

Another study conducted by Lubienski (2006) used data from the fourth grade population in NAEP 2000 to examine the relationship between reformed teaching and the mathematics performance of students across different racial groups. Lubiensky created composite scales for reformed teaching based on a set of individual variables using factor analysis. With hierarchical linear modeling, she found that, although the reform-oriented composite factor about teachers' use of collaborative problem-solving was significant and positive predictors of the overall mathematics achievement of all the fourth graders after controlling for SES, race, disability status, gender, and school sector, it was not

significantly related with Hispanic and African-American students' overall mathematics achievement.

In summary, although the existing studies showed some evidence regarding the impact of reformed teaching on African and Hispanic students' performance, the existing literature had several clear limitations in providing any reliable empirical data for the relationship between the reformed and traditional teaching, and the different mathematics performances such as problem-solving, basic mathematics knowledge and skills across various racial groups. First, the traditional teaching was not clearly defined and its effects were not measured as a base to compare with those of reformed teaching. Second, student performances were measured without a clear distinction between problems solving skills and basic mathematics knowledge and skills. Third, very few racial groups were involved in comparison. My dissertation will help contribute to addressing these gaps and limitations by examining the relationship between the two types of teaching and three types of student mathematics performance measures (overall mathematics achievement, problem-solving achievement, and basic mathematics knowledge and skills achievement) of students from different racial groups.

## **CHAPTER FOUR: METHODOLOGY**

In this chapter, I describe and justify the method, data sources, and analysis for my dissertation designed to address the following research questions:

- 1) Is reformed teaching positively and significantly related to the problem-solving, basic skills, and overall mathematics achievement of students from four racial groups respectively?
- 2) Is traditional teaching positively and significantly related to the problem-solving, basic skills, and overall mathematics achievement of students from four racial groups respectively?
- 3) Controlling for traditional teaching, does students' problem-solving score significantly predict their basic mathematics knowledge and skills score when they are exposed to more or less reformed teaching?
- 4) Controlling for reformed teaching, does students' basic mathematics knowledge and skills score significantly predict their problem-solving score when they are exposed to more or less traditional teaching?

I first present the conceptual model for investigating the research questions, then justify the use of TIMSS 2007 data set as the data source, and describe the participants and sampling. After that, I explain the variables selection for reformed and traditional teaching and for student performance measures. Finally, I provide the rationale for using

hierarchical linear modeling (HLM) as the data analytic approach, describe the detailed data analysis procedures, including preparing the two level data files, creating the composite variables, and the HLM equation building.

### Conceptual Model

The conceptual model used to operationalize the research questions for this study (Khan, n.d.) was developed based on the two lines of theoretical debates described in the theoretical framework. As shown below, this conceptual model includes three parts, i.e., different kinds of teaching, various groups of students, and different kinds of students' learning outcome as suggested by Goe (2007).

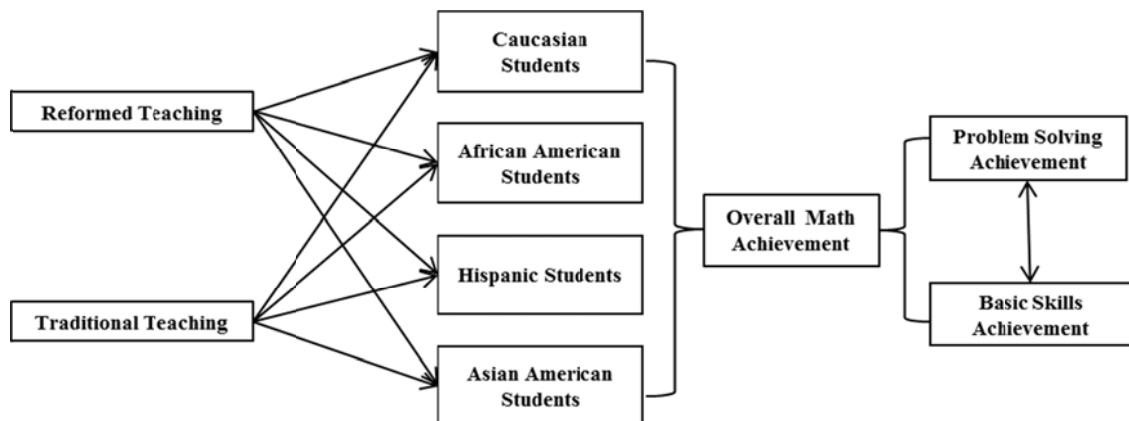


Figure 1. Conceptual model for investigating research questions.

Guided by the two lines of theoretical debates, research question 1 and 2 of this dissertation investigate whether the reformed and traditional teaching approaches are related positively and significantly to the mathematics achievement including problem-solving skills, basic mathematics knowledge and skills, and overall mathematics

achievement of Caucasian, African-American, Hispanic, and Asian-American students respectively; research question 3 investigates whether students' problem-solving score significantly predicts their basic mathematics knowledge and skills score when they are exposed to more or less reformed teaching while research question 4 investigates whether students' basic mathematics knowledge and skills score significantly predicts their problem-solving score when they are exposed to more or less traditional teaching.

### **Data Source**

TIMSS 2007 U.S. dataset was selected as the data source for this study based on the following considerations. First, since the research questions focus on the relationship between two kinds of teaching approaches and the mathematics achievement of students from four racial groups in the US, a large sample size is needed in order to make the results more generalizable. TIMSS 2007 is a large-scale dataset adopting a large, nationally representative student sample that can be further classified into different racial groups. Such feature of TIMSS 2007 can enhance the generalizability of the research results. In addition, this dataset is especially useful in studying achievement related issues of minority students, as it includes enough nationally representative minority student samples that are often hard to secure in individually designed experimental studies (Schneider, Carnoy, Kilpatrick, Schmidt, & Shavelson, 2007).

Second, TIMSS 2007 assessed mathematics knowledge and skills that students



have learned at school (Mullis et al., 2005), which is useful for investigating the impact of teachers' instructional approaches on students' achievement. From students' achievement data, the overall mathematics achievement, problem-solving achievement, and basic mathematics knowledge and skills achievement of students across racial groups can be identified (Mullis et al., 2005).

Third, by design, the individual student can be linked to their classroom mathematics teachers in TIMSS 2007. More importantly, the teachers' questionnaire in TIMSS 2007 contains mathematics teachers' instructional practice variables that can be grouped into reformed and traditional teaching as defined in Chapters 1 and 2. Although such survey data cannot provide in-depth descriptions of teachers' instructional practice as on-site observations do, they are able to involve large population of teachers to yield findings of external generalizability, which is often unable to achieve in many qualitative studies (Schneider et al., 2007). In addition, in spite of the generally low reliable nature of self-report data, the survey about teachers' instructional practices is more reliable and can be used (Mayer, 1998, 1999; McCaffrey et al., 2001; Porter, Kirst, Osthoff, Smithson, & Schneider, 1993) when the respondents are surveyed anonymously (Aquilino, 1994, 1998), are asked to describe their behaviors instead of judging the quality of their behaviors (Mullens & Gayler, 1999), and when composite variables instead of a single variable are used (Mayer, 1999). In TIMSS 2007, teachers were asked to anonymously account for

their classroom teaching rather than assess their teaching (Mullis et al., 2005). Moreover, several variables from teachers' questionnaire can be used to construct composite variables for the two kinds of teaching as suggested (Raudenbush, Rowan, & Cheong, 1993). These features of TIMSS 2007 make it possible to be used to address my research questions.

Among the two population datasets (e.g., fourth and eighth grade) in TIMSS 2007, the eighth grade data was used for this study because compared with the fourth grade data there are more variables describing teachers' classroom instructional practices in the eighth grade data (International Association for the Evaluation of Educational Achievement, 2007a, 2007c), which can be grouped into reformed and traditional teaching, and thus allows for a broader analysis of the relationship between the two types of teaching and students' achievement.

### **Participants and Sampling**

U.S. eighth grade students in TIMSS 2007 from both public and private schools were the sources of participants in this study. The two-stage, nonrandom sampling design of TIMSS 2007 ensured these students formed a nationally representative sample (Foy & Olson, 2009; Joncas, 2008). At the first stage, schools were selected using probability-proportional-to-size sampling. The school samples were drawn in 2005 and no oversampling of low-income schools was administered for the eighth grade. To achieve a

self-weighting student sample and reduce the chance of selecting smaller schools for cost efficiency, the probability of selection for the schools was based on the schools' measure of size (MOS) that is proportional to its share of student enrollment. After removing ineligible and nonparticipating schools, a total of 239 schools were selected from the original 300 sampled schools (Foy & Olson, 2009; Joncas, 2008).

At the second stage, one or two whole classes were randomly selected in each school sample (Olson, Martin, & Mullis, 2008). The U.S. samples were drawn from students who were about to finish eighth grade in the above schools. There were a total of 7,377 U.S. eighth grade students and 416 mathematics teachers selected for TIMSS 2007 (Olson, Martin, & Mullis, 2008).

Students from different racial groups were selected from the above sample using their answers to Question 2, items B and C in the student questionnaire (International Association for the Evaluation of Educational Achievement, 2007b). Students were asked in item B whether they were Hispanic or Latino, and then in item C they were asked whether they belong to the following racial groups: White, African-American, Asian, American Indian/Alaska Native, Native Hawaiian or other Pacific Islander. This student racial background information allows me to identify and classify four racial groups of students for this study, i.e., Caucasian, African-American, Hispanic, and Asian-American students. The corresponding total number of students for the four racial groups is 3,873,

949, 1,787, and 243, with percentages of 52.3%, 12.9%, 24.2%, and 3.3% respectively.

Thus, this makes it possible to model the relationship between the two teaching approaches and the achievement of students across these racial groups. 90 Native American students, 58 Pacific Islander students, 282 students who reported having two or more races, and 95 students who did not answer their racial information were deleted because they are not the focus of the study.

Among the 416 mathematics teachers, only 405 teachers had students from one or more of the four racial groups in their classrooms. Therefore, these 405 mathematics teachers were retained for the analysis in this study. The selected 3,873 Caucasian students, 949 African-American students, 1,787 Hispanic students, and 243 Asian-American students were taught by 349, 216, 311, and 114 mathematics teachers correspondingly. Caucasian, African-American, Hispanic, and Asian-American students in each teacher' classroom ranged from 0 to 39, 0 to 38, 0 to 42, and 0 to 13 respectively.

In the two-stage, non-random sampling design, sampling weights were assigned to schools and students to ensure that their participation in TIMSS 2007 matches their actual percentage of the population; the proper use of these weights are therefore necessary for computing accurately the nationally representative estimates (Mullis et al., 2005).

### **Variables Construction and Justification**

In the first and second research questions, I am interested in finding out whether reformed teaching and traditional teaching can predict the overall mathematics achievement, problem-solving achievement, and basic mathematics knowledge and skills achievement of students across four racial groups. Thus, the independent variables for the first two research questions are reformed and traditional teaching while the dependent variables are the overall mathematics performance, performance in problem-solving, and performance in basic mathematics knowledge and skills of student across four racial groups.

In the third research question, I am interested in finding out, while controlling for traditional teaching, whether students' problem-solving score can predict their basic mathematics knowledge and skills score when students are exposed to more or less reformed teaching. The independent variables are students' problem-solving score and reformed teaching, the dependent variable is students' basic mathematics knowledge and skills score, while traditional teaching serves as a covariate.

Similarly, in the fourth research question, I am interested in finding out, while controlling for reformed teaching, whether students' basic mathematics knowledge and skills score can predict their problem-solving score when students are exposed to more or less traditional teaching. The independent variables are students' basic mathematics

knowledge and skills score, and traditional teaching; the dependent variable is students' problem-solving score, while reformed teaching serves as a covariate.

In the following section, I present the details regarding how to create each of the dependent variables, independent variables, and covariates. Specifically, I discuss why and how the reformed and traditional teaching composite variables are constructed.

### **Student achievement measures.**

Students' overall mathematics achievement, as well as achievement on problems solving, and basic mathematics knowledge and skills were used as the dependent variables or covariates. The mathematics tests in TIMSS 2007 were developed according to what students are supposed to learn about mathematics from their school curriculum (Mullis et al., 2005). The eighth grade students' mathematics achievement dataset in TIMSS 2007 contains measures that can be used to represent students' overall mathematics performance, as well as performances on problems solving, basic mathematics knowledge and skills. I will discuss each of the three measures below.

Students' mathematics achievement in TIMSS 2007 was assessed using a framework in consistence with NCTM's *Principles and Standards for School Mathematics* (2000) to construct the mathematics achievement measurement items (Mullis et al., 2005). According to this assessment framework, students' mathematics competence was evaluated based on *content* and *cognitive* domains, the *content* domain

covers number, algebra, geometry, and data and chance, and the *cognitive* domain includes *knowing*, *applying*, and *reasoning*.

In TIMSS 2007, the items in the *knowing* cognitive domain the students were assessed covers the mathematical “facts” that include the “factual knowledge that provides the basic language of mathematics, and the essential mathematical facts and properties that form the foundation for mathematical thought,” mathematical “procedures” that serves as “a bridge between more basic knowledge and the use of mathematics for solving routine problems, especially those encountered by many people in their daily lives,” as well as mathematics “concepts” that enable students to “make connections between elements of knowledge” (Mullis et al., 2005, p. 33-34). Items in the *applying* domain focused on assessing students’ ability to solve “more familiar and routine” problems (Mullis et al., 2005, p. 36) that typically involve applying “mathematical knowledge of facts, skills, and procedures” (p. 35). As explained in Chapter 2 of the dissertation, these facts, procedures, and concepts are considered as the basic mathematics knowledge, while using these facts, procedures, and concepts to solve routine problems is considered as basic mathematics skills (Gamoran, 2001; Geary, 1994; Greeno et al., 1996; Wu, 1999). Therefore, students’ achievement score in the *knowing* and *applying* domain will be used as the basic mathematics knowledge and skills achievement.

In addition, students in TIMSS 2007 were also assessed on the basis of another cognitive domain, i.e., *reasoning*. In this domain, students are assessed on their ability to use higher-order thinking to solve “non-routine,” “complex” and “multi-step problems” that require more cognitive demands (Mullis et al., 2005, p. 37). Since solving this type of problems is the focus of reformed teaching as I explained in Chapter 2 of this dissertation (NCTM, 1989, 2000; Romberg, 1992), students’ achievement scores in the *reasoning* domain will be used as their problem-solving achievement.

In TIMSS 2007, Students’ performance measures on each test item as well as in each domain were obtained after the test; students’ overall achievement measure was simply the overall scale score of all the *content* and *cognitive* domains (Mullis et al., 2003, 2005). This measure, which represents the eighth grade students’ overall mathematics capability, is used as students’ overall mathematics achievement, one of the dependent variables, for this study.

All the tests in both *content* and *cognitive* domains included standardized multiple choice questions as well as open-ended items. An established scoring rubric was provided for the scorers on the open-ended items. Students in TIMSS 2007 were only tested on a portion of the total assessment items as it is too costly and time consuming for the students to complete all the test items (Williams et al., 2009). To estimate students’ total score on each of the content and cognitive domains, item response theory (IRT)



model were used (Olson, Martin, & Mullis, 2008). The estimated scores obtained through random draw are called plausible values, which are imputed values based on the students' performance on the portion of the test items. There are a total of five plausible values for students' overall mathematics competence and for each of the cognitive domain. These values represent the estimated performance of the students on all test items if they had taken all the tests (Foy & Olson, 2009).

It is recommended that, in any analysis with TIMSS data that includes achievement measures, the actual analysis should be performed five times, each with a separate plausible value, then "average each set of five parameter estimates" as the final result (Williams et al., 2009, p. 105). This study follows this recommendation, run the analysis five times with the plausible values for students' mathematics achievement, and finally averages the parameter estimates in order to generate accurate results.

#### **Variables selection for reformed and traditional teaching.**

I used the relevant literature on reformed and traditional teaching to guide the selection of five items to represent the reformed teaching and another three items to represent the traditional teaching from survey question number 17 in the teacher's questionnaire of TIMSS 2007 (International Association for the Evaluation of Educational Achievement, 2007a). TIMSS 2007 teachers' questionnaire was designed according to the same contextual framework as TIMSS 2003 in which NCTM's

*Principles and Standards for School Mathematics* (2000) was used as a guide to construct the survey questions (Ferrini-Mundy & Schmidt, 2005; Mullis et al., 2003, 2005) in order to identify the extent to which mathematics teachers' teaching is aligned with NCTM's recommendation for mathematics instruction in the US (Lubienski, 2006; Mullis et al., 2003, 2005).

Table 1

*Initial Coding and Recoding of TIMSS 2007 Items Indicating Reformed Teaching*

TIMSS item description (How often do teachers ask students to...?)	Original coding	Recoding
a) decide on their own procedures for solving complex problems	1=every or almost every lesson	1=never 2=some lessons
b) work on problems for which there is no immediately obvious method of solution	2=about half the lessons	3=about half the lessons
c) explain their answers	3=some lessons	4=every or almost every
d) write equations and functions to represent relationships	4=never 8=not administered	lesson 8, 9=missing data
e) relate what they are learning in math to their daily lives	9=omitted	

As explained in Chapter 2, reformed teaching focusing on problem-solving and reasoning emphasizes the teaching of (1) solving complex, non-routine problems that require more cognitive command on the students, (2) encouraging students to justify their solutions to these problems, (3) represent their mathematics ideas and problem-solving approaches in various ways, and (4) connect problem-solving process to students' real life experiences (Hiebert, et al., 2004; NCTM, 2000; Romberg, 1992; Schoenfeld, 2004).

Corresponding to these emphasized aspects in reformed teaching, I selected items a, b, c,

d, and e to indicate reformed teaching. These items are a) decide on their own procedures for solving complex problems, b) work on problems for which there is no immediately obvious method of solution, c) explain their answers, d) write equations and functions to represent relationships, and e) relate what they are learning in mathematics to their daily lives (see Table 1).

In addition, the existing literature suggests that traditional teaching emphasizes basic mathematics skills training such as computation, rote memorization, and routine problem-solving instead of complex problems, as explained in Chapter 2 (Gamoran, 2001; Geary, 1994; Wu, 1999); therefore, I chose items f, g, and h to indicate traditional teaching. These items corresponding to the emphasized aspects in traditional teaching are f) practice adding, subtracting, multiplying, and dividing without using a calculator, g) memorize formulas and procedures, h) apply facts, concepts and procedures to solve routine problems (see Table 2).

The frequency of these items is divided into four levels: *1) in every lesson or almost every lesson, 2) in about half the lessons, 3) in some lessons, and 4) never*. To prepare for factor analysis and multilevel modeling, variable recoding was conducted to reverse the rank of frequency so that larger numbers indicate higher frequency while smaller numbers indicate lower frequency of using these instructional practices (See Table 1 & 2 for details).

Table 2

*Initial Coding and Recoding of TIMSS 2007 Items Indicating Traditional Teaching*

TIMSS item description (How often do teachers ask students to...?)	Original coding	Recoding
f) practice adding, subtracting, multiplying, and dividing without using a calculator	1=every or almost every lesson 2=about half the lessons	1=never 2=some lessons 3=about half the lessons
g) memorize formulas and procedure	3=some lessons	4=every or almost every lesson
h) apply facts, concepts and procedures to solve routine problems	4=never 8=not administered 9=omitted	8, 9=missing data

The above selected variables from question number 17 to indicate reformed or traditional teaching are consistent with prior studies published in high profile books or peer-reviewed journals including the ones hosted by American Educational Research Association (AERA). Among these, two studies used teacher self-reported instructional variables from TIMSS data set (Desimone, Smith, Baker, & Ueno, 2005; Hamilton & Martinez, 2007) and one study used adapted TIMSS variables to indicate either reformed or traditional teaching approaches (Spillane & Zeuli, 1999). Moreover, several other studies also used similar items to describe the two teaching approaches (Hamilton et al., 2003; Le et al., 2009; Mayer, 1999; Smerdon, Burkam, & Lee, 1999). This study, consistent with these above studies, recognizes that although teacher self-reported practice cannot provide in-depth descriptions of teachers' instructional practice as on-site observations do, they do have the strength of involving large population of teachers to

yield findings of external generalizability (Schneider et al., 2007) if they are anonymously obtained (Aquilino, 1994, 1998), behavior-describing instead of behavior-quality judging (Mullens & Gayler, 1999), which is the case for TIMSS 2007 teacher survey. Therefore, the distinction between reformed teaching and traditional teaching in this study is consistent with the definitions used in other studies on mathematics teaching reform in the US.

Despite the difference between the two types of teaching, mathematics teachers do not necessarily use one of the two approaches exclusively in the actual classrooms. Teachers' adoption of a traditional teaching approach does not rule out the possibility that they also use reformed activities, and vice versa (Hamilton & Martinez, 2007; Hamilton et al., 2003); that is, teachers may tend to choose a more reformed or more traditional teaching approach, or they might use a balanced approach between the two to teach their students. Within the constraint of the non-experimental design of TIMSS 2007, this study aims to find out whether one type of teaching approach (reformed or traditional) can be positively related to students' mathematics achievements while controlling for the other approach.

#### **Factor structure of reformed and traditional teaching variables.**

To test whether the two groups of teaching variables can form composite variables to represent the reformed or traditional teaching, I performed factor analysis of

the variables. To construct a single composite variable to represent either reformed or traditional teaching is important for this study because, firstly, using composite variable to describe a certain teaching practice is more reliable and valid than using a single variable item (Mayer, 1999); and secondly, the use of several single, collinear variables in HLM equation can lead to serious model instability while using composite variable can avoid this concern (Raudenbush & Bryk, 2002). In order to construct separate composite variables for reformed and traditional teaching, I first conducted exploratory factor analysis of the variables, and then created two composite variables using the factor scores from the factor analysis.

Before conducting factor analysis, I obtained the descriptive statistics of the variables, which showed that the variables are normally distributed (see Table 3). Although the kurtosis values of “apply facts, concepts,” “practice adding, subtracting,” and “relate to daily life” are larger than 1, they are smaller than 2 and so they are acceptable. Among the total 405 mathematics teachers, 39 did not answer any of the eight items in the questionnaire, reducing the original teacher sample from 405 to 366. In addition, five teachers (IDs 44802, 50901, 56503, 58101, and 60003) were deleted because they only answered some of the reformed or traditional items, which reduced the teacher sample for to 361. However, the sample size of 361 for the teacher sample is still adequate for performing factor analysis of the teachers’ instructional variables (Camrey

& Lee, 1992).

Table 3

*Descriptive Statistics of Reformed and Traditional Teaching Variables*

	N	Mean	SD	Skewness	Kurtosis
Reformed teaching variables					
Decide on own solving problem	364	2.59	0.79	0.53	-0.70
Work on problems	363	2.17	0.73	0.65	0.58
Explain answers	361	3.30	0.82	-0.69	-0.90
Write equations	363	2.56	0.74	0.58	-0.51
Relate to daily life	363	2.80	0.83	0.24	-1.21
Traditional teaching variables					
Practice adding, subtracting	365	2.93	1.04	-0.24	-1.43
Apply facts, concepts	364	3.33	0.77	-0.64	-1.04
Memorize formula	364	2.37	0.75	0.56	0.02

I then examined the factor structures of reformed teaching and traditional teaching items with a series of exploratory factor analyses using the teacher sample. Bivariate correlations, Anti-image matrices, Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO), Bartlett's Test of Sphericity, and Measures of Sampling Adequacy (MSA) were used to determine the factorability of the items, screen plots and the total explained variance were used to determine the number of factors (Tabachnick & Fidell, 2007). Among the correlation coefficients of the five reformed teaching variables and the three traditional variables, some are greater than .30 (see Tables 4), Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) for the variables is .722, which is greater than .50; Bartlett's Test of Sphericity are both significant at .05 level; the values in the anti-image

correlation matrix are small while the Measures of Sampling Adequacy (MSA) values are large for individual variables, which showed that the correlation matrixes of the five reformed variables and the three traditional variables are factorable (Tabachnick & Fidell, 2007).



Table 4

*Correlations of Teaching Variables*

	Apply facts	Decide on own solve	Connect to daily life	Explain answers	Memorize formula	Practice adding	Write equations	Work on problems
Apply facts	1.000							
Decide on own solve	.230**	1.000						
Connect to daily life	.164**	.439**	1.000					
Explain answers	.185**	.383**	.374**	1.000				
Memorize formula	.323**	.208**	.061	.058	1.000			
Practice adding	.197**	-.001	.096*	.006	.138**	1.000		
Write equations	.266**	.261**	.108*	.117*	.265**	-.007	1.000	
Work on problems	.115*	.505**	.268**	.252**	.109*	-.040	.251**	1.000

Note. \*\* Correlation is significant at the 0.01 level (1-tailed). \* Correlation is significant at the 0.05 level (1-tailed).

Finally, principal component analysis with varimax rotation method showed that two factors with eigenvalue greater than 1 were generated for the group of items (the eigenvalues for the reformed teaching and traditional teaching factors were 2.48 and 1.33 respectively) (see Tables 5). The four reformed teaching items had factor loadings ranging from .670 to .813, while the four traditional teaching items had factor loading ranging from .496 to .740, indicating a high degree of consistency among the items (see Tables 6). The variable “write equations and functions to represent relationships,” which was originally classified as a reformed teaching variable according to the emphasis of reformed teaching as discussed in the theoretical framework, turned out to be a variable indicating the traditional teaching. The reformed and traditional teaching factors explained 47.58% of the variance in the eight items (see Tables 5).

Table 4

*Extraction Sums of Squared Loadings of Teacher Classroom Instruction Components*

Factors	Eigenvalue	% of variance	Cumulative %
Reformed teaching	2.48	30.95	30.95
Traditional teaching	1.33	16.64	47.58

The internal reliability scores (Cronbach alpha coefficients) for the four reformed teaching variables and the four traditional teaching variables were .701 and .462 respectively. Although Cronbach’s Alphas of at least .70 are generally desired for designing a survey (Nunnally & Bernstein, 1994), lower alpha values were considered acceptable when the goal was not to design a new survey, but to create composites of

existing survey items that capture various aspects of reformed and traditional instruction (Lubienski, 2006).

Table 5

*Components Generated Along with Item Factor Loadings from Principal Component*

*Analysis with Oblimin Rotation*

Items	Factor loadings	
	Reformed teaching	Traditional teaching
Decide on own solve	.813	.250
Work on problems	.703	.114
Connect to daily life	.686	.107
Explain answers	.670	.073
Memorize formula	.135	.740
Apply facts & concepts	.250	.733
Write equations to represent	.345	.522
Practice adding	-.091	.496

**Creating composite variables for reformed and traditional teaching.**

Finally, I developed composite variables for reformed and traditional teaching by using the factor scores of the two factors from the principal component analysis. Each of the two composite variables is presented below.

*Reformed teaching* was a composite scale composed of the factor score of four items measuring how often teachers use the following to teach mathematics to their students (on a 4-point scale ranging from *never*, *in some lessons*, *in about half the lessons*, to *in every lesson or almost every lesson*): a) decide on their own procedures for solving complex problems, b) work on problems for which there is no immediately obvious

method of solution, c) relate what they are learning in math to their daily lives, and d) explain their answers.

*Traditional teaching* was a composite scale composed of the factor score of the four items that loaded on the traditional teaching factor. These items measure how often teachers use the following to teach mathematics to their students (on a 4-point scale ranging from *never*, *in some lessons*, *in about half the lessons*, to *in every lesson or almost every lesson*): a) memorize formulas and procedures, b) apply facts, concepts and procedures to solve routine problems, c) write equations and functions to represent relationships, and d) practice adding, subtracting, multiplying, and dividing without using a calculator.

The correlation between the reformed and traditional teaching composites is .176. This positive and weak correlation indicates teachers do tend to use both teaching approaches in their actual teaching. The final sample sizes at level 1 (ranging from 214 to 3,599) and at level 2 (ranging from 99 to 318) for each of the four racial groups are presented in Tables 7 & 8. The unbalanced sample size in each classroom and the comparatively larger sample size at level 2 are appropriate for HLM modeling using HLM, which applies empirical Bayesian technique for parameter estimation (Hox, 2010; Raudenbush & Bryk, 2002).

Table 6

*Frequency of Mathematics Teachers and Distribution of Students across Racial Groups in U.S. TIMSS 2007*

Race	No. of math teachers	No. of students per classroom
White, not Hispanic	318	0-39
African American, not Hispanic	187	0-38
Hispanic	275	0-42
Asian	99	0-13

Table 7

*Frequency and Percentage for Different Racial Groups of Students in U.S. TIMSS 2007*

Race	Frequency
White, not Hispanic	3,599
African American, not Hispanic	783
Hispanic	1,554
Asian	214
Total	6,150

### **Data Analytic Approach and Justification**

To answer the four research questions, I conducted data analysis using a two-level hierarchical linear modeling (HLM) approach (Hox, 2010; Raudenbush & Bryk, 2002). This approach is appropriate because the two-stage sampling design of TIMSS 2007 yielded a hierarchical data structure in which students' achievement data belongs to the student level while teacher practices variables dwell at the classroom level (Rutkowski, Gonzalez, Joncas, & von Davier, 2010). This hierarchical structure needs to be addressed by two-level HLM models (Hox, 2010; Raudenbush & Bryk, 2002). When one-level regression approach (e.g., Ordinary Least Square regression) is used to analyze the

two-level data, researchers either aggregate student data to the teacher level, which results in aggregation bias, or aggregate teacher level data to the student level, which violates the basic assumption of independent observation in OLS regression and causes underestimated standard errors that leads to high probability of arriving at inaccurate results (Hox, 2010; Raudenbush & Bryk, 2002). To solve aggregation issue, hierarchical modeling is more appropriate for answering the research questions that involve data at multiple levels (Hox, 2010; Raudenbush & Bryk, 2002).

The common standard regression analysis software systems such as SPSS and SAS assume simple random sampling, thus they cannot handle the complex nonrandom, hierarchical data structure (Foy & Olson, 2009). Currently, the most appropriate multi-level linear regression software for modeling the large data base such as TIMSS and PISA is HLM (Rutkowski et al., 2010). HLM is capable of handling the hierarchical data and enabling the researchers to specify sampling weights at each level (Raudenbush, Bryk, Cheong, & Congdon, 2004b). Therefore, HLM (Raudenbush, Bryk, Cheong, & Congdon, 2004a) was chosen as the analytical software for modeling the relationship between teaching approaches and students' mathematics achievement, as was asked in the research questions.

Since the sampled teachers in TIMSS 2007 data set self-reported identical teaching practices to all the students in one classroom they taught, the study chose to

directly examine the assumptions of reformed and traditional teaching approaches, i.e., the relationship between either teaching approach and the achievements of students across racial groups would be positive and statistically significant, and indirectly investigate the assumption held by culturally relevant pedagogy theory, i.e., the relationship between either teaching approach and the achievements of students across racial groups would not be all positive and statistically significant.

### **Data Analysis Procedures**

#### **Data screening.**

Before model building and analysis, I followed the suggestion for data screening by Raudenbush and Bryk (2002) and examined the normality of Level 1 and Level 2 variables, the linear relationship among the dependent and independent variables, along with the homogeneity of Level 1 and Level 2 variances. Firstly, for the reformed and traditional teaching composite variables, the descriptive statistics showed that the skewness and kurtosis values are within the normal range (see Table 9). No outliers or non-normal data were identified.

Table 8

#### *Descriptive Statistics of Reformed and Traditional Teaching Scales*

	N	Mean	SD	Skewness	Kurtosis
Reformed teaching	363	2.71	0.58	0.15	-0.60
Traditional teaching	366	2.76	0.55	0.08	-0.42

For the achievement measures of Caucasian, African-American, Hispanic, and

Asian-American students, the descriptive statistics indicated that the skewness and kurtosis values of these variables are within the normal range. No outliers, missing values, or non-normal data were identified. For the sake of readability, Tables 10-13 only showed the descriptive statistics of the first plausible value of the achievement measures for the four racial groups.

Table 9

*Descriptive Statistics for the Mathematics Achievement Measures of Caucasian Students*

	N	Mean	SD	Skewness	Kurtosis
1st PV math knowing	3,599	534.27	62.12	-0.08	-0.18
1st PV math applying	3,599	525.12	72.04	-0.17	-0.11
1st PV math reasoning	3,599	524.26	67.60	-0.06	-0.18
1st PV mathematics	3,599	532.79	67.18	-0.07	-0.13
Valid N (listwise)	3,599				

Table 10

*Descriptive Statistics for the Mathematics Achievement Measures of African-American*

*Students*

	N	Mean	SD	Skewness	Kurtosis
1st PV math knowing	783	469.71	60.08	0.14	-0.10
1st PV math applying	783	450.95	68.91	-0.16	-0.15
1st PV math reasoning	783	462.57	66.11	0.02	-0.01
1st PV mathematics	783	454.07	68.351	0.08	-0.07
Valid N (listwise)	783				



Table 11

*Descriptive Statistics for the Mathematics Achievement Measures of Hispanic Students*

	N	Mean	SD	Skewness	Kurtosis
1st PV math knowing	1,554	481.78	65.08	0.20	-0.12
1st PV math applying	1,554	466.07	75.82	-0.12	-0.15
1st PV math reasoning	1,554	475.18	69.11	0.06	-0.19
1st PV mathematics	1,554	471.56	72.89	0.09	-0.19
Valid N (listwise)	1,554				

Table 12

*Descriptive Statistics for the Mathematics Achievement Measures of Asian-American Students*

	N	Mean	SD	Skewness	Kurtosis
1st PV math knowing	214	550.13	62.82	0.02	-0.29
1st PV math applying	214	542.59	70.89	-0.05	-0.38
1st PV math reasoning	214	539.76	65.32	0.15	-0.41
1st PV mathematics	214	549.33	69.16	0.13	-0.25
Valid N (listwise)	214				

I also examined the linear relationship among the dependent and independent variables, and the homogeneity of variance at both levels. Curve estimation showed that the linear relationship between the dependent and independent variables are all significant,  $p < .001$ . The histograms of the standardized residuals showed that the residuals are very close to normal; the scatter plot of ZRESID and ZPRED showed that the points scatter randomly and evenly around the best fitting line; therefore, the assumption of homogeneity of variance is satisfied. For the sake of readability, only the histogram and

scatter plots of the first plausible value of Caucasian student are presented here.

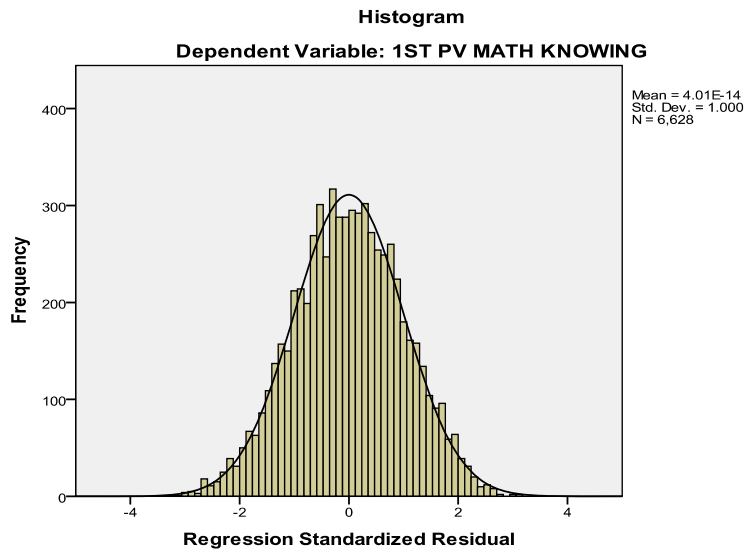


Figure 2. A histogram of the first plausible value of math knowing for Caucasian students.

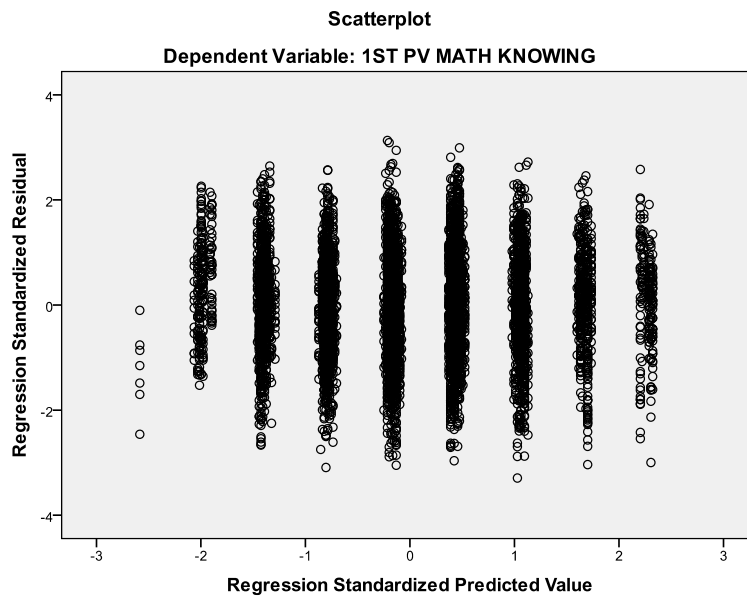
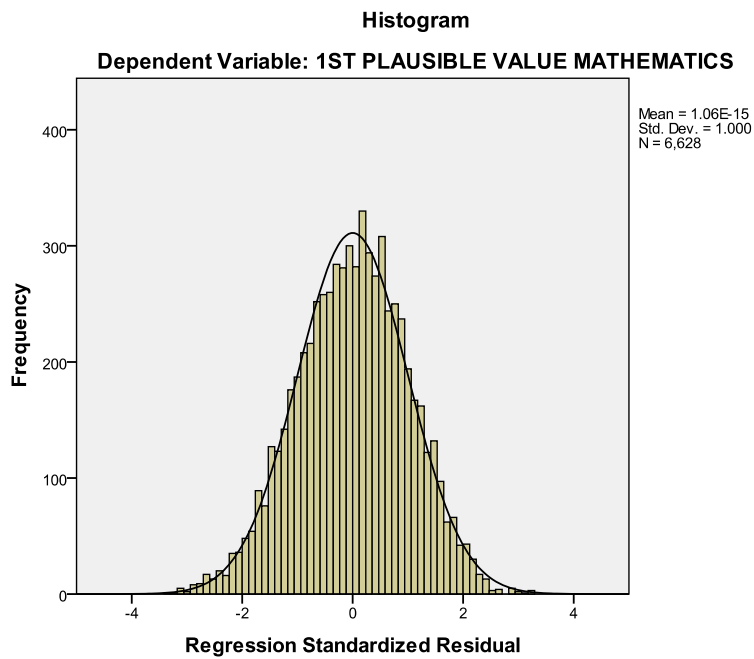
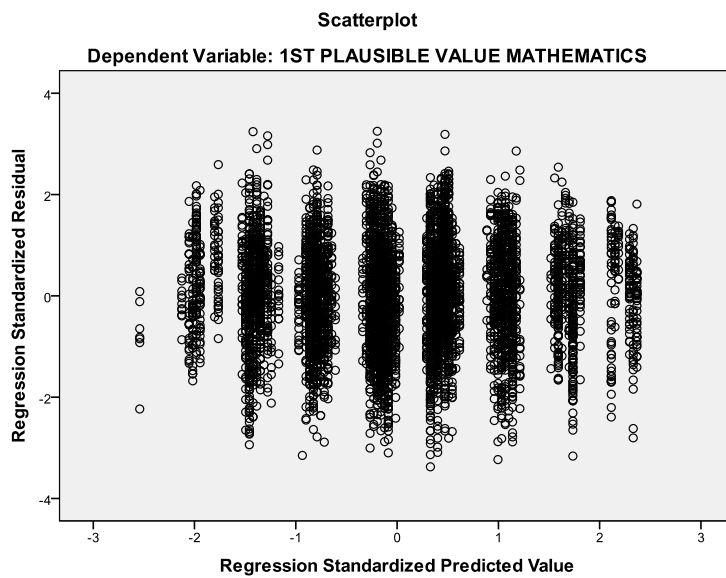


Figure 3. A scatter plot of the first plausible value of math knowing for Caucasian students.



*Figure 4.* A histogram of the first math plausible value for Caucasian students.



*Figure 5.* A scatter plot of the first math plausible value for Caucasian students.

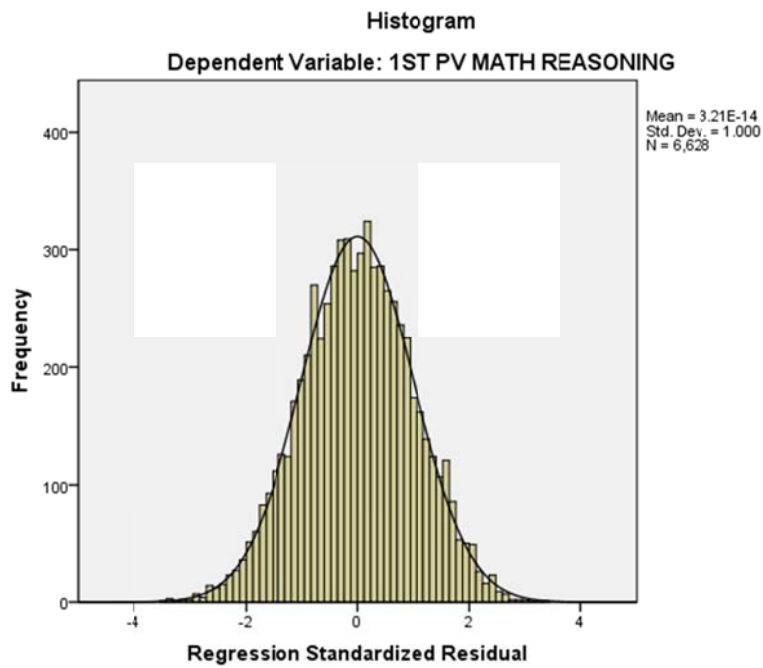


Figure 6. A histogram of the first math reasoning plausible value for Caucasian students.

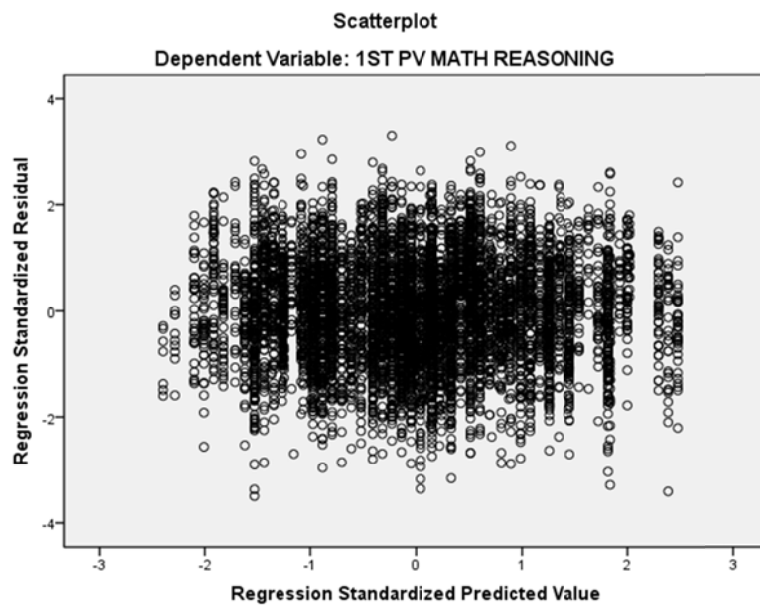


Figure 7. A scatter plot of the first math reasoning plausible value for Caucasian students.

### **Creating two-level data files.**

To answer the four research questions, I conducted the following steps of analysis using two-level hierarchical linear modeling. Some steps, such as creating two-level data files, building level 1 and level 2 unconditional model equations, variance partitioning, and building level 1 conditional model equations, are very similar for answering all four questions. Therefore, I will describe these steps in the first place. The actual steps in building level 2 conditional model equations differ for answering the four research questions, thus I will elaborate separately on how to create these level 2 conditional model equations for each research question lastly.

The data files at the student level and teacher level both contain the variable “Teacher ID” that links a student with a teacher who taught the student. The student level data also contains student racial background variables that were dummy coded into three vectors such that in each vector, one of the four racial groups was represented by “1” whereas all the other racial groups were represented by “0.”

In addition, students’ achievement data was contained in the student level as well. The classroom level data has teaching practice composite variables that were already created and would be used as predictors for students’ achievement or covariate. Separate data files at the student and classroom levels were created according to the recommendation of Raudenbush and Bryk (2002).

### **Model building.**

The model building process is similar for answering the first and second research question, while the model building process is similar for answering the third and fourth research question. I will first present how to build the HLM models for addressing the first and second research question, and then I will present the model HLM building process for addressing the third and fourth research question.

#### ***Model building for research question 1 and 2.***

*Unconditional model.* The first stage of the analysis was building unconditional models that are the simplest models without predictor variables from any level to partition the total variance in students' mathematics achievements (overall mathematics, problem-solving and basic mathematics skills achievement respectively) into within-, and between-classroom components to estimate the intraclass correlations (ICC), an indicator of the appropriateness of the application of a multi-level modeling approach (Raudenbush & Bryk, 2002).

At the student level, equation (1) treats the overall mathematics achievement, problems solving, or basic skills achievement of student  $i$  with teacher  $j$  as a function of the classroom mean achievement,  $\beta_{0j}$ , and each student's deviation from that mean,  $r_{ij}$ , a level 1 random error that assumes normal distribution with a mean of 0 and variance of  $\sigma^2$ :

$$Y_{ij} = \beta_{0j} + r_{ij} \quad (1)$$

In equation (2), the classroom mean mathematics achievement,  $\beta_{0j}$ , which is the intercept at level one, is modeled as a function of the grand mean score,  $\gamma_{00}$ , and a classroom-specific random error,  $u_{0j}$ , a level 2 random error that assumes normal distribution with a mean of 0 and variance of  $\tau_{00}$ :

$$\beta_{0j} = \gamma_{00} + u_{0j} \quad (2)$$

Then the combined model with fixed effect  $\gamma_{00}$  and random effect  $u_{0j} + r_{ij}$  would be:

$$Y_{ij} = \gamma_{00} + u_{0j} + r_{ij} \quad (3)$$

*Variance partitioning.* The two-level model built above partitions the total variance in students' achievement into a within-classroom component,  $\sigma^2$ , and a between-classroom component,  $\tau_{00}$ . Then the intraclass correlation coefficients (ICC) can be calculated to estimate the appropriateness of using a two-level HLM modeling by following the formula below:

$$ICC = \frac{\tau_{00}}{\tau_{00} + \sigma^2} \quad (4)$$

*Conditional models.* The fully conditional model was then gradually built to estimate how much variance is attributed to the student level and the teacher level, and to answer whether reformed or traditional teaching approach is related to Caucasian, African-American students' mathematics achievements. At the student level, dummy

coded racial vectors were added first, and then at the teacher level, the teaching practice variables were added. In the following, I will present how to build the conditional models using Caucasian students as the dummy coded reference group in order to answer whether reformed or traditional teaching approach is related to Caucasian students' mathematics achievements.

*Level-1 model.* The dummy coded student racial background vectors were added as independent variables to the Level-1 equation to further partition the variance at both levels. The student level equation is as follows:

$$Y_{ij} = \beta_{0j} + \beta_{1j}(Hisp) + \beta_{2j}(Black) + \beta_{3j}(Asian) + r_{ij} \quad (5)$$

Where,  $Y_{ij}$  is one of the three mathematics achievement scores (i.e., overall mathematics score, problems solving score and basic skill score) for student  $i$  with teacher  $j$  (i.e., in a classroom taught by teacher  $j$ );  $\beta_{0j}$  is the mean mathematics achievement score for Caucasian students serving as the reference group that was dummy coded as 0,  $\beta_{1j}, \beta_{2j}, \beta_{3j}$  are the racial achievement difference due to a racial group taught by teacher  $j$  for Hispanic, African-American, and Asian-American students respectively, and  $r_{ij}$  is the student level random error.

*Level-2 model.* The intercept and slopes of equation (5) at the student level was used as outcomes in the teacher-level model equations. First, the traditional teaching composite variable was entered to Level-2 equation with grand mean centered and as



assumed to have fixed effects across classrooms to obtain the traditional teaching model; then the traditional teaching variable was replaced by the reformed teaching composite variable with grand mean centered and as assumed to have fixed effects across classrooms in the Level-2 equation to obtain the reformed teaching model. In the end, both traditional and reformed teaching variables were entered into the level-2 equation together to obtain the full model. The Level-2 fixed effects full-model equations are as follows:

$$\beta_{0j} = \gamma_{00} + \gamma_{01}(RfmTch) + \gamma_{02}(TrdTch) + u_{0j} \quad (6)$$

$$\beta_{1j} = \gamma_{10} + \gamma_{11}(RfmTch) + \gamma_{12}(TrdTch) + u_{1j} \quad (7)$$

$$\beta_{2j} = \gamma_{20} + \gamma_{21}(RfmTch) + \gamma_{22}(TrdTch) + u_{2j} \quad (8)$$

$$\beta_{3j} = \gamma_{30} + \gamma_{31}(RfmTch) + \gamma_{32}(TrdTch) + u_{3j} \quad (9)$$

Where in equation (6),  $\gamma_{00}$  is the control group's average class mathematics achievement score across all teachers;  $\gamma_{01}, \gamma_{02}$  are the slopes for classroom level predictors (reformed teaching and traditional teaching composite variables) that describes their possible relationship to the student level intercept; and  $u_{0j}$  is the teacher level random effect. In equation (7),  $\gamma_{10}$  is the difference between Caucasian and Hispanic students in the average class mathematics achievement score across all teachers;  $\gamma_{11}, \gamma_{12}$  are the difference in the slopes for the teacher level predictor s (reformed teaching and traditional teaching composite variables) that describe their possible relationship to the student level effect between Caucasian and Hispanic students;  $u_{1j}$  is the teacher level random effect.

Equations (8) and (9) can be interpreted similarly as equation (7), the difference being that equations (8) and (9) are about African-American and Asian-American students respectively.

To answer whether reformed or traditional teaching approach is related to African-American, Hispanic, and Asian-American students' mathematics achievements, a similar modeling building process at Level 1 and Level 2 was used. The major difference was the use of other racial groups other than Caucasian students as the reference group in dummy coding. The explanation of the Level 1 and Level 2 equations is also similar.

***Model building for research question 3 and 4.***

*Unconditional model.* The first stage of the analysis was building unconditional models that are the simplest models without predictor variables from any level to partition the total variance in students' mathematics achievements (problem-solving and basic mathematics skills achievement respectively) into within-, and between-classroom components to estimate the intraclass correlations (ICC), an indicator of the appropriateness of the application of a multi-level modeling approach (Raudenbush & Bryk, 2002).

At the student level, equation (10) treats the problems solving or basic skills achievement of student  $i$  with teacher  $j$  as a function of the classroom mean achievement,

$\beta_{0j}$ , and each student's deviation from that mean,  $r_{ij}$ , a level-1 random error that assumes normal distribution with a mean of 0 and variance of  $\sigma^2$ :

$$Y_{ij} = \beta_{0j} + r_{ij} \quad (10)$$

In equation (11), the classroom mean mathematics achievement,  $\beta_{0j}$ , which is the intercept at level one, is modeled as a function of the grand mean score,  $\gamma_{00}$ , and a classroom-specific random error,  $u_{0j}$ , a level 2 random error that assumes normal distribution with a mean of 0 and variance of  $\tau_{00}$ :

$$\beta_{0j} = \gamma_{00} + u_{0j} \quad (11)$$

Then the combined model with fixed effect  $\gamma_{00}$  and random effect  $u_{0j}$ ,  $r_{ij}$  would be:

$$Y_{ij} = \gamma_{00} + u_{0j} + r_{ij} \quad (12)$$

*Variance partitioning.* The two-level model built above partitions the total variance in students' achievement into a within-classroom component,  $\sigma^2$ , and a between-classroom component,  $\tau_{00}$ . Then the intraclass correlation coefficients (ICC) can be calculated to estimate the appropriateness of using a two-level HLM modeling by following the formula below:

$$ICC = \frac{\tau_{00}}{\tau_{00} + \sigma^2} \quad (13)$$

*Conditional models.* In order to obtain the conditional models, firstly, dummy coded variables were entered to Level-1 equation to further partition the variance at both

levels. Then students' problem-solving achievement was entered to Level-1 equation to obtain the problem-solving model for answering the third research question, and students' basic skills achievement was entered to Level-1 equation to obtain the basic skills model for answering the fourth research question. After that, traditional teaching composite variable was entered to Level-2 equation to obtain the traditional teaching model. Then the traditional teaching variable was replaced by the reformed teaching composite variable at Level-2 equation to obtain the reformed teaching model. In the end, problem-solving or basic skills achievement variable, traditional and reformed teaching variables were retained in the level-2 equation together to obtain the full model.

In the following, I will present how to build the conditional models using Caucasian students as the dummy coded reference group in order to answer the third and fourth research questions, i.e., controlling for traditional teaching, whether students' problem-solving score significantly predict their basic mathematics knowledge and skills score when they are exposed to more or less reformed teaching, and controlling for reformed teaching, whether students' basic mathematics knowledge and skills score significantly predict their problem-solving score when they are exposed to more or less traditional teaching.

*Level-1 model.* The dummy coded student racial background vectors were first added as independent variables to the student level. Then, students' problem-solving

achievement was added to level-1 equations for answering the third research question.

Similarly, students' basic skills achievement was added to level-1 equations for answering the fourth research question. The student level equation was as follows:

$$Y_{ij} = \beta_{0j} + \beta_{1j}(Hisp) + \beta_{2j}(Black) + \beta_{3j}(Asian) + \beta_{4j}(Pr bslvAch / BskillAch) + r_{ij} \quad (14)$$

Where,  $Y_{ij}$  is one of the two mathematics achievement scores (i.e., problems solving score or basic skill score) for student  $i$  with teacher  $j$  (i.e., in a classroom taught by teacher  $j$ );  $\beta_{0j}$  is the mean mathematics achievement score for Caucasian students serving as the reference group that was dummy coded as 0,  $\beta_{1j}, \beta_{2j}, \beta_{3j}$  are the racial achievement differences due to a racial group taught by teacher  $j$  for Hispanic, African-American, and Asian-American students respectively,  $\beta_{4j}$  is the slope for the student level predictor (problem-solving achievement for the third research question or basic skills achievement for the fourth research question) that describe its possible relationship with the student level dependent variable, and  $r_{ij}$  is the student level random error.

*Level-2 model.* The intercept and slopes of equation (14) at the student level were used as outcomes in the teacher-level model equations. The covariate for the third research question, traditional teaching composite variable, or the covariate for the fourth research question, reformed teaching composite variable, was added to the level-2 equations first. Then, reformed teaching composite variable was added to level-2 equations with grand mean centered and as assumed to have fixed effects across

classrooms for answering research question 3. Similarly, traditional teaching composite variable was added to level-2 equations with grand mean centered and as assumed to have fixed effects across classrooms for answering research question 4.

The Level-2 fixed effects equations are as follows:

$$\beta_{0j} = \gamma_{00} + \gamma_{01}(RfmTch) + \gamma_{02}(TrdTch) + u_{0j} \quad (15)$$

$$\beta_{1j} = \gamma_{10} + \gamma_{11}(RfmTch) + \gamma_{12}(TrdTch) + u_{1j} \quad (16)$$

$$\beta_{2j} = \gamma_{20} + \gamma_{21}(RfmTch) + \gamma_{22}(TrdTch) + u_{2j} \quad (17)$$

$$\beta_{3j} = \gamma_{30} + \gamma_{31}(RfmTch) + \gamma_{32}(TrdTch) + u_{3j} \quad (18)$$

$$\beta_{4j} = \gamma_{40} + \gamma_{41}(RfmTch) + \gamma_{42}(TrdTch) + u_{4j} \quad (19)$$

Where in equation (15),  $\gamma_{00}$  is the control group's average class mathematics achievement score across all teachers;  $\gamma_{01}, \gamma_{02}$  are the slopes for classroom level predictors (reformed teaching and traditional teaching composite variables) that describes their possible relationship to the student level intercept; and  $u_{0j}$  is the teacher level random effect. In equation (16),  $\gamma_{10}$  is the difference between Caucasian and Hispanic students in the average class mathematics achievement score across all teachers;  $\gamma_{11}, \gamma_{12}$  are the differences in the slopes for the teacher level predictors (reformed teaching and traditional teaching composite variables) that describe their possible relationship to the student level effect between Caucasian and Hispanic students;  $u_{1j}$  is the teacher level random effect. Equations (17) and (18) can be interpreted similarly as equation (16), the

difference being that equations (17) and (18) are about African-American and Asian-American students respectively. In equation (19),  $\gamma_{40}$  is the average teaching practice effect on students across all teachers;  $\gamma_{41}, \gamma_{42}$  are the slopes for the teacher level predictor of teacher practice variable (reformed teaching and traditional teaching composite variables) that describe their possible relationship to the student level effect;  $u_{4j}$  is the teacher level random effect.

To answer whether the problems solving achievement predicts basic skills achievement, or whether the basic skills achievement predicts problems solving achievement for African-American, Hispanic, and Asian-American students, a similar model building process at Level 1 and Level 2 was used. The major difference was the use of other racial groups other than Caucasian students as the reference group in dummy coding. The explanation of the Level 1 and Level 2 equations is also similar.

The variables from the reformed and traditional teaching approaches were entered into the equations in the final models as predictors simultaneously, which acknowledged the fact that teachers do use both approaches in their actual teaching. For the interpretation of the results, if only  $\gamma_{01}$  (reformed teaching) in equation (6) about Caucasian American students is found to be positive and statistically significant, then it can be interpreted that, when holding constant the effect of traditional teaching, reformed teaching has a positive and statistically significant relationship with Caucasian American

students' mathematics achievement (e.g., overall achievement, problems solving or basic skills score); while when holding constant the effect of reformed teaching, traditional teaching does not have a significant relationship with Caucasian American students' mathematics achievement (e.g., overall achievement, problems solving or basic skills score).

### **Sampling weights.**

In order to make the findings from the study more generalizable to the target population of the eighth graders in the TIMSS 2007 study, proper weighting need to be considered and applied to account for the unequal sampling probabilities in the TIMSS 2007 sampling framework (Foy & Olson, 2009). The two level model estimates in this dissertation were weighted at the student level based on the advice from Williams et al (2009), as TIMSS 2007 surveyed national representative sample of students instead of the teachers.



## **CHAPTER FIVE: RESULTS**

The analysis from the two-level hierarchical linear modeling leads to several interesting results. First, I present the findings about the relationships between reformed and traditional teaching and students' overall mathematics achievement, problem-solving achievement, basic mathematics knowledge and skills achievement across different racial groups respectively. Second, I present the findings regarding whether students' problems solving achievement can predict their basic skills achievement when they are exposed to more or less reformed teaching. Last, I report the findings regarding whether students' basic skills achievement can predict their problems solving achievement when they are exposed to more or less traditional teaching approach.

### **Relationship between Reformed, Traditional Teaching and Students' Overall**

#### **Mathematics Achievement**

In the analysis of a series of models with students' overall mathematics achievement as the dependent variable, the intraclass correlation (ICC) coefficients from the base model was .53,  $p < .001$ , which indicated that substantial variability in students' total mathematics achievement can be attributed to the classroom level and the use of hierarchical linear modeling is warranted (see Table 14).

Table 14

*Hierarchical Linear Modeling Results from the Empty and Racial Vector Models across Four Racial Groups with Students' Overall*

*Mathematics Achievement as the Dependent Variable*

Variables	Caucasian	African-American	Hispanic	Asian-American
	Fixed effects (parameter (standard error))			
Empty model ( $\gamma_{00}$ )	505.72 (3.33)***	505.72 (3.33)***	505.72 (3.33)***	505.72 (3.33)***
Vector model ( $\gamma_{00}$ )	518.72 (3.08)***	478.33 (3.95)***	488.91 (3.54)***	530.42 (5.03)***
	Random effects			
Empty model $\tau_{00} / \sigma^2$	3233.25***/2904.30	3233.25***/2904.30	3233.25***/2904.30	3233.25***/2904.30
$\chi^2$ (df)	6481.85 (359)	6481.85 (359)	6481.85 (359)	6481.85 (359)
Vector model $\tau_{00} / \sigma^2$	2458.30***/2757.42	2653.73***/2757.69	2719.69***/2757.22	2140.62***/2758.02
$\chi^2$ (df)	176.71 (40)	108.81 (40)	122.97 (40)	52.79 (40)
	Proportion of variance explained			
Empty model	Level 2/Level 1 53%/47%	Level 2/Level 1 53%/47%	Level 2/Level 1 53%/47%	Level 2/Level 1 53%/47%
Vector model	24%/5%	18%/5%	16%/5%	22%/4%
	Deviance/Number of estimated parameters			
Empty model	67476.43/3	67476.43/3	67476.43/3	67476.43/3
Vector model	67159.84/15	67159.78/15	67159.79/15	67159.92/15

Note. \* $P < .05$ . \*\* $P < .01$ . \*\*\* $P < .001$ .

When the dummy coded racial vectors were added to the level-1 equation, the variance in the overall mathematics achievement was reduced by 24%, 18%, 16%, and 22% at level-2, and by 5%, 5%, 5%, and 4% at level-1 for Caucasian, African-American, Hispanic, and Asian-American students respectively (see Table 14)..

Then the traditional teaching variable was added to level-2 equation to obtain the traditional teaching model. Compared with the racial vector model, traditional teaching composite variable reduced the variance in students' overall mathematics achievement at Level 2 by 5%, 2%, 5%, and 4% for Caucasian, African-American, Hispanic, and Asian-American students respectively, but it only reduced less than 1% of the variance at Level 1 for all the four racial groups. Substantial variance in students' overall mathematics achievement at Level 2 still exists, all  $ps < .001$ . Results from the traditional teaching model showed that, when using only the traditional teaching variable as the predictor in the model, a statistically significant relationship was found between traditional teaching and the overall mathematics achievement of Caucasian students ( $\gamma_{01} = 10.77$ ,  $t(358) = 3.58$ ,  $p < .001$ ) and Hispanic students ( $\gamma_{01} = 11.55$ ,  $t(358) = 3.34$ ,  $p < .001$ ), indicating that every unit increase in teachers' use of traditional teaching is associated with 10.77 and 11.55 points increase in the overall mathematics achievement of Caucasian and Hispanic students respectively. However, traditional teaching was not significantly related to African and Asian-American students' overall mathematics achievement, all  $ps > .05$  (see

Table 15).

In the reformed teaching model, reformed teaching composite variable was added to the level-2 equation and this model was compared with the racial vector model, which showed that reformed teaching composite variable reduced the variance in students' overall mathematics achievement at Level 2 by 3%, 6%, and 4% for Caucasian, African-American, and Hispanic students respectively, but it did not reduce any variance in Asian-American students' overall mathematics achievement at Level 2. Besides, reformed teaching composite variable reduced the variance in students' overall mathematics achievement at Level 1 by less than 1% for Caucasian, African-American, Hispanic, and Asian-American students respectively. Substantial variance in students' overall mathematics achievement at Level 2 still exist for all the four racial groups, all  $ps < .001$  (see Table 15).

Table 15

*Hierarchical Linear Modeling Results from the Traditional and Reformed Teaching Models across Four Racial Groups with Students'*

*Overall Mathematics Achievement as the Dependent Variable*

Variables	Caucasian	African-American	Hispanic	Asian American
Fixed effects (parameter (standard error))				
TradTch model ( $\gamma_{00}$ )	518.56 (3.01)***	478.34 (3.91)***	488.38 (3.47)***	530.18 (4.96)***
TradTch ( $\gamma_{01}$ )	10.77 (3.01)***	5.21 (4.00)	11.55 (3.46)***	5.73 (5.30)
RfTch model ( $\gamma_{00}$ )	519.05 (3.04)***	477.83 (3.90)***	488.94 (3.49)***	529.46 (5.01)***
RfTch ( $\gamma_{01}$ )	9.56 (3.07)**	11.59 (4.00)**	9.63 (3.49)**	-1.07 (5.28)
Random effects				
TradTch model $\tau_{00} / \sigma^2$	2757.42*** / 2343.55	2609.11*** / 2758.89	2580.08*** / 2758.26	2049.52*** / 2759.05
$\chi^2$ (df)	188.06 (39)	114.87 (39)	126.47 (39)	55.71 (39)
RfTch model $\tau_{00} / \sigma^2$	2758.36*** / 2382.71	2495.72*** / 2756.47	2617.92*** / 2756.21	2206.97*** / 2756.35
$\chi^2$ (df)	165.68 (39)	93.06 (39)	109.68 (39)	52.54 (39)
$\chi^2$ (df)	174.81 (38)	95.88 (38)	116.92 (38)	54.94 (38)
Proportion of variance explained				
	Level 2/Level 1	Level 2/Level 1	Level 2/Level 1	Level 2/Level 1
TradTch model	5%/0%	2%/0%	5%/0%	4%/0%
RfTch model	3%/0%	6%/0%	4%/0%	-3%/0%
Deviance/Number of estimated parameters				
TradTch model	67141.05/19	67141.02/19	67141.02/19	67141.11/19
RfTch model	67142.294/19	67142.259/19	67142.27/19	67142.35/19

Note. \*  $P < .05$ . \*\*  $P < .01$ . \*\*\*  $P < .001$ .

Result from the reformed teaching model showed that, when using only the reformed teaching variable as the predictor in the model, a statistically significant relationship was found between reformed teaching and the overall mathematics achievement of Caucasian students ( $\gamma_{01} = 9.56$ ,  $t(358) = 3.11$ ,  $p = .002$ ), African-American students ( $\gamma_{01} = 11.59$ ,  $t(358) = 2.90$ ,  $p = .004$ ), and Hispanic students ( $\gamma_{01} = 9.63$ ,  $t(358) = 2.76$ ,  $p = .006$ ), indicating that every unit increase in teachers' use of reformed teaching is associated with 9.56, 11.59, and 9.63 points increase in the overall mathematics achievement of Caucasian, African-American, and Hispanic students respectively. However, a non-significant relationship was found between reformed teaching and the overall mathematics achievement of Asian-American students,  $p > .05$  (see Table 15).

In the full model, reformed and traditional teaching composite variables together reduced the variance in students' overall mathematics achievement at Level 2 by 6%, 8%, and 8% for Caucasian, African-American, and Hispanic students respectively. Again, both teaching variables did not reduce any variance in Asian-American students' overall mathematics achievement at Level 2. In addition, both teaching composite variables together reduced the variance in students' overall mathematics achievement at Level 1 by less than 1% for Caucasian, African-American, Hispanic, and Asian-American students. Substantial variance in students' overall mathematics achievement at Level 2 still exist for all the four racial groups, all  $ps < .001$  (see Table 16).

Results from the full model showed that, firstly, when controlling for reformed teaching, a statistically significant relationship was found between traditional teaching and overall mathematics achievement for Caucasian students ( $\gamma_{01} = 9.37$ ,  $t(357) = 3.08$ ,  $p = .002$ ) and Hispanic students ( $\gamma_{01} = 10.18$ ,  $t(357) = 2.94$ ,  $p = .003$ ), indicating that every unit increase in teachers' use of traditional teaching is associated with 9.37 and 10.18 points increase in Caucasian and Hispanic students' overall mathematics achievement respectively. However, no significant relationship was found between traditional teaching and the overall mathematics achievement of African-American and Asian-American students, both  $ps > .05$  (see Table 16).

Secondly, when controlling for traditional teaching, a statistically significant relationship was found between reformed teaching and the overall mathematics achievement for Caucasian students ( $\gamma_{01} = 7.90$ ,  $t(357) = 2.56$ ,  $p = .011$ ), African-American students ( $\gamma_{01} = 11.37$ ,  $t(357) = 2.78$ ,  $p = .006$ ), and Hispanic students ( $\gamma_{01} = 8.00$ ,  $t(357) = 2.30$ ,  $p = .022$ ), indicating that every unit increase in teachers' use of reformed teaching is associated with 7.90, 11.37, and 8.00 points increase in Caucasian, African-American, and Hispanic students' overall mathematics achievement respectively. However, no significant relationship was found between reformed teaching and overall mathematics achievement of Asian-American students,  $p > .05$  (see Table 16).

Table 16

*Hierarchical Linear Modeling Results from the Full Models across Four Racial Groups with Students' Overall Mathematics Achievement as the Dependent Variable*

Variables	Caucasian	African-American	Hispanic	Asian American
Fixed effects (parameter (standard error))				
Full model ( $\gamma_0$ )	518.84 (2.99) <sup>***</sup>	477.79 (3.85) <sup>***</sup>	488.46 (3.43) <sup>***</sup>	529.28 (4.96) <sup>***</sup>
TradTch ( $\gamma_{11}$ )	9.37 (3.04) <sup>**</sup>	2.79 (4.04)	10.18 (3.47) <sup>**</sup>	5.26 (5.37)
RfTch ( $\gamma_{12}$ )	7.90 (3.08) <sup>*</sup>	11.37 (4.09) <sup>**</sup>	8.00 (3.48) <sup>*</sup>	-2.27 (5.30)
Random effects				
Full model $\tau_{00} / \sigma^2$	2300.98 <sup>***</sup> / 2756.67	2443.87 <sup>***</sup> / 2757.81	2502.70 <sup>***</sup> / 2757.29	2146.90 <sup>***</sup> / 2757.31
$\chi^2$ (df)	174.81 (38)	95.88 (38)	116.92 (38)	54.94 (38)
Proportion of variance explained				
Full model	Level 2/Level 1 6%/0%	Level 2/Level 1 8%/0%	Level 2/Level 1 8%/0%	Level 2/Level 1 0%/0%
Full model	Deviance/Number of estimated parameters 67126.27/23			
	67126.26/23			
	67126.30/23			

Note. <sup>\*</sup>  $P < .05$ . <sup>\*\*</sup>  $P < .01$ . <sup>\*\*\*</sup>  $P < .001$ .



In addition, the parameter estimates of traditional teaching are larger than those of reformed teaching for both Caucasian and Hispanic students, which indicated that, compared with reformed teaching, traditional teaching has a stronger effect on the overall mathematics achievements of Caucasian and Hispanic students. However, for African-American students, the opposite is true, i.e., reformed teaching has a much stronger effect than the traditional teaching on African-American students' overall mathematics achievement (see Table 16).

### **Relationship between Reformed, Traditional Teaching and Students'**

#### **Problem-Solving Achievement**

In the analysis of a series of models with students' problem-solving achievement as the dependent variable, the intraclass correlation (ICC) coefficient from the base model was .41,  $p < .001$ , indicating that substantial variability in students' problem-solving achievement can be attributed to the classroom level and the use of hierarchical linear modeling is warranted. When the dummy coded racial vectors were added to the level-1 equation, the variance in the problem-solving achievement was reduced by 22%, 29%, 17%, and 23% at level-2, and by 3% at level-1 for Caucasian, African-American, Hispanic, and Asian-American students respectively (see Table 17).

Table 17

## Hierarchical Linear Modeling Results from the Empty and Racial Vector Models across Four Racial Groups with Students'

## Problem-Solving Achievement as the Dependent Variable

Variables	Caucasian	African-American	Hispanic	Asian American
	Fixed effects (parameter (standard error))			
Empty model ( $\tau_{00}$ )	502.38 (2.81)***	502.38 (2.81)***	502.38 (2.81)***	502.38 (2.81)***
Vector model ( $\tau_{00}$ )	513.42 (2.69)***	478.76 (3.49)***	487.38 (3.17)***	520.92 (5.10)***
	Random effects			
Empty model $\tau_{00} / \sigma^2$	2216.80*** / 3189.22	2216.80*** / 3189.22	2216.80*** / 3189.22	2216.80*** / 2904.30
$\chi^2$ (df)	4213.52 (359)	4213.52 (359)	4213.52 (359)	4213.52 (359)
Vector model $\tau_{00} / \sigma^2$	1726.73*** / 3095.94	1567.24*** / 3096.32	1843.00*** / 3096.77	1700.56*** / 3096.94
$\chi^2$ (df)	113.98 (40)	80.76 (40)	86.42 (40)	51.92 (40)
	Proportion of variance explained			
	Level 2/Level 1	Level 2/Level 1	Level 2/Level 1	Level 2/Level 1
Empty model	41.0%/49%	41.0%/49%	41.0%/49%	41.0%/49%
Vector model	22%/3%	29%/3%	17%/3%	23%/3%
	Deviance/Number of estimated parameters			
Empty model	67896.55/3	67896.55/3	67896.55/3	67896.55/3
Vector model	67688.40/15	67688.41/15	67688.43/15	67688.48/15

Note. \*  $P < .05$ . \*\*  $P < .01$ . \*\*\*  $P < .001$ .

In the traditional teaching model with only traditional teaching variable as the predictor, traditional teaching composite variable reduced the variance in students' problem-solving achievement at Level 2 by 4%, 1%, 6%, and 4% for Caucasian, African-American, Hispanic, and Asian-American students respectively, but it only reduced less than 1% of the variance at Level 1 for all the four racial groups. Substantial variance in students' problem-solving achievement at Level 2 still exist, all  $ps < .001$ . Results from the traditional teaching model showed that, using only traditional teaching variable as the predictor, a statistically significant relationship was found between traditional teaching and the problem-solving achievement of Caucasian students ( $\gamma_{01} = 8.29$ ,  $t(358) = 3.14$ ,  $p = .002$ ) and Hispanic students ( $\gamma_{01} = 9.76$ ,  $t(358) = 3.17$ ,  $p = .002$ ), indicating that every unit increase in teachers' use of traditional teaching is associated with 8.29 and 9.76 points increase in the problem-solving achievement of Caucasian and Hispanic students respectively. However, the relationship between traditional teaching and the problem-solving achievement of African and Asian-American students was non-significant, both  $ps > .05$  (see Table 18).

In the reformed teaching model with reformed teaching variable as the predictor, reformed teaching composite variable reduced the variance in students' problem-solving achievement at Level 2 by 2%, 10%, and 4% for Caucasian, African-American, and Hispanic students respectively, but it did not reduce any variance in Asian-American

students' problem-solving achievement at Level 2. Besides, reformed teaching composite variable reduced the variance in students' problem-solving achievement at Level 1 by less than 1% for Caucasian, African-American, Hispanic, and Asian-American students.

Substantial variance in students' problem-solving achievement at Level 2 still exist for all the four racial groups, all  $ps < .001$ . Results from the reformed teaching model showed that, when using only the reformed teaching variable as the predictor, a statistically significant relationship was found between reformed teaching and the problem-solving achievement of Caucasian students ( $\gamma_{01} = 6.83$ ,  $t(358) = 2.53$ ,  $p = .012$ ), African-American students ( $\gamma_{01} = 11.78$ ,  $t(358) = 3.33$ ,  $p < .001$ ), and Hispanic students ( $\gamma_{01} = 8.98$ ,  $t(358) = 2.89$ ,  $p = .004$ ), indicating that every unit increase in teachers' use of reformed teaching is associated with 6.83, 11.78, and 8.98 points increase in the problem-solving achievement of Caucasian, African-American, and Hispanic students respectively. However, a non-significant relationship was found between reformed teaching and the problem-solving achievement of Asian-American students,  $p > .05$  (see Table 18).

Table 18

## Hierarchical Linear Modeling Results from the Traditional and Reformed Models across Four Racial Groups with Students'

## Problem-Solving Achievement as the Dependent Variable

Variables	Caucasian	African-American	Hispanic	Asian American
	Fixed effects (parameter (standard error))			
TradTch model ( $\gamma_{00}$ )	513.29 (2.64) <sup>***</sup>	478.71 (3.47) <sup>***</sup>	486.82 (3.10) <sup>***</sup>	520.63 (5.03) <sup>***</sup>
TradTch ( $\gamma_{01}$ )	8.29 (2.64) <sup>**</sup>	3.88 (3.57)	9.76 (3.08) <sup>**</sup>	5.62 (5.41)
RfTch model ( $\gamma_{00}$ )	513.60 (2.67) <sup>***</sup>	477.75 (3.43) <sup>***</sup>	487.47 (3.12) <sup>***</sup>	520.40 (5.12) <sup>***</sup>
RfTch ( $\gamma_{01}$ )	6.83 (2.70) <sup>*</sup>	11.78 (3.53) <sup>***</sup>	8.98 (3.10) <sup>**</sup>	0.49 (5.43)
	Random effects			
TradTch model $\tau_{00} / \sigma^2$	1657.46 <sup>***</sup>	1547.11 <sup>***</sup>	1738.41 <sup>***</sup>	1627.95 <sup>***</sup>
$\chi^2$ (df)	119.43 (39)	83.13 (39)	88.33 (39)	54.46 (39)
RfTch model $\tau_{00} / \sigma^2$	1691.42 <sup>***</sup>	1415.02 <sup>***</sup>	1763.65 <sup>***</sup>	1764.51 <sup>***</sup>
$\chi^2$ (df)	109.60 (39)	66.52 (39)	76.00 (39)	51.59 (39)
	Proportion of variance explained			
	Level 2/Level 1	Level 2/Level 1	Level 2/Level 1	Level 2/Level 1
TradTch model	4%/0%	1%/0%	6%/2.3%	4%/0%
RfTch model	2%/0%	10%/0%	4%/0%	-4%/0%
	Deviance/Number of estimated parameters			
TradTch model	67672.95/19	67672.95/19	67673.00/19	67673.06/19
RfTch model	67670.63/19	67670.63/19	67670.63/19	67670.94/19

Note. <sup>\*</sup>  $P < .05$ . <sup>\*\*</sup>  $P < .01$ . <sup>\*\*\*</sup>  $P < .001$ .

In the full model that included both teaching variables, reformed and traditional teaching composite variables together reduced the variance in students' problem-solving achievement at Level 2 by 5%, 11%, and 9% for Caucasian, African-American, and Hispanic students respectively when compared with the racial vector model. Again, both teaching variables did not reduce any variance in Asian-American students' problem-solving achievement at Level 2. In addition, both teaching composite variables together reduced the variance in students' problem-solving achievement at Level 1 by less than 1% for Caucasian, African-American, Hispanic, and Asian-American students. Again, substantial variance in students' problem-solving achievement at Level 2 still exist for all the four racial groups, all  $ps < .001$ .

Results from the full model showed that when controlling for reformed teaching, a statistically significant relationship was found between traditional teaching and problem-solving achievement for Caucasian students ( $\gamma_{01} = 7.31$ ,  $t(357) = 2.73$ ,  $p = .007$ ) and Hispanic students ( $\gamma_{01} = 8.56$ ,  $t(357) = 2.78$ ,  $p = .006$ ), indicating that every unit increase in teachers' use of traditional teaching is associated with 7.31 and 8.56 points increase in Caucasian and Hispanic students' problem-solving achievement respectively. However, a non-significant relationship was found between traditional teaching and problem-solving achievement of African-American and Asian-American students, both  $ps > .05$  (see Table 19).

Table 19

*Hierarchical Linear Modeling Results from the Full Models across Four Racial Groups with Students' Problem-Solving Achievement*

*as the Dependent Variable*

Variables	Caucasian	African-American	Hispanic	Asian American
Fixed effects (parameter (standard error))				
Full model ( $\gamma_0$ )	513.45 (2.63) <sup>***</sup>	477.82 (3.40) <sup>***</sup>	486.98 (3.07) <sup>***</sup>	519.93 (5.06) <sup>***</sup>
TradTch ( $\gamma_{u1}$ )	7.31 (2.68) <sup>**</sup>	1.17 (3.60)	8.56 (3.08) <sup>**</sup>	5.20 (5.50)
RfTch ( $\gamma_{u2}$ )	5.54 (2.72) <sup>*</sup>	11.81 (3.65) <sup>***</sup>	7.67 (3.09) <sup>*</sup>	-0.53 (5.44)
Random effects				
Full model $\tau_{00} / \sigma^2$	1639.88 <sup>***</sup> / 3093.96	1395.75 <sup>***</sup> / 3094.18	1677.72 <sup>***</sup> / 3094.89	1721.95 <sup>***</sup> / 3094.81
$\chi^2$ (df)	113.94 (38)	66.73 (38)	80.67 (38)	53.91 (38)
Proportion of variance explained				
Full model	Level 2/Level 1 5%/0%	Level 2/Level 1 11%/0%	Level 2/Level 1 9%/0%	Level 2/Level 1 -1%/0%
Full model	Deviance/Number of estimated parameters 67657.00/23			
	67657.03/23			

Note. <sup>\*</sup> $P < .05$ . <sup>\*\*</sup> $P < .01$ . <sup>\*\*\*</sup> $P < .001$ .

Results from the full model also showed that when controlling for traditional teaching, a statistically significant relationship was found between reformed teaching and problem-solving achievement for Caucasian students ( $\gamma_{01} = 5.54$ ,  $t(357) = 2.04$ ,  $p = .042$ ), African-American students ( $\gamma_{01} = 11.81$ ,  $t(357) = 3.24$ ,  $p = .001$ ), and Hispanic students ( $\gamma_{01} = 7.67$ ,  $t(357) = 2.48$ ,  $p = .014$ ), indicating that every unit increase in teachers' use of reformed teaching is associated with 5.54, 11.81, and 7.67 points increase in Caucasian, African-American, and Hispanic students' problem-solving achievement respectively. However, a non-significant relationship was found between reformed teaching and problem-solving achievement of Asian-American students,  $p > .05$  (see Table 19).

In addition, the parameter estimates of traditional teaching are larger than those of reformed teaching for both Caucasian and Hispanic students, which indicated that, compared with reformed teaching, traditional teaching has a stronger effect on the problem-solving achievements of Caucasian and Hispanic students. However, for African-American students, the opposite is true, i.e., reformed teaching has a much stronger effect than the traditional teaching on African-American students' problem-solving achievement (see Table 19).

### **Relationship between Reformed and Traditional Teaching and Students' Basic Skills Achievement**

In the analysis of a series of models with students' basic skills achievement as the



dependent variable, the intraclass correlation (ICC) coefficient from the base model was .51,  $p < .001$ , indicating that substantial variability in students' basic skills achievement can be attributed to the classroom level and the use of hierarchical linear modeling is warranted. When the dummy coded racial vectors were added to the level-1 equation, the variance in the basic skills achievement was reduced by 20%, 23%, 14%, and 22% at level-2, and by 4% at level-1 for Caucasian, African-American, Hispanic, and Asian-American students respectively (see Table 20).

Table 20

*Hierarchical Linear Modeling Results from the Empty and Racial Vector Models across Four Racial Groups with Students' Basic*

*Skills Achievement as the Dependent Variable*

Variables	Caucasian	African-American	Hispanic	Asian American
	Fixed effects (parameter (standard error))			
Empty model ( $\gamma_{00}$ )	505.70 (3.19)***	505.70 (3.19)***	505.70 (3.19)***	505.70 (3.19)***
Vector model ( $\gamma_{00}$ )	517.07 (3.02)***	482.19 (3.73)***	490.05 (3.45)***	527.55 (5.05)***
	Random effects			
Empty model $\tau_{00} / \sigma^2$	2952.84*** / 2804.78	2952.84*** / 2804.78	2952.84*** / 2804.78	2952.84*** / 2804.78
$\chi^2$ (df)	6232.91 (359)	6232.91 (359)	6232.91 (359)	6232.91 (359)
	Proportion of variance explained			
	Level 2/Level 1	Level 2/Level 1	Level 2/Level 1	Level 2/Level 1
Empty model	51%/49%	51%/49%	51%/49%	51%/49%
Vector model	20%/4%	23%/4%	14%/4%	22%/4%
	Deviance/Number of estimated parameters			
Empty model	67145.59/3	67145.59/3	67145.59/3	67145.59/3
Vector model	66889.29/15	66889.18/15	66889.19/15	66889.22/15

Note. \*  $P < .05$ . \*\*  $P < .01$ . \*\*\*  $P < .001$ .

In the traditional teaching model with only traditional teaching variable as the predictor, traditional teaching composite variable reduced the variance in students' basic skills achievement at Level 2 by 5%, 2%, 6%, and 4% for Caucasian, African-American, Hispanic, and Asian-American students respectively, but it only reduced less than 1% of the variance at Level 1 for all the four racial groups. Substantial variance in students' basic skills achievement at Level 2 still exist, all  $ps < .001$ . Result from the traditional teaching model showed that, when using only traditional teaching variable as the predictor in the model, a statistically significant relationship was found between traditional teaching and the basic skills achievement of Caucasian students ( $\gamma_{01} = 10.69$ ,  $t(358) = 3.62$ ,  $p < .001$ ) and Hispanic students ( $\gamma_{01} = 11.94$ ,  $t(358) = 3.56$ ,  $p < .001$ ), indicating that every unit increase in teachers' use of traditional teaching is associated with 10.69 and 11.94 points increase in the basic skills achievement of Caucasian and Hispanic students respectively. However, the relationship between traditional teaching and the basic skills achievement of African and Asian-American students was non-significant, both  $ps > .05$  (see Table 21).

In the reformed teaching model with only the reformed teaching variable as the predictor, reformed teaching composite variable reduced the variance in students' basic skills achievement at Level 2 by 2%, 8%, and 4% for Caucasian, African-American, and Hispanic students respectively, but it did not reduce any variance in Asian-American students' basic skills achievement at Level 2. Besides, reformed teaching composite

variable reduced the variance in students' basic skills achievement at Level 1 by less than 1% for Caucasian, African-American, Hispanic, and Asian-American students. Substantial variance in students' basic skills achievement at Level 2 still exist for all the four racial groups, all  $ps < .001$ . Result from the reformed teaching model showed that, when using only reformed teaching variable as the predictor in the model, a statistically significant relationship was found between reformed teaching and the basic skills achievement of Caucasian students ( $\gamma_{01} = 8.61$ ,  $t(358) = 2.83$ ,  $p = .005$ ), African-American students ( $\gamma_{01} = 11.77$ ,  $t(358) = 3.13$ ,  $p = .002$ ), and Hispanic students ( $\gamma_{01} = 9.27$ ,  $t(358) = 2.71$ ,  $p = .007$ ), indicating that every unit increase in teachers' use of reformed teaching is associated with 8.61, 11.77, and 9.27 points increase in the basic skills achievement of Caucasian, African-American, and Hispanic students respectively. However, a non-significant relationship was found between reformed teaching and the basic skills achievement of Asian-American students,  $p > .05$  (see Table 21).

Table 21

*Hierarchical Linear Modeling Results from the Traditional and Reformed Teaching Models across Four Racial Groups with Students'*

*Basic Skills Achievement as the Dependent Variable*

Variables	Caucasian	African-American	Hispanic	Asian American
	Fixed effects (parameter (standard error))			
TradTch model ( $\gamma_{00}$ )	516.89 (2.96) <sup>***</sup>	482.19 (3.70) <sup>***</sup>	489.43 (3.37) <sup>***</sup>	527.24 (4.98) <sup>***</sup>
TradTch ( $\gamma_{01}$ )	10.69 (2.96) <sup>***</sup>	4.97 (3.80)	11.94 (3.35) <sup>***</sup>	6.56 (5.31)
RfTch model ( $\gamma_{00}$ )	517.31 (2.99) <sup>***</sup>	481.45 (3.67) <sup>***</sup>	490.11 (3.40) <sup>***</sup>	526.41 (5.04) <sup>***</sup>
RfTch ( $\gamma_{01}$ )	8.61 (3.03) <sup>**</sup>	11.77 (3.77) <sup>**</sup>	9.27 (3.40) <sup>**</sup>	-0.99 (5.32)
	Random effects			
TradTch model $\tau_{00} / \sigma^2$	2253.64 <sup>***</sup> / 2683.94	2228.88 <sup>***</sup> / 2684.19	2395.15 <sup>***</sup> / 2683.35	2199.85 <sup>***</sup> / 2684.30
$\chi^2$ (df)	186.41 (39)	111.73 (39)	123.51 (39)	64.16 (39)
RfTch model $\tau_{00} / \sigma^2$	2309.51 <sup>***</sup> / 2681.38	2095.14 <sup>***</sup> / 2681.90	2455.14 <sup>***</sup> / 2681.39	2380.59 <sup>***</sup> / 2681.64
$\chi^2$ (df)	170.79 (39)	88.92 (39)	108.42 (39)	60.81 (39)
	Proportion of variance explained			
	Level 2/Level 1	Level 2/Level 1	Level 2/Level 1	Level 2/Level 1
TradTch model	5%/0%	2%/0%	6%/0%	4%/0%
RfTch model	2%/0%	8%/0%	4%/0%	-4%/0%
	Deviance/Number of estimated parameters			
TradTch model	66869.48/19	66869.39/19	66869.39/19	66869.41/19
RfTch model	66871.31/19	66871.09/19	66871.10/19	66871.10/19

Note. \*  $P < .05$ . \*\*  $P < .01$ . \*\*\*  $P < .001$ .

In the full model with both reformed and traditional teaching composite variables as the predictors, they together reduced the variance in students' basic skills achievement at Level 2 by 6%, 9%, and 9% for Caucasian, African-American, and Hispanic students respectively. Again, both teaching variables did not reduce any variance in Asian-American students' basic skills achievement at Level 2. In addition, both teaching composite variables together reduced the variance in students' basic skills achievement at Level 1 by less than 1% for Caucasian, African-American, Hispanic, and Asian-American students. Again, substantial variance in students' basic skills achievement at Level 2 still exist for all the four racial groups, all  $ps < .001$  (see Table 22).

Results from the full models showed that, when controlling for reformed teaching, a statistically significant relationship was found between traditional teaching and basic skills achievement for Caucasian students ( $\gamma_{01} = 9.45$ ,  $t(357) = 3.16$ ,  $p = .002$ ) and Hispanic students ( $\gamma_{01} = 10.68$ ,  $t(357) = 3.18$ ,  $p = .002$ ), indicating that every unit increase in teachers' use of traditional teaching is associated with 9.45 and 10.68 points increase in Caucasian and Hispanic students' basic skills achievement respectively. However, a non-significant relationship was found between traditional teaching and basic skills achievement of African-American and Asian-American students, both  $ps > .05$  (see Table 22).

Table 22

*Hierarchical Linear Modeling Results from the Full Models across Four Racial Groups with Students' Basic Skills Achievement as*

*the Dependent Variable*

Variables	Caucasian	African-American	Hispanic	Asian American
Fixed effects (parameter (standard error))				
Full model ( $\gamma_{00}$ )	517.10 (2.94) <sup>***</sup>	481.44 (3.62) <sup>***</sup>	489.56 (3.33) <sup>***</sup>	526.08 (4.99) <sup>***</sup>
TradTch ( $\gamma_{01}$ )	9.45 (2.99) <sup>**</sup>	2.36 (3.82)	10.68 (3.36) <sup>**</sup>	6.14 (5.38)
RfTch ( $\gamma_{02}$ )	6.93 (3.03) <sup>*</sup>	11.63 (3.85) <sup>**</sup>	7.58 (3.37) <sup>*</sup>	-2.36 (5.33)
Random effects				
Full model $\tau_{00} / \sigma^2$	2226.15 <sup>***</sup> / 2682.26	2053.87 <sup>***</sup> / 2682.83	2323.93 <sup>***</sup> / 2682.27	2312.53 <sup>***</sup> / 2682.47
$\chi^2$ (df)	178.12 (38)	91.22 (38)	116.50 (38)	63.33 (38)
Proportion of variance explained				
Full model	Level 2/Level 1 6%/0%	Level 2/Level 1 9%/0%	Level 2/Level 1 9%/0%	Level 2/Level 1 -1%/0%
Full model	Deviance/Number of estimated parameters 66853.57/23			
	66853.40/23			
	66853.39/23			

Note. <sup>\*</sup> $P < .05$ . <sup>\*\*</sup> $P < .01$ . <sup>\*\*\*</sup> $P < .001$ .

Results from the full models also showed that controlling for traditional teaching, a statistically significant relationship was found between reformed teaching and basic skills achievement for Caucasian students ( $\gamma_{01} = 6.93$ ,  $t(357) = 2.28$ ,  $p = .023$ ), African-American students ( $\gamma_{01} = 11.63$ ,  $t(357) = 3.03$ ,  $p = .003$ ), and Hispanic students ( $\gamma_{01} = 7.58$ ,  $t(357) = 2.23$ ,  $p = .026$ ), indicating that every unit increase in teachers' use of reformed teaching is associated with 6.93, 11.63, and 7.58 points increase in Caucasian, African-American, and Hispanic students' basic skills achievement respectively. However, a non-significant relationship was found between reformed teaching and basic skills achievement of Asian-American students,  $p > .05$  (see Table 22).

In addition, the parameter estimates of traditional teaching are larger than those of reformed teaching for both Caucasian and Hispanic students, which indicated that, compared with reformed teaching, traditional teaching has a stronger effect on the basic skills achievements of Caucasian and Hispanic students. However, for African-American students, the opposite is true, i.e., reformed teaching has a much stronger effect than the traditional teaching on African-American students' basic skills achievement (see Table 22).

### **Problem-Solving Achievement Predicting Basic Skills Achievement**

In the analysis with a series of models with students' basic skills achievement as the dependent variable and their problem-solving achievement as the predictor, the intraclass



correlation (ICC) coefficient from the base model was .52,  $p < .001$ , indicating that substantial variability in students' basic skills achievement can be attributed to the classroom level and the use of hierarchical linear modeling is warranted. When the dummy coded racial vectors were added to the level-1 equation, the variance in the basic skills achievement was reduced by 20%, 23%, 14%, and 21% at level-2, and by 4% at level-1 for Caucasian, African-American, Hispanic, and Asian-American students respectively (see Table 23).

Table 23

*Hierarchical Linear Modeling Results from the Empty, Racial Vector, and Problem-Solving Models across Four Racial Groups with Students' Basic Skills Achievement as the Dependent Variable*

Variables	Caucasian	African-American	Hispanic	Asian American
Fixed effects (parameter (standard error))				
Empty model ( $\gamma_{00}$ )	505.70 (3.19)***	505.70 (3.19)***	505.70 (3.19)***	505.70 (3.19)***
Vector model ( $\gamma_{00}$ )	517.07 (3.02)***	482.19 (3.73)***	490.05 (3.45)***	527.55 (5.05)***
PS model ( $\gamma_{00}$ )	511.75 (1.33)***	497.07 (2.04)***	499.62 (1.69)***	516.66 (3.07)***
PS ( $\gamma_{10}$ )	0.70 (0.01)***	0.70 (0.01)***	0.70 (0.01)***	0.70 (0.01)***
Random effects				
Empty model $\tau_{00}/\sigma^2$	2952.84***/2804.78	2952.84***/2804.78	2952.84***/2804.78	2952.84***/2804.78
$\chi^2$ (df)	6232.91 (359)	6232.91 (359)	6232.91 (359)	6232.91 (359)
Vector model $\tau_{00}/\sigma^2$	2365.47***/2683.22	2267.67***/2683.33	2550.59***/2682.58	2299.87***/2683.52
$\chi^2$ (df)	176.69 (40)	105.87 (40)	118.94 (40)	61.17 (40)
PS model $\tau_{00}/\sigma^2$	333.62*/1322.77	348.62*/1323.00	370.09*/1322.93	312.75/1322.96
$\chi^2$ (df)	86.07 (40)	59.73 (39.80)	62.20 (39.60)	49.03(39.80)
$\chi^2$ (df)	83.66 (38)	57.71 (37.80)	62.67 (37.60)	48.57 (37.80)
Proportion of variance explained				
	Level 2/Level 1	Level 2/Level 1	Level 2/Level 1	Level 2/Level 1
Empty model	52%/48%	52%/48%	52%/48%	52%/48%
Vector model	20%/4%	23%/4%	14%/4%	21%/4%
PS model	86%/51%	84%/51%	85%/51%	85%/51%
Deviance/Number of estimated parameters				
Empty model	67145.59/3	67145.59/3	67145.59/3	67145.59/3
Vector model	66889.29/15	66889.18/15	66889.19/15	66889.22/15
PS model	62209.13/21	62209.13/21	62209.11/21	62209.17/21

Note. \*  $P < .05$ . \*\*  $P < .01$ . \*\*\*  $P < .001$ .

In the problem-solving model with students' problem-solving achievement as the only predictor, the problem-solving achievement variable reduced the variance in students' basic skills achievement by 86%, 84%, 85%, and 85% at Level 2, and 51% at Level 1 for Caucasian, African-American, Hispanic, and Asian-American students respectively. Substantial variance in students' basic skills achievement at Level 2 still exist for Caucasian, African-American, and Hispanic students, all  $ps < .05$ , while not for Asian-American students. Result from the problem-solving model showed that, when using students' problem-solving achievement as the only predictor, a statistically significant relationship was found between students' problem-solving achievement and the basic skills achievement of Caucasian students ( $\gamma_{01} = .70$ ,  $t(359) = 72.39$ ,  $p < .001$ ), African-American students ( $\gamma_{01} = .70$ ,  $t(359) = 72.28$ ,  $p < .001$ ), Hispanic students ( $\gamma_{01} = .70$ ,  $t(359) = 72.37$ ,  $p < .001$ ), and Asian-American students ( $\gamma_{01} = .70$ ,  $t(359) = 72.36$ ,  $p < .001$ ), indicating that every unit increase in students' problem-solving achievement is associated with .70 point increase in the basic skills achievement of Caucasian, African-American, Hispanic, and Asian-American students (see Table 24).

In the traditional teaching model with traditional teaching variable as the predictor at level-2 and students' problem-solving achievement at level-1, traditional teaching composite variable reduced the variance in students' basic skills achievement at Level 2 by 5%, 1%, 6%, and 3%, and the variance in the slope of problem-solving variable by 3% for

Caucasian, African-American, Hispanic, and Asian-American students respectively, but it only reduced less than 1% of the variance in students' basic skills achievement at Level 1 for all the four racial groups. Substantial variance in students' basic skills achievement at Level 2 still exist for Caucasian, African-American, and Hispanic students, all  $ps < .05$ , while not for Asian-American students (see Table 24).

Result from the traditional teaching model showed that when controlling for traditional teaching, a statistically significant relationship was found between students' problem-solving achievement and the basic skills achievement of Caucasian students ( $\gamma_{01} = .70$ ,  $t(358) = 72.63$ ,  $p < .001$ ), African-American students ( $\gamma_{01} = .70$ ,  $t(358) = 72.53$ ,  $p < .001$ ), Hispanic students ( $\gamma_{01} = .70$ ,  $t(358) = 72.61$ ,  $p < .001$ ), and Asian-American students ( $\gamma_{01} = .70$ ,  $t(358) = 72.60$ ,  $p < .001$ ), indicating that every unit increase in students' problem-solving achievement is associated with .70 point increase in the basic skills achievement of Caucasian, African-American, Hispanic, and Asian-American students (see Table 24).

In the reformed teaching model with reformed teaching variable as the predictor at level-2 and students' problem-solving achievement at level-1, reformed teaching composite variable reduced the variance in students' basic skills achievement at Level 2 by 5%, 6%, and 3% for Caucasian, African-American, and Hispanic students respectively, but it did not reduce any variance in Asian-American students' basic skills achievement at

Level 2. Besides, reformed teaching composite variable reduced the variance in students' basic skills achievement at Level 1 by less than 1% for Caucasian, African-American, Hispanic, and Asian-American students. Substantial variance in students' basic skills achievement at Level 2 still exist for Caucasian, African-American, and Hispanic students, all  $ps < .05$ , while not for Asian-American students (see Table 24).

Result from the reformed teaching model showed that when controlling for reformed teaching, a statistically significant relationship was found between problem-solving and the basic skills achievement of Caucasian students ( $\gamma_{01} = .70$ ,  $t(358) = 72.37$ ,  $p < .001$ ), African-American students ( $\gamma_{01} = .70$ ,  $t(358) = 72.26$ ,  $p < .001$ ), Hispanic students ( $\gamma_{01} = .70$ ,  $t(358) = 72.36$ ,  $p < .001$ ), and Asian-American students ( $\gamma_{01} = .70$ ,  $t(358) = 72.35$ ,  $p < .001$ ), indicating that every unit increase in students' problem-solving achievement is associated with .70 point increase in the basic skills achievement of Caucasian, African-American, Hispanic, and Asian-American students (see Table 24).

Table 24

*Hierarchical Linear Modeling Results from the Traditional and Reformed Teaching Models across Four Racial Groups with Students'*

*Basic Skills Achievement as the Dependent Variable*

Variables	Caucasian	African-American	Hispanic	Asian American
Fixed effects (parameter (standard error))				
TradTch model ( $\gamma_{00}$ )	511.72 (1.31) <sup>***</sup>	496.97 (2.04) <sup>***</sup>	499.27 (1.67) <sup>***</sup>	516.64 (3.05) <sup>***</sup>
PS ( $\gamma_{10}$ )	0.70 (0.01) <sup>***</sup>	0.70 (0.01) <sup>***</sup>	0.70 (0.01) <sup>***</sup>	0.70 (0.01) <sup>***</sup>
TradTch ( $\gamma_{01}$ )	4.46 (1.31) <sup>***</sup>	1.88 (2.09)	4.93 (1.64) <sup>**</sup>	1.83 (3.31)
RfTch model ( $\gamma_{00}$ )	511.91 (1.32) <sup>***</sup>	496.74 (2.04) <sup>***</sup>	499.64 (1.68) <sup>***</sup>	516.46 (3.06) <sup>***</sup>
PS ( $\gamma_{10}$ )	0.70 (0.01) <sup>***</sup>	0.70 (0.01) <sup>***</sup>	0.70 (0.01) <sup>***</sup>	0.70 (0.01) <sup>***</sup>
RfTch ( $\gamma_{01}$ )	3.39 (1.34) <sup>*</sup>	3.76 (2.12)	2.48 (1.66)	-1.08 (3.25)
Random effects				
TradTch model $\tau_{00} / \sigma^2$	317.06 <sup>*</sup> /1322.03	344.96 <sup>*</sup> /1322.25	347.18 <sup>*</sup> /1322.18	303.02/1322.19
$\chi^2$ (df)	86.07 (39)	60.65 (38.80)	63.69 (38.60)	49.27 (38.80)
RfTch model $\tau_{00} / \sigma^2$	326.30 <sup>*</sup> /1322.61	327.83 <sup>*</sup> /1322.83	360.80 <sup>*</sup> /1322.87	314.47/1322.71
$\chi^2$ (df)	83.93 (39)	57.57 (38.80)	60.47 (38.60)	48.53 (38.80)
Proportion of variance explained				
	Level 2/Level 1	Level 2/Level 1	Level 2/Level 1	Level 2/Level 1
TradTch model	5%/0%	1%/0%	6%/0%	3%/0%
RfTch model	5%/0%	6%/0%	3%/0%	-1%/0%
Deviance/Number of estimated parameters				
TradTch model	62189.42/26	62189.43/26	62189.41/26	62189.46/26
RfTch model	62197.18/26	62197.17/26	62197.17/26	62197.21/26

Note. <sup>\*</sup> $P < .05$ . <sup>\*\*</sup> $P < .01$ . <sup>\*\*\*</sup> $P < .001$ .

In the full model with reformed and traditional teaching variables as the predictors at level-2 and students' problem-solving achievement at level-1, problem-solving achievement, reformed and traditional teaching composite variables together reduced the variance in students' basic skills achievement at Level 2 by 86%, 86%, 86%, and 87% for Caucasian, African-American, Hispanic and Asian-American students respectively. In addition, problem-solving achievement and both teaching composite variables together reduced the variance in students' basic skills achievement at Level 1 by 51% for Caucasian, African-American, Hispanic, and Asian-American students. Again, Substantial variance in students' basic skills achievement at Level 2 still exist for Caucasian, African-American, and Hispanic students, all  $ps < .05$ , while not for Asian-American students (see Table 25).

Result from the full model showed that when controlling for traditional teaching and when students are exposed to more or less reformed teaching, a statistically significant relationship was found between problem-solving achievement and basic skills achievement for Caucasian students ( $\gamma_{01} = .70$ ,  $t(357) = 72.64$ ,  $p < .001$ ), African-American students ( $\gamma_{01} = .70$ ,  $t(357) = 72.55$ ,  $p < .001$ ), Hispanic students ( $\gamma_{01} = .70$ ,  $t(357) = 72.63$ ,  $p < .001$ ), and Asian-American students ( $\gamma_{01} = .70$ ,  $t(357) = 72.62$ ,  $p < .001$ ), indicating that every unit increase in problem-solving achievement is associated with .70 point increase in Caucasian, African-American, Hispanic, and Asian-American students' basic skills achievement respectively (see Table 25)

Table 25

*Hierarchical Linear Modeling Results from the Full Models across Four Racial Groups with Students' Basic Skills Achievement as the Dependent Variable*

Variables	Caucasian	African-American	Hispanic	Asian American
Fixed effects (parameter (standard error))				
Full model ( $\gamma_0$ )	511.85 (1.30)***	496.68 (2.03)***	499.31 (1.66)***	516.45 (3.04)***
PS ( $\gamma_0$ )	0.70 (0.01)***	0.70 (0.01)***	0.70 (0.01)***	0.70 (0.01)***
TradTch ( $\gamma_0$ )	3.96 (1.33)*	1.06 (2.15)	4.62 (1.65)	1.72 (3.34)
RfTch ( $\gamma_0$ )	2.68 (1.35)*	3.71 (2.19)	1.86 (1.66)	-1.47 (3.28)
Random effects				
Full model $\tau_0 / \sigma^2$	313.80* / 1321.94	324.09* / 1322.14	340.20* / 1322.19	307.80 / 1322.02
$\chi^2$ (df)	83.66 (38)	57.71 (37.80)	62.67 (37.60)	48.57 (37.80)
Proportion of variance explained				
Full model	Level 2/Level 1 86%/51%	Level 2/Level 1 86%/51%	Level 2/Level 1 86%/51%	Level 2/Level 1 87%/51%
Deviance/Number of estimated parameters				
Full model	62179.81/31	62179.81/31	62179.80/31	62179.83/31

Note. \* $P < .05$ . \*\* $P < .01$ . \*\*\* $P < .001$ .



### **Basic Skills Achievement Predicting Problem-Solving Achievement**

In the analysis with a series of models with students' problem-solving achievement as the dependent variable and their basic skills achievement as the predictor, the intraclass correlation (ICC) coefficient from the base model was .41,  $p < .001$ , indicating that substantial variability in students' problem-solving achievement can be attributed to the classroom level and the use of hierarchical linear modeling is warranted. When the dummy coded racial vectors were added to the level-1 equation, the variance in the problem-solving achievement was reduced by 22%, 29%, 17%, and 23% at level-2, and by 3% at level-1 for Caucasian, African-American, Hispanic, and Asian-American students respectively (see Table 26).

In the basic skills model with students' basic skills achievement as the only predictor, basic skills achievement variable reduced the variance in students' problem-solving achievement by 99%, 99%, 99%, and 98% at Level 2, and 53% at Level 1 for Caucasian, African-American, Hispanic, and Asian-American students. Almost all variance in students' problem-solving achievement at Level 2 has been explained, all  $ps > .05$  (see Table 26).

Result from the basic skills model showed that, when using students' basic skills achievement as the only predictor, a statistically significant relationship was found between students' basic skills achievement and the problem-solving achievement of

Caucasian students ( $\gamma_{01} = .41$ ,  $t(359) = 15.37$ ,  $p < .001$ ), African-American students ( $\gamma_{01} = .41$ ,  $t(359) = 15.39$ ,  $p < .001$ ), Hispanic students ( $\gamma_{01} = .41$ ,  $t(359) = 15.39$ ,  $p < .001$ ), and Asian-American students ( $\gamma_{01} = .41$ ,  $t(359) = 15.39$ ,  $p < .001$ ), indicating that every unit increase in students' basic skills achievement is associated with .41 point increase in the problem-solving achievement of Caucasian, African-American, Hispanic, and Asian-American students (see Table 26).

Table 26

*Hierarchical Linear Modeling Results from the Empty, Racial Vector and Basic Skills Models across Four Racial Groups with Students' Problem-Solving Achievement as the Dependent Variable*

Variables	Caucasian	African-American	Hispanic	Asian American
Fixed effects (parameter (standard error))				
Empty model ( $\tau_{00}$ )	502.38 (2.81) <sup>***</sup>	502.38 (2.81) <sup>***</sup>	502.38 (2.81) <sup>***</sup>	502.38 (2.81) <sup>***</sup>
Vector model ( $\tau_{00}$ )	513.42 (2.69) <sup>***</sup>	478.76 (3.49) <sup>***</sup>	487.38 (3.17) <sup>***</sup>	520.92 (5.10) <sup>***</sup>
BS model ( $\tau_{00}$ )	505.73 (0.77) <sup>***</sup>	500.86 (1.56) <sup>***</sup>	501.72 (1.13) <sup>***</sup>	506.09 (2.87) <sup>***</sup>
Basic skills ( $\tau_{00}$ )	0.41 (0.03) <sup>***</sup>	0.41 (0.03) <sup>***</sup>	0.41 (0.03) <sup>***</sup>	0.41 (0.03) <sup>***</sup>
Random effects				
Empty model $\tau_{00} / \sigma^2$	2216.80 <sup>***</sup> / 3189.22	2216.80 <sup>***</sup> / 3189.22	2216.80 <sup>***</sup> / 3189.22	2216.80 <sup>***</sup> / 3189.22
$\chi^2$ (df)	4213.52 (359)	4213.52 (359)	4213.52 (359)	4213.52 (359)
Vector model $\tau_{00} / \sigma^2$	1726.73 <sup>***</sup> / 3095.94	1567.24 <sup>***</sup> / 3096.32	1843.00 <sup>***</sup> / 3096.77	1700.56 <sup>***</sup> / 3096.94
$\chi^2$ (df)	1113.98 (40)	80.76 (40)	86.42 (40)	51.92 (40)
PS model $\tau_{00} / \sigma^2$	19.17 / 1467.09	17.75 / 1467.26	14.30 / 1467.41	26.41 / 1467.49
$\chi^2$ (df)	31.03 (38.60)	31.38 (34)	36.03 (34.80)	28.67 (33.80)
Proportion of variance explained				
Empty model	Level 2/Level 1 41%/59%	Level 2/Level 1 41%/59%	Level 2/Level 1 41%/59%	Level 2/Level 1 41%/59%
Vector model	22%/3%	29%/3%	17%/3%	23%/3%
BS model	99%/53%	99%/53%	99%/53%	98%/53%
Deviance/Number of estimated parameters				
Empty model	67896.55/3	67896.55/3	67896.55/3	67896.55/3
Vector model	67688.40/15	67688.41/15	67688.43/15	67688.48/15
BS model	62345.77/28	62345.76/28	62345.75/28	62345.77/28

Note. \*  $P < .05$ . \*\*  $P < .01$ . \*\*\*  $P < .001$ .

In the traditional teaching model with traditional teaching variable as the predictor at level-2 and students' basic skills achievement at level-1, traditional teaching composite variable reduced the variance in students' basic skills achievement at Level 2 by 2%, 2%, 2%, and 6%, and the variance in the slope of basic skills variable by 2%, for Caucasian, African-American, Hispanic, and Asian-American students respectively. However, it only reduced less than 2% of the variance at Level 1 for all the four racial groups. Almost all variance in students' problem-solving achievement at Level 2 has been explained, all  $ps > .05$  (see Table 27).

Result from the traditional teaching model showed that when controlling for traditional teaching, a statistically significant relationship was found between students' basic skills achievement and the problem-solving achievement of Caucasian students ( $\gamma_{01} = .41$ ,  $t(358) = 15.39$ ,  $p < .001$ ), African-American students ( $\gamma_{01} = .41$ ,  $t(358) = 15.41$ ,  $p < .001$ ), Hispanic students ( $\gamma_{01} = .41$ ,  $t(358) = 15.40$ ,  $p < .001$ ), and Asian-American students ( $\gamma_{01} = .41$ ,  $t(358) = 15.41$ ,  $p < .001$ ), indicating that every unit increase in students' basic skills achievement is associated with .41 point increase in the problem-solving achievement of Caucasian, African-American, Hispanic, and Asian-American students (see Table 27).

In the reformed teaching model with reformed teaching variable as the predictor at level-2 and students' basic skills achievement at level-1, reformed teaching composite

variable reduced the variance in students' problem-solving achievement at Level 2 by 3%, 23%, 9%, and 12% for Caucasian, African-American, Hispanic, and Asian-American students respectively. Besides, reformed teaching composite variable reduced the variance in students' problem-solving achievement at Level 1 by 2%, 11%, and 2% for Caucasian, African-American, and Asian-American students, but it did not reduce any variance at Level 1 for Hispanic students. Almost all variance in students' problem-solving achievement at Level 2 has been explained, all  $ps > .05$  (see Table 27).

Result from the reformed teaching model showed that when controlling for reformed teaching, a statistically significant relationship was found between the basic skills and problem-solving achievement of Caucasian students ( $\gamma_{01} = .41$ ,  $t(358) = 15.38$ ,  $p < .001$ ), African-American students ( $\gamma_{01} = .41$ ,  $t(358) = 15.40$ ,  $p < .001$ ), Hispanic students ( $\gamma_{01} = .41$ ,  $t(358) = 15.39$ ,  $p < .001$ ), and Asian-American students ( $\gamma_{01} = .41$ ,  $t(358) = 15.40$ ,  $p < .001$ ), indicating that every unit increase in students' basic skills achievement is associated with .41 point increase in the problem-solving achievement of Caucasian, African-American, Hispanic, and Asian-American students (see Table 27).

Table 27

*Hierarchical Linear Modeling Results from the Traditional and Reformed Teaching Models across Four Racial Groups with Students' Problem-Solving Achievement as the Dependent Variable*

Variables	Caucasian	African-American	Hispanic	Asian American
Fixed effects (parameter (standard error))				
TradTch model ( $\gamma_{00}$ )	505.71 (0.77)***	500.92 (1.58)***	501.66 (1.14)***	506.07 (2.86)***
Basic skills ( $\gamma_{10}$ )	0.41 (0.03)***	0.41 (0.03)***	0.41 (0.03)***	0.41 (0.03)***
TradTch ( $\gamma_{01}$ )	-0.27 (0.78)	-0.36 (1.59)	0.31 (1.09)	0.19 (3.18)
RfTch model ( $\gamma_{00}$ )	505.83 (0.77)***	500.68 (1.59)***	501.79 (1.13)***	506.10 (2.87)***
Basic skills ( $\gamma_{10}$ )	0.41 (0.03)***	0.41 (0.03)***	0.41 (0.03)***	0.41 (0.03)***
RfTch ( $\gamma_{01}$ )	0.56 (0.79)	0.97 (1.63)	1.37 (1.10)	2.60 (3.05)
Random effects				
TradTch model $\tau_{00} / \sigma^2$	18.78/1466.71	17.44/1466.87	14.08/1467.03	24.95/1467.11
$\chi^2$ (df)	30.91 (37.60)	31.32 (33)	36.15 (33.80)	28.62 (32.80)
RfTch model $\tau_{00} / \sigma^2$	18.54/1466.87	13.75/1467.06	12.98/1467.16	23.25/1467.27
$\chi^2$ (df)	30.93 (37.60)	30.79 (33)	34.81 (33.80)	28.10 (32.80)
Proportion of variance explained				
TradTch model	Level 2/Level 1	Level 2/Level 1	Level 2/Level 1	Level 2/Level 1
	2%/1%	2%/0%	2%/2%	6%/1%
RfTch model	3%/2%	23%/11%	9%/-1%	12%/2%
Deviance/Number of estimated parameters				
TradTch model	62342.62/34	62342.61/34	62342.60/34	62342.62/34
RfTch model	62337.40/34	62337.41/34	62337.41/34	62337.43/34

Note. \*  $P < .05$ . \*\*  $P < .01$ . \*\*\*  $P < .001$ .

In the full model with reformed and traditional teaching variables as the predictors at level-2 and students' basic skills achievement at level-1, basic skills achievement, reformed and traditional teaching composite variables together reduced the variance in students' problem-solving achievement at Level 2 by 99% for Caucasian, African-American, Hispanic and Asian-American students. In addition, basic skills achievement and both teaching composite variables together reduced the variance in students' problem-solving achievement at Level 1 by 54%, 84%, 85%, and 51% for Caucasian, African-American, Hispanic, and Asian-American students. Almost all variance in students' problem-solving achievement at Level 2 has been explained, all  $ps > .05$  (see Table 28).

Result from the full model showed that when controlling for reformed teaching and when students are exposed to more or less traditional teaching, a statistically significant relationship was found between the basic skills and problem-solving achievement of Caucasian students ( $\gamma_{01} = .41$ ,  $t(357) = 15.41$ ,  $p < .001$ ), African-American students ( $\gamma_{01} = .41$ ,  $t(357) = 15.42$ ,  $p < .001$ ), Hispanic students ( $\gamma_{01} = .41$ ,  $t(357) = 15.42$ ,  $p < .001$ ), and Asian-American students ( $\gamma_{01} = .41$ ,  $t(357) = 15.43$ ,  $p < .001$ ), indicating that every unit increase in students' basic skills achievement is associated with .41 point increase in the problem-solving achievement of Caucasian, African-American, Hispanic, and Asian-American students (see Table 28).

Table 28

*Hierarchical Linear Modeling Results from the Full Models across Four Racial Groups with Students' Problem-Solving Achievement*

*as the Dependent Variable*

Variables	Caucasian	African-American	Hispanic	Asian American
Fixed effects (parameter (standard error))				
Full model ( $\gamma_{00}$ )	505.81 (0.77)***	500.78 (1.58)***	501.74 (1.13)***	506.11 (2.85)***
Basic skills ( $\gamma_{10}$ )	0.41 (0.03)***	0.41 (0.03)***	0.41 (0.03)***	0.41 (0.03)***
TradTch ( $\gamma_{20}$ )	-0.42 (0.79)	-0.66 (1.65)	0.13 (1.09)	-0.12 (3.23)
RfTch ( $\gamma_{30}$ )	0.66 (0.81)	1.17 (1.71)	1.36 (1.12)	2.66 (3.10)
Random effects				
Full model $\tau_{00} / \sigma^2$	17.97/1466.51	11.98/1466.72	12.70/1466.81	22.20/1466.92
$\chi^2$ (df)	30.82 (36.60)	30.79 (32)	34.92 (32.80)	27.95 (31.80)
Proportion of variance explained				
Full model	Level 2/Level 1 99%/54%	Level 2/Level 1 99%/84%	Level 2/Level 1 99%/85%	Level 2/Level 1 99%/51%
Deviance/Number of estimated parameters				
Full model	62333.20/40	62333.14/40	62333.14/40	62333.16/40

Note. \*  $P < .05$ . \*\*  $P < .01$ . \*\*\*  $P < .001$ .



## **CHAPTER SIX: LIMITATIONS OF THE STUDY, DISCUSSION, AND IMPLICATIONS**

### **Limitations of the Study**

This study has several limitations. First of all, this study used a secondary data set as its data source. Although U.S. TIMSS 2007 contains a nationally representative sample, it is not an experimental study. Thus, treatment effect of reformed or traditional type of teaching approaches cannot be identified in this study as there were no control or treatment groups; also, causal relationships between the two types of teaching and students' mathematics achievement cannot be identified in this study. In addition, this study only used the U.S. eighth grade sample of TIMSS 2007. Findings from this study can only be applicable to this population of students along with their teachers.

Furthermore, this study used teacher's self-reported instructional practices to construct reformed and traditional teaching composite variables. Although some researchers maintain that they are reliable in some circumstances (e.g., Mayer, 1998, 1999; McCaffrey et al., 2001; Porter et al., 1993), other researchers considered them unreliable when comparing teachers' self-reports with on-site classroom observations (Brophy & Good, 1986; Burstein et al., 1995). However, classroom observations can be time-consuming and costly, which limits its application in a large scale study such as TIMSS. Additionally, TIMSS 2007 does not have student prior achievement data, which

limits the usefulness of this data set in modeling teacher instructional approaches on student achievement as their gain scores cannot be identified, which suggests that a better quasi-experimental design that includes students' prior achievement data in TIMSS study is necessary in the future.

Last, this study did not use students' socio-economic status (SES) as a control variable mainly because TIMSS 2007 data set did not provide sufficient information for constructing a reliable SES composite variable by following the four dimensions of indicators for SES, i.e., parental education, occupation, income (Hauser, 1994; Mueller & Parcel, 1981) and home location (Sirin, 2005). Even if using one dimension of indicator such as parental education, extensive missing data will cause a major concern for conducting a two-level hierarchical linear modeling. Moreover, SES was conflated with the racial factor in the US. Since student racial background information was used as the independent variables in this study, it seems not imperative to use SES as a control variable. Nonetheless, it is acknowledged that SES may influence students' mathematics performance to a large extent. This background variable would be considered in the design of future studies along this line.

## **Discussion**

In spite of these limitations, the study came to several interesting findings. Regarding the first research question that asks whether the reformed teaching is positively

and significantly related to the problem-solving, basic skills, and overall mathematics achievements of students from four racial groups respectively, the study found that the reformed teaching is not necessarily related positively and significantly to the performances of all racial groups of students as expected by the proponents of reformed teaching. As shown in the study, although reformed teaching approach is positively and significantly related to Caucasian, African-American, and Hispanic students' overall mathematics, problem-solving, and basic skills achievements, it is not related to Asian-American students' three performance measures.

This finding does not support the results from other studies that found the reformed teaching to be effective for all students in improving their overall mathematics and problem-solving achievement regardless of their racial backgrounds (e.g., Hamilton et al., 2003; Le et al., 2009; Carpenter et al., 1989; Ginsburg-Block & Fantuzzo, 1998; Wenglinsky, 2000, 2002; Wood & Sellers, 1996). The different results might be due to the fact these previous studies focused on the students as a homogeneous group while in my study the U.S. students were considered as a heterogeneous group. In addition, this finding also differs from results from the studies of Brewer and Goldhaber (1997) and Schwerdt and Wuppermann (2011), which found reformed teaching is not effective for improving students' overall mathematics achievement. The different result might be caused by the fact that Brewer and Goldhaber (1997) and Schwerdt and Wuppermann

(2011) used single variables to represent reformed teaching, which might not be reliable compared with using composite variables (Mayer, 1999).

Regarding the second research question that asks whether the traditional teaching is positively and significantly related to the problem-solving, basic skills, and overall mathematics achievements of students from four racial groups respectively, this study found that the traditional teaching is not necessarily related positively and significantly to the performance of all racial groups of students as expected by the proponents of traditional teaching. As shown in the study, although traditional teaching approach is positively and significantly related to Caucasian and Hispanic students' overall mathematics, problem-solving, and basic skills achievements, it is not related to African-American and Asian-American students' three performance measures. In other words, while traditional teaching might be able to help Caucasian and Hispanic students to improve their basic skills achievement, it might not be effective in helping African-American and Asian-American students. This finding differs from the results of other studies that found traditional teaching to be useful in helping all U.S. students to improve their basic skill achievement (Brenner et al., 1997; Cobb et al., 1991; Peterson et al., 1989; Saxe et al., 1999). Again, the different results might be due to the fact these previous studies considered their sampled students as a homogeneous group while in my study the U.S. students were considered as a heterogeneous group.

In addition, the finding that Caucasian, African-American, Hispanic, and Asian-American students respond differently to both traditional teaching and reform-oriented teaching seem to support the assumption of culturally relevant pedagogy theory, which holds that students with different racial and cultural backgrounds may develop different learning needs, styles, and habits that may require different kinds of teaching for effective learning (Ladson-Billings, 1997). Thus, it challenged the assumption of reformed and traditional teaching as the same type of teaching approach might not be equally effective for students of different racial backgrounds.

Furthermore, the finding that traditional teaching approach was not related to African-American and Asian-American students' mathematics performance, and reformed teaching was not related to Asian-American students' mathematics performance may engender questions about the basic assumption underlying mathematics education reform in that teaching quality is the major contributor to students' mathematics performance (Kennedy, 2010; NCTM, 1989, 1991, 2000). Perhaps, these assumptions may divert attention from the examination of other more important factors including the deeper social and economic inequalities that African-American students experience, which may have contributed more significantly to their school performance than teaching factors (Apple, 1996). Other cultural and family factors might have contributed more significantly than the teaching factor to the mathematics performance of Asian-American

students, but these factors did not contribute more importantly than the teaching factor for Caucasian and Hispanic students' mathematics performance (Huntsinger, Jose, Liaw, & Ching, 1997; Moon & Lee, 2009). The curriculum of the home, as these factors that exist outside schools and classrooms were called (Redding, 1992), plays an important role in shaping students' performance. But it seems that the influence of this curriculum on students' mathematics performance differs from one racial group to another.

Moreover, results from the factor analysis of the teachers' instructional variables in TIMSS 2007 U.S. eighth grade data set revealed that four variables formed the reformed and traditional teaching factors respectively with very clear distinction between the two factors. The data set sufficiently supported the theoretical construct of reformed and traditional teaching. However, result from the factor analysis also revealed that, although theoretically the variable "Teachers ask students to write equations and functions to represent relationships" is categorized as a variable indicating reformed teaching, results from the factor analysis showed that this variable belongs to the traditional teaching factor along with "practice adding, subtracting, multiplying, and dividing without using a calculator," "memorize formulas and procedure," and "apply facts, concepts and procedures to solve routine problems." This suggested that the issue of how to better conceptualize reformed or traditional teaching in TIMSS design needs to be addressed. Therefore, results from using this variable to indicate reformed teaching in the study by

Desimone et al. (2005) might not be valid. As the design of TIMSS 2007 teachers' questionnaire was guided by a contextual framework that was informed by NCTM's 2000 standards document (Ferrini-Mundy & Schmidt, 2005; Mullis et al., 2003, 2005), better variables to represent one of the five process standards of NCTM needs to be selected since the variable "teachers ask students to write equations and functions to represent relationships" cannot accurately capture the dimension of "representation" process standard.

Last, this study found that the students' problem-solving and basic mathematics skills achievements are reciprocally related, as was indicated by the nearly identical parameter estimates from the two-level hierarchical linear modeling for all four racial groups of students. To be specific, result from this study showed that, when students are exposed to more or less reformed teaching and when controlling for traditional teaching, every unit increase in the problem-solving achievement is associated with .70 point increase in the basic skills achievement; and when students are exposed to more or less traditional teaching and when controlling for reformed teaching, every unit increase in students' basic skills achievement is associated with .41 point increase in the problem-solving achievement for Caucasian, African-American, Hispanic, and Asian-American students. The nearly identical parameter estimate could indicate that TIMSS 2007 assessment could not effectively differentiate the relationship between the

two types of skills achievement for the four racial groups, and it could also indicate the two types of skills are reciprocally related for students across different racial groups. In the latter case, these findings indicated that the assumptions of both the reformed and traditional teaching tend to hold true. Proponents of reformed teaching proposed that by focusing on students' higher order mathematics thinking skills, students' basic mathematics knowledge and skills will be improved as well (NCTM, 2000; Romberg, 1992), which is supported by the result. Supporters of traditional teaching argue that by focusing on students' lower order mathematics thinking skills such as solid memorization of algorithms, facts and rules, routine computational drill, procedural skill practice, and using algorithms, facts, rules and concepts to solve simple, routine problems, students' higher order thinking skills such as problem-solving will be improved as well (Gamoran, 2001; Geary, 1994; Greeno et al., 1996; Wu, 1999), which is also supported by the result. Based on this result, it seems that the debates over which type of teaching is more useful in mathematics teaching could be less meaningful as students' lower level thinking skills such as basic mathematics knowledge and skills, and their higher level thinking skills such as problem-solving are closely related to each other.

However, as TIMSS 2007 is a non-experimental design, this study cannot identify whether traditional teaching that focuses on students' basic mathematics skills can really foster students' higher level mathematics thinking skills such as



problem-solving, and likewise, whether reformed teaching that focuses on students' problem-solving can really help students learn the basic mathematics skills.

### **Implications**

The findings of the study provide mathematics teachers, educators and policy makers with some important implications. First, the finding that neither reformed nor traditional teaching approach can be positively and significantly related to the mathematics achievement of students across different racial groups implies that it is important for school mathematics teachers to recognize the different learning needs and cultural backgrounds of students from different racial groups. Since both reformed and traditional teaching approaches can be positively and significantly related to Caucasian and Hispanic students' mathematics performance but the traditional teaching seems to have a stronger effect on their mathematics achievement than the reformed teaching, school mathematics teachers would be encouraged to use more of the traditional instructional activities although a balanced use of the two would be beneficial.

Additionally, for African-American students, this study found that reformed teaching instead of traditional teaching was positively and significantly related to their mathematics achievement. This result is consistent with that in the study by Manswell-Butty (2001), who found that reform-oriented instruction was significantly more effective than traditional teaching for improving the overall achievement of the

12th-grade African-American students. In view of the fact that African-American students tend to be taught by more traditionally oriented and drill-based instruction that focuses on the acquisition of basic computational skills (Ladson-Billings, 1997; Means & Knapp, 1991), school mathematics teachers would be encouraged to use more reform-oriented instructional activities to help African-American students learn mathematics since the traditional teaching seems not helpful for them.

Neither type of teaching can be related to Asian-American students' mathematics achievement seems to imply that whichever type of instructional approach a teacher use does not impact greatly the mathematics achievement of Asian-American students. As was mentioned earlier, the curriculum of the home might play a more influential role in Asian-American students' mathematics learning. Therefore, teachers need to strengthen their communication with Asian-American students' parents in order to better inform them of what is being taught and learned in school so that better support can be provided for the students from their parents. Also, it would be meaningful for researchers to further investigate how this curriculum of home can better serve students' learning and teachers' instruction, and investigate why this curriculum is not so useful in helping other racial groups of students learn mathematics.

Overall, this study found that only a very small proportion of the variance in students' mathematics achievement can be explained by teaching, which implies that

there are more important factors than teachers' instructions that can influence students' mathematics learning. Therefore, policy that focuses on improving the teaching quality of the school mathematics teachers might not be able to achieve its desired result.

Researchers and policy makers should focus on other potentially more important and more influential factors in order to improve U.S. students' mathematics performance and close the racial achievement gaps.

### **Future Research**

This study raises some questions for further research. First, a carefully designed large-scale experimental study is needed to examine whether reformed teaching that focuses on students' higher level mathematics thinking skills can help students across different racial groups learn the basic mathematics skills, and whether traditional teaching that focuses on students' lower level thinking skills can foster students' higher level thinking skills. In this design, it would be interesting to see if there are significant performance differences between the two groups of students taught by reformed or traditional type of teaching approaches in their lower level as well as higher level mathematics thinking skills.

Second, as this study only involved teachers' instructional approaches as the predictor at the classroom level and there is no predictor except the dummy coded racial vector at the student level, it would be meaningful to take into consideration other

important factors such as student socioeconomic status, prior achievement, and teachers' professional development for using reformed teaching to see whether the two types of teaching still can be positively and significantly related to the mathematics achievements of students across different racial groups in the US.

Furthermore, to address the limitation that causal relationships between teaching approaches and students' mathematics achievement cannot be evaluated in the current study, it would be interesting and meaningful to apply causal inference techniques such as instrumental variables and regression discontinuity estimation in future studies to identify whether reformed or traditional type of teaching approaches is more effective for improving the mathematics achievement of students from different racial backgrounds.

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