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Do Variations of Science Teaching Approaches Make Difference in Shaping Student Content and Problem Solving Achievement across Different Racial/Ethnic Groups?

Su Gao[a], and Jian Wang[a]

[a]University of Central Florida, Florida, USA; [b]Texas Tech University, Lubbock, USA

ABSTRACT

Students' frequent exposure to inquiry-based science teaching is presumed more effective than their exposure to traditional didactic instruction in helping improve competence in content knowledge and problem solving. Framed through theoretical perspectives of inquiry-based instruction and culturally relevant pedagogy, this study examines this assumption using TIMSS 2007 US eighth-grade student data. Data analysis revealed three instructional approaches, including more inquiry based, mixed, and practice based, were popularly practiced in classrooms. More inquiry-based instruction was not significantly associated with content and problem solving achievements across Caucasian, African American, and Hispanic American students. The mixed teaching approach had a significant positive relationship for Hispanic American student's content and problem solving achievement. The relationship between practice-based approach with content and problem solving achievements of all three racial/ethnic groups were not significant. This study questions the popular assumption of the effectiveness of science teaching approaches and offers important implications for science teaching reform.

KEYWORDS
Inquiry, Science performances, teaching approaches, and students' racial groups

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Introduction

A country's quality and equity of science literacy is central to economic competitiveness in a global world (Bybee & Fuchs, 2006), and plays a key role in enabling democratic operations necessary for dealing with emergent social, economic, political, and cultural problems (McFarlane, 2013), and the pursuit of social mobility for citizens in an equitable manner (Lynch, 2000). Such science

CORRESPONDENCE Su Gao ✉ su.gao@ucf.edu

literacy involves the knowledge of science content, such as understanding specific facts and well-developed theories, and problem solving skills, such as the ability to reason and pursue solutions to problems (American Association for the Advancement of Science, 1989; Barba & Ruba, 1992; Glasson, 1989). The Next Generation Science Standards (NGSS) further emphasize that one of the important goals of classroom instruction is to help students learn the content knowledge and enable them to become experts in organizing their knowledge and using it to problem solve (National Research Council, 2012). Consequently, science curriculum standards have been established and refined to allow US schools to meet these goals (Elio, 1990; National Research Council, 2010; Achieve, 2013; Chen & She, 2013).

While the quality of students' science learning at middle grade level plays an important role in shaping later science achievement (Kwon & Lawson, 2000; Jackson & Davis, 2000), US middle grade students showed consistently poor performance in science content and problem solving skills in a series of international comparative studies (Gonzales & Williams, 2009; Martin et al., 2000; OECD, 2009; OECD, 2012). Such low performance in student science content and problem solving skills at middle grade levels poses a serious challenge to economic prosperity, the democratic process, and the individual pursuit of equity and happiness (Quinn & Cooc, 2015).

While science teaching quality is seen as an important factor shaping student science achievement (Fogleman, McNeill, & Krajcik, 2011; Kloser, 2014; Seidel & Shavelson, 2007), didactic science teaching is presumed to be popularly practiced in the US classrooms and ineffective in helping students develop conceptual understanding about science content and problem solving skills (Smerdon, Burkam, & Lee, 1999). Science instruction is seen as relying on textbooks and lectures to convey science content and focuses on students reading about science or by memorizing the steps of the scientific method (Barrow, 2006; Capps et al., 2012; Duschl, Schweingruber, & Shouse, 2007). In contrast, inquiry-based instruction is seen as useful in helping all students develop problem solving skills and gaining a better understanding of content knowledge by actively engaging students in science practices, such as making observations, posing questions, designing and planning investigations, collecting and analyzing data, and proposing and communicating explanations to each other (NGSS Lead States, 2013; Keys, Bryan, & Hall, 2001; Tekkumru-Kisa, Stein, & Schunn, 2015). These assumptions constitute an important conceptual basis for reform efforts developed over the last decade to help teachers change their beliefs and instruction practices from didactic to more inquiry-based science instruction (Capps, Crawford, & Constas, 2012; Keys, Bryan, & Hall, 2001).

However, these assumptions are empirically contentious in several ways. First, whether and to what extent didactic science teaching is popularly and consistently practiced in schools has not been empirically supported (Hudson, McMahon, & Overstreet, 2002; Weiss, Pasley, Smith, Banilower, & Heck, 2003). Second, there is insufficient evidence as to whether and to what extent inquiry based science instruction is better in shaping students' content knowledge and problem solving skills (Blanchard et al., 2010; Blank, Porter, & Smithson, 2001; Mayer, 2004) versus didactic science teaching (Barrow, 2006; Cuevas, Lee, Hart, & Deaktor, 2005). For example, inquiry-based science teaching does not show significant differences when compared to other teaching strategies based on content knowledge recall performance (Glasson, 1989) but it can make a difference based on the perspective of how well the learning transfers to new problems and settings (National Research Council, 2000). Third, it is still not clear empirically whether and to what extent inquiry-based instruction is effective for African, Hispanic, and Caucasian-American students in terms of science content and problem solving skills as compared with other teaching approaches popularly practiced in science classrooms (Lee, Luykx, Buxton, & Shaver, 2007; Luykx & Lee, 2007).

This study is designed to contribute to the much needed empirical understanding of what science teaching approaches are practiced in middle-grade classrooms. It identifies potential relationships between teaching approaches and science content knowledge and problem solving skills of middle-grade students across different racial/ethnic groups. In particular, this study examines the following three questions. First, what kinds of science teaching approaches in relation to the components of inquiry-based and traditional didactic teaching approaches as conceptualized are popularly practiced in eighth grade US science classrooms? Second, whether and to what extent does each of these teaching approaches contribute positively to the science content knowledge and problem solving skills of Caucasian, African, and Hispanic American students?

Literature Bases

Theoretical Assumptions

This study is situated in two influential yet contentious theoretical assumptions about effective science teaching approaches for student science learning. The first assumption is that inquiry based science teaching is a more effective teaching approach than didactic science teaching assumed to practice popularly in the science classrooms in improving all student science learning in content knowledge and problem solving (Bransford, Brown, & Cocking, 1999).

Underlying these assumptions are two paths of reasoning. On the first path, children are seen as natural problem solvers who have the biological capacity for making sense of the world around them (National Research Council, 2000). Therefore an approach that assists g in developing science knowledge has to engage students in interacting with social and physical environments (Dewey, 1916, 1956; Piaget, 1973; Vygotsky, 1978). Inquiry-based science teaching is perceived as effective in meeting this need for several reasons (Bransford, Brown, & Cocking 1999; Pedaste et al., 2015): it helps create (1) a learner-centered environment in which students are able to draw on prior experience and knowledge to develop meaningful questions leading to new understandings, (2) a knowledge-centered environment in which teachers are able to help students use their own observations and investigations to build general and transferable principles or ideas, (3) an assessment-centered environment in which students are able to monitor and regulate their own learning through investigation activities, and (4) a community-centered environment in which students are able to interact with others through group work to articulate ideas and challenge each other through discussions.

On the second path, didactic science teaching is seen as a popular yet ineffective science teaching method as it focuses on the transmission of facts to students through teachers' lecture and students' drill and practices following textbooks in order to memorize factual knowledge (Smerdon, Burkam, & Lee, 1999). Such instruction offers students fewer opportunities to develop science knowledge and solve problems by drawing on their own experience and prior knowledge (Leonard & Chandler, 2012). Consequently, it is seen as an important contributing factor to US students' lower performance in content knowledge and problem solving skills (Meyer & Crawford, 2011).

The perspective on inquiry-based instruction versus didactic instruction constitutes an important conceptual basis for the establishment of US national science standards (National Research Council, 1996, 2012; NGSS Lead States, 2013) and the development of teacher education and professional development programs (Capps, Crawford, & Constas, 2012; Grove, Dixon, & Pop, 2009; Luft, 2001). Many of these efforts are intended to move science teachers from didactic science teaching towards inquiry-based instruction through enhancing understanding of science and changing beliefs of science learning and teaching. Thus it becomes important to empirically examine whether and to what extent the didactic teaching is practiced in science classrooms and whether and to what extent inquiry-based science teaching is more effective than didactic science teaching in shaping student's science content knowledge and problem solving performance.

A second theoretical assumption is that of culturally relevant teaching (Ladson-Billings, 1994, 1997), which presumes an effective teacher should practice teaching that is able to "match the cultures students bring with them from home" (Castagno & Brayboy, 2008, p. 946). Such a teacher is able to understand that culture manifests in his or her classrooms in various ways within how students prefer to learn and use differentiated instruction to tailor learning to these aspect of a student's culture (Gay, 2010). It further suggests that when a teacher is able to practice teaching in such a manner, it will improve students' long-term academic achievement central to improving their social economic status and making informed decisions about their lives, help students to recognize and honor their own cultural beliefs and practices, and find ways for "students to recognize, understand, and critique current and social inequalities" (Ladson-Billings, 1995, p. 476).

The fundamental premise stressing effective teaching as student culture relevant poses a challenge to the inquiry-based teaching as a ultimate effective teaching in improving the science learning of all students no matter their differences in cultural norms and adaptations manifested in classrooms (Carlone, Haun-Frank, & Webb, 2011; Mutegi, 2011) since not all the students came from the same cultural backgrounds that encourage inquiry practices (Lee et al., 2006). For example, engaging students in investigation activity may conflict with the accepted norms in the culture, such as valuing the knowledge of teachers or elders in the community (Lee, 2003). Consequently, inquiry-based instruction may force students with those cultural backgrounds to learn science in a way incongruent with their cultural values, disregarding norms of learning they familiar with and pushing them to avoid or resist learning science (Allen & Crawley, 1998; Meyer & Crawford, 2011). It is therefore worthwhile to empirically examine whether and to what extent inquiry-based instruction in science education is able to improve science learning of students with different racial and ethnic backgrounds as compared with other science teaching approaches. This study is developed to examine this issue based on the assumption of the culturally relevant teaching.

Empirical Basis

To situate the research question in current empirical literature, a search of four databases was conducted (ERIC, Academic Search Premier, PsycINFO, and PsycARTICLES) using keywords “effective instruction”, “inquiry”, “didactic teaching”, “direct instruction”, “constructivist teaching”, “science instruction”, and “science teaching” from 1996 to present. Our review of literature emerging from these searches lead to the following findings relevant to each research question.

First, existing studies were not able to offer sufficient evidence to support the assumption that didactic teaching was popularly practiced in the US science classrooms (Barrow, 2006; Duschl, Schweingruber, & Shouse, 2007). Of the two studies frequently cited to support didactic teaching as a popular method, the National Survey of Science and Mathematics Education, using 529 middle school science teachers across the US (Hudson, McMahon, & Overstreet, 2002) showed that relatively small portions of teachers include the components of inquiry-based science teaching in their science lessons, such as asking students to explain scientific ideas and evaluate arguments based on scientific evidence. By observing 64 middle school science lessons and interviewing the teachers involved in the study, a second study (Weiss, Pasley, Smith, Banilower, & Heck, 2003) revealed that only 9% of science lessons focused on the important processes of science inquiry. Although revealing that inquiry was seldom used in both cases, researchers failed to directly examine the assumption that didactic teaching was popular. In order to clarify this issue, this study was developed to explore what kinds of science teaching approaches are popularly practiced in eighth grade US science classrooms and whether and to what extent to the components of inquiry-based and didactic teaching approaches are reflected in the popular science teaching practices.

Second, many studies show that inquiry-based teaching has more positive effects on overall science achievements when compared with traditional didactic teaching while others posed challenge to this conclusion. For example, Furtak, Seidel, Iverson, and Briggs (2012) examined 37 experimental and quasi-experimental studies published between 1996 and 2006 and found that inquiry-based science teaching had a positive influence on student science performance when compared to traditional didactic science teaching. This is confirmed by another review study based on 42 comparative experimental (or quasi-experimental) studies between 2001 to 2006 (Minner, Levy, & Century, 2010) that showed teaching strategies actively engaging students in the learning process through scientific investigations are more likely to increase conceptual understanding than strategies that rely on more passive techniques. This finding was further confirmed by recent studies (Akkus, Gunel & Hand, 2007; Odom, Stoddard, & LaNasa, 2007). In contrast, however, other studies (Pine, et al., 2006; Wolf & Fraser, 2007) did not find significantly different effects of these two teaching strategies on student overall science performance.

Third, studies that examined the effects of these two teaching approaches on student performance in content knowledge and problem solving skills were under-developed and often led to mixed results. In a study by Wilson, Taylor, Kowalski, and Carlson (2010), researchers assigned fifty-eight 14–16 year old students randomly to a group that was exposed to inquiry-based instruction or a group that received traditional instruction (control group). Students were taught and then interviewed individually for the quality of their claim, evidence, and reasoning before and after exposure to each teaching method. Students in the inquiry-based group performed significantly better than students in the control group based on achievements in reasoning and argumentation. This result is consistent with another study (Taraban, Box, Myers, Pollard, & Bowen 2007) that assessed the performance of 408 high-school students in six classrooms who were classified as either inquiry-based teaching featuring teacher's guided-inquiry lab activity or traditional teaching with the characteristics of teachers' direct transmission of information, whole-class activities, and cookbook of experiments. In contrast, these results are challenged by the study (Glasson, 1989) that involved 54 9th graders in two classrooms. This study found that while the students' achievements in science content knowledge were almost identical in both classroom where instruction focused on more on hands on inquiry activities and that where teachers replied on direct demonstration for instruction although students in the inquiry group performed better in applying the concepts presentenced in the instruction.

In the above studies, student population was in limited regions and there was no consistent definition for science content knowledge and problem solving competence. This study is designed to address such limitations by examining the influences of science teaching approaches that incorporated with different components of inquiry and traditional didactic science instructional practices using carefully defined on students' achievements of both science content and problem solving skills based on large database with students from different parts of the United States.

Fourth, few studies were developed to measure the effectiveness of inquiry-based instruction on the performance of the students across different racial /ethnic group. One relevant study (Kahle, Meece, & Scantlebury, 2000) administered questionnaires and achievement tests at eight schools with African-American middle-school students. It found that African-American students scored higher on general science achievement when they reported their teacher using more inquiry-based teaching. Another study (Lynch, Kuipers, Pyke, & Szesze, 2005) also found that AfricanAmerican and Hispanic students from five middle schools taught using inquiry-based chemistry curriculum outperformed peers in a comparison group.

In either study, only limited amount of students were involved, science content knowledge and problem solving skills were not carefully broken down for examination. This study is designed to address these limitations by examining the relationship between different science teaching approaches involving various components of inquiry and didactic teaching approaches and the science content and problem solving performances of students from Caucasian, African, and Hispanic American students.

Methodology

Data Source

Data from the 2007 Trends in International Mathematics and Science Study (TIMSS) was selected for this study based on five reasons: First, it was a large-scale database with more representational of US eight grade classrooms. For example, the database included 7, 273 eighth grade students in 239 schools at 8th grade from different parts of the United States (Williams, Roey, Kastberg, Gonzales, & Easton, 2009), who were selected using the two-stage, nonrandom to ensure they formed a nationally representative sample (Foy & Olson, 2009).

Second, a range of students' race/ethnicity background information was collected in TIMSS 2007, which allowed this study to examine our research questions with three major racial and ethnic groups of students. As a result, we were able to include 3,869 Caucasian, 934 African American, and 1,756 Hispanic students at the eighth grade level in this study.

Third, students participating in TIMSS 2007 were surveyed using a questionnaire on the frequencies of students' exposure to various teaching activities in their science classrooms including both inquiry and didactic teaching components. As seen in Table 1 below, nine of these science teaching activities were more consistent with the components of inquiry based teaching (Pedaste, et al., 2015) while seven of them were aligned with the components of didactic instruction (Smerdon, Burkam, & Lee, 1999) as following:

Table 1. TIMSS 2007 Teaching Items and Recoding

How often do you do these things in your science lessons?	Original coding	Recoding
Inquiry Components		
1) Observe natural phenomena and describe what we see	1=every or almost every lesson 2=about half the lessons 3=some lessons 4=never 8=not administered 9=omitted	1=never 2=some lessons 3=about half the lessons 4=every or almost every lesson 8=missing data 9=missing data
2) Design or plan experiments or investigations		
3) Conduct experiment or investigation		
4) Work in small groups on experiment or investigation		
5) Read our science textbooks or other resource materials		
6) Use science formula and laws to solve problems		
7) Give explanations about we are studying		
8) Relate daily lives		
Traditional Didactic Teaching Components		
9) We watch the teacher demonstrate an experiment or investigation		
10) Memorize science facts and principles		
11) Review our homework		
12) Listen to the teacher give a lecture-style presentation		
13) Work problems on our own		
14) Begin our homework in class		
15) Have a quiz or test		

We used the data from student questionnaire instead of the teacher survey in this study to gather science teaching information based on two reasons. (1) The teaching activities surveyed in the student questionnaire covered more teaching activities aligned with the inquiry based and didactic science teaching. (2) Student responses to the questionnaire on the teaching activities used in the classrooms were more likely to reflect what was going on in their classrooms and could decrease the social desirability bias when teachers repost what they did in their classroom (Martínez, Borko, & Stecher, 2012).

Fourth, student achievement of science was measured at "knowing," "applying," and "reasoning" cognitive levels in TIMSS 2007 (Mullis et al., 2005), which offers researchers a chance to understand the relationship of various science teaching approaches with science content knowledge achievement and two levels of problem solving achievement. For example, at knowing level, students are measured for their knowledge of science facts, procedures, and concepts using questions as shown in the released assessment item, *Which food contains the highest percentage of protein? A. rice, B. dates, C. carrots, and D. chicken*. At applying level, students were measured for their competence in using science knowledge and concepts to solve a routine problem in a relatively simple context using questions such as the following released item:

The weathering (gradual breaking down) of rocks can be caused by both physical and chemical process. Write down one physical process and one chemical process. Explain how each can cause the weathering of the rocks.

At the reasoning level, they were measured for their ability to use science knowledge to solve problems in unfamiliar situations and complex contexts using questions such as the following released item,

The organisms that live in the intertidal zone have special adaptions that allow them to survive the effects of tides. Select an organism from the intertidal zone. Identify a physical feature or behavior of this organism. Explain how this feature or behavior helps the organism to survive low tide.

Name of organism:

Feature or behavior:

Explanation:

Variables Construction

Three kinds of variables were constructed for this study. First, the independent variables were popular science teaching approaches in eighth grade US science classroom, which were constructed in several steps. First, all 15 items of the science instructional activities in the student questionnaire were recoded to construct the independent variables as shown in Table 1.

Second, Explanatory Factor Analysis (EFA) was conducted with students' responses to these items to identify any teaching approaches popularly exist in the classrooms in the suggested steps (Vogt, 2007). The internal reliability was checked for the 16 items with the result of Cronbach alpha coefficients, .821. Then EFA from the Maximum Likelihood factoring with oblique solutions was conducted to identify underlying factor structures among items, each of which were used to construct each independent variable of science teaching approach.

We used the composite variable based on multiple items instead of a single item variable as our independent variables for two reasons. It represented science teaching approach popularly practiced in the classrooms more closely (Mayer, 1999) and helped avoid instability caused by single item variables in a multilevel model that we used to estimate their effects on student science performance as suggested (Raudenbush & Bryk, 2002).

Second, two control variables were used in this study. They were students' answers to the questions on their Social Economic Status (SES) and self-confidence of learning science. Such variables are theoretically and empirically related with their science achievements in the positive manner (Byrnes & Miller, 2007; White, 1982). Thus, the variables could confound the effects of different science teaching approaches on student science achievement and thus, should be controlled at student level as suggested (Schmidt, Burroughs, Zoido, & Houang, 2015).

The SES variables was created using EFA based on three kinds of data revealed in the student questionnaire as done in other study (Wang & O'dwyer, 2011), (1) number of books in student home, (2) their parents' highest education levels, and (3) their possesses study aids at home. The science self-confidence variable was created as an index variable in TIMSS 2007 data set that was computed by averaging students' responses to the four source questions ("I usually do well in science", "Science is harder for me than for many of my classmates", "I'm just not good at science" and " I learn things quickly in science") in the student questionnaire (Williams et al., 2009).

Third, students' performances at each of three cognitive levels in TIMSS 2007 database were used as three dependent variables in this study to represent student science content knowledge and two level of problem solving achievements respectively. In TIMSS 2007 database, each student performance in the assessment was represented by five plausible values developed based on the student's observed responses to assessment items and on background variables since each student only took different item sets from the pool (Foy & Olson, 2009). To estimate students' science content and process knowledge score for the full test on all test items, item response theory (IRT) were used (Olson, Martin, & Mullis, 2008) in TIMSS 2007 to impute five plausible values for each dependent achievement variable based on the student's observed responses to assessment items and on background variables (Olson, Martin, & Mullis, 2008).

Missing Data and Sampling Weights.

Missing data in this study was handled in the following manner as they were not missing completely at random (MCAR) ($p< .001$) according to the missing data pattern test-Little 's MCAR test (Schlomer, Bauman, & Card, 2010). As suggested in the literature (Wang & O'dwyer, 2011), a new data set was created for all missing values that were imputed with maximum likelihood values based on observed relationships using EM, a maximum likelihood approach since all the independent variables used had rather low (<2%) missing data except parents' highest education level (19%).

Since the design of TIMSS 2007 is not simple random sampling, the weight for a student was considered to reflect the probabilities of student's school being selected and the student being selected within that school (Williams et al., 2009). Sampling weights were considered in TIMSS 2007 data to accommodate the fact that some units (class, teachers, or students) were selected with differing probabilities (Foy & Olson, 2009). Consequently, two weights were generated at the student level (student weight factor*student weight adjustment) and at class level (class weight factor*class weight adjustment*school weight factor*school weight adjustment) respectively as suggested in the literature (Rutkowski, Gonzalez, Joncas, & von Davier, 2010).

Data Analysis

To develop answers to the three questions of this study, following levels of analysis were conducted using various statistics models. First, to identify the existing science teaching approaches popularly practiced in the science classrooms based on various components of inquiry and traditional didactic science instructions, we conducted EFA with science teaching question items in the student questionnaire to identify the kinds of science teaching approaches in TIMSS 2007 database and computed composite score for the frequency means of each science teaching approach. Then, one-way repeated measure analysis of variance (ANOVA) was conducted to detect differences between the frequency mean scores of different science teaching approaches to identify the popularity level of each teaching approach was practiced in the students' classrooms in the study since the frequency mean differences indicates how often the approach being conducted in the classroom (Foy & Olson, 2009).

Second, to capture the relationship between various teaching approaches with Caucasian student science content knowledge and problem solving achievements, we conducted two-level Hierarchical Linear Modeling (HLM). First, unconditional (null) model was built using knowing, applying, and reasoning scores that Caucasian 8th students achieved respectively to allow partitioning of the total variability in each of the three science achievements into within and between classroom variance components. Second, control variables, SES and self-confidence of science learning were grand centered as suggested (Enders & Tofighi, 2007) and added to the student level (Model 1). Finally, the independent variables, the frequency means of various kinds teaching approaches emerged from the EFA analysis were aggregated within each class and added to class level using the full model (Model 2) as specified in the following to examine the relationship between various teaching approaches and Caucasian student science content knowledge achievement (Raudenbush & Bryk, 2002):

Level-1 Model

$$KNOWING_{ij} = \beta_{0j} + \beta_{1j}{*}(SES_{ij}) + \beta_{2j}{*}(SELFCONF_{ij}) + r_{ij}$$

Level-2 Model

$$\beta_{0j} = \gamma_{00} + \gamma_{01}{*}(Inquiry_j) + \gamma_{02}{*}(Didactic_j) + \gamma_{03}{*}(Other_j) + u_{0j}$$

$$\beta_{1j} = \gamma_{10}$$

$$\beta_{2j} = \gamma_{20}$$

$$\beta_{3j} = \gamma_{30}$$

$$\beta_{4j} = \gamma_{40}$$

$$\beta_{5j} = \gamma_{50}$$

To examine the relationship between different teaching approaches with the science problem solving achievements of Caucasian students, the same model building processes were used but applying and reasoning achievement needs to be used respectively instead. Finally, the same two-level HLM model-building processes were used within Hispanic and African American students group respectively to examine the relationship between various teaching approaches with science content knowledge (knowing) and problem solving (applying and reasoning) achievements of each group students.

Results

Teaching Approaches Popularly Practiced in Classrooms

Our analysis of the students' answers to the 15 question items relevant to teaching activities leads us to two findings relevant to the popularly practiced science teaching approaches in the students' classrooms. First, three kinds of science teaching approaches popular practiced in the students' classrooms emerged from EFA. *The more inquiry-based instruction*, which includes five teaching components with four inquiry based components, (1) *observe natural phenomenon and describe what we see,* (2) *design or plan an experiment or investigation,* (3) *conduct an experiment or investigation,* and (4) *work in small groups on an experiment or investigatio*n, and one didactic teaching component, (5) w*atch the teacher demonstrate an experiment or investigation*. *The mixed teaching approach* that encompasses six teaching components with three inquiry-based components, (1) *use scientific formulas and laws to solve problems,* (2) *give explanations about what we are studying* and (3) *relate what we are learning in science to our daily lives* and three didactic teaching components, (4) *read our science textbooks and other resource materials,* (5) *listen teacher lecture,* and (6) *memorize science facts and principle*. The last is *the practice-based teaching* including four traditional didactic components, (1) *review our homework*, (2) *begin our homework in class*, (3) *work problems on our own*, and (4) *have a quiz or test*.

Our EFA analysis in the following steps supports the above the finding. We measured the sampling adequacy for the student sample in the study using Kaiser-Meyer-Olkin and Bartlett tests and come to the high results, .912, and the significant result, χ^2= 15884844.688775, p < .001 respectively (Ferguson & Cox, 1993), which suggest that the sample in the study was appropriate for factor analysis. Next, we conducted the exploratory factor analysis from the Maximum Likelihood factoring solution with oblique solutions on 15 items. This analysis led us to three factors that accounted for 41.479% of the variance of the science teaching activities together, each of which is loaded substantially in terms of coefficient (> .3) as shown in Table 2 below.

Table 2. Results of Exploratory Factor Analysis and ANOVA on Science Teaching Activities

Results of Exploratory Factor Analysis			
Question Items on Teaching Activities	Factor 1	Factor 2	Factor 3
• Make observations and describe what we see	.590		
• Watch the teacher demonstrate and experiment or investigation	.679		
• Design or plan an experiment or investigation	.773		
• Conduct an experiment or investigation	.873		
• Work in small groups on an experiment or investigation	.684		
• Read our science textbooks and other resource materials		.346	
• Memorize science facts and principles		.686	
• Use scientific formulas and laws to solve problems		.615	
• Give explanations about what we are studying		.507	
• Relate what we are learning in science to our daily lives		.314	
• Listen teacher lecture		.334	
• Review our homework			.463
• Work problems on our own			.356
• Begin our homework in class			.649
• Have a quiz or test			.352
Kinds of Teaching Approaches:	More-Inquiry	Mixed	Practice
%Variance	30.929	7.599	2.952
Reliability (Cronbach's Alpha)	.864	.749	.601
Factor Correlation			
Factor 1	1.000	.502	.341
Factor 2	.502	1.000	.547
Factor 3	.341	.547	1.000

These three factors were then labeled as *the more inquiry-based instruction* loaded with 5 items, *the mixed teaching approach* with 6 items, and *the practice-based teaching approach* with 4 items. Factor 1 and factor 2 were correlated at .502 while the factor 1 and factor 3 were correlated at .341, which suggests that these three teaching approaches were positively related to each other.

Second, these three teaching approaches were all related with each other and popularly practiced in the students' classrooms based on the frequency of each approach. However, the mixed science teaching approach was the most frequently implemented while the inquiry approaches was the least. The descriptive results of three teaching approaches were shown in Table 3. It indicated the average frequency of each teaching approaches (2.82, 2.94, and 2.88) being used in the US classrooms.

Table 3. Descriptive Statistics of Three Science Teaching Approaches

	Mean	Std. Deviation	N
More Inquiry	2.8201	.75857	7273
Mix	2.9450	.63304	7273
Practice	2.8760	.67124	7273

A one-way repeated measures ANOVA was further conducted to compare these three teaching approaches (Moreinquiry, Mix, and Practice). As shown in Table 4, there was a significant difference among the means of these three teaching approaches, F (1.820) = 114.707, p < .001.

Table 4. Test of Main Effect

		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Teaching	Sphericity Assumed	56.977	2	28.489	114.707	.000	.016
	Greenhouse-Geisser	56.977	1.820	31.304	114.707	.000	.016

Post hoc tests (pairwise comparison) using the Bonferroni correction (see Table 5) further revealed that more inquiry-based instruction was significantly less than both the mixed science teaching approach with M=-.125, SD= .008, p< .001 and practice teaching with M =- .056, SD= .009, p< .001. The results also showed that the mean of the frequency of the mix science teaching approach was significantly higher than practice teaching with M= .069, SD= .007, p< .001.

Table 5. Pairwise Comparisons of Three Teaching Approaches

Teaching	(J) Teaching	Mean Difference (I-J)	Std. Error	Sig.[b]
ore inquiry	Mix	-.125*	.008	.000
	Practice	-.056*	.009	.000
Mix	More inquiry	.125*	.008	.000
	Practice	.069*	.007	.000
Practice	More Inquiry	.056*	.009	.000
	Mix	-.069*	.007	.000

Based on estimated marginal means

b. Adjustment for multiple comparisons: Bonferroni

Science Teaching Approaches and Students' Content and Problem Solving Performance

Our HLM analyses lead several findings about the relationship between each of the three science teaching approaches and the science content and problem solving achievements of three racial and ethnic groups of students controlling for students SES and self-confidence of science learning. First, three teaching approaches popular practiced in the students' classrooms in this study only explained very little variance of science content and problem solving achievement of three different racial groups. For Caucasian students as seen in Table 6, three teaching approaches only explained about 1% the variance of science achievement of knowing including 0.74% of knowing, 1.03%, of applying, and 0. 84% of reasoning variance at classroom level. For African American students as seen in Table 7, three teaching approaches explained less than 1% of variance for all three level science achievement (.28% for knowing, .65% for applying, and .22% for reasoning). In case of Hispanic American students as seen in Table 8, three teaching approaches explained 3.78% of knowing, 4.18% of applying, and 3.19% of reasoning achievement variance at classroom level respectively.

Table 6. HLM Analysis Results of the relationship between three science teaching approaches with the achievements at knowing, applying, and reasoning three levels for Caucasian American students

Knowing	Null model	Model 1		Model 2	
Student level variables					
SES		13.16 (1.43)	***	13.13 (1.57)	***
Self-confidence		24.25 (1.62)	***	24.30 (1.77)	***
Class level variables					
More inquiry				-3.56 (6.10)	
Mix				-1.14 (10.78)	
Practice				-5.65 (7.85)	
Variance components					
Level 1 variance	3193.40	2875.33		2875.05	
Level 2 variance	2107.49	1507.03		1495.89	***
Proportion of Variance explained					
Level 1		9.96%			
Level 2				.74%	
Applying	Null model	Model 1		Model 2	
Student level variables					
SES		12.11 (2.24)	***	13.13 (1.57)	***
Self-confidence		20.82 (2.43)	***	24.30 (1.77)	***
Class level variables					
More inquiry				-6.18 (5.27)	
Mix				4.84 (10.02)	
Practice				-6.90 (7.24)	
Variance components					
Level 1 variance	2822.82	2584.20		2584.06	
Level 2 variance	1851.05	1341.72		1327.81	***
Proportion of Variance explained					
Level 1		8.52%			
Level 2				1.03%	

Table 6. Continued.

Reasoning	Null model	Model 1		Model 2	
Student level variables					
SES		8.85 (1.40)	***	13.13 (1.57)	***
Self-confidence		17.87 (1.80)	***	24.30 (1.77)	***
Class level variables					
More inquiry				-1.57 (6.32)	
Mix				4.87 (10.74)	
Practice				-9.48 (7.84)	
Variance components					
Level 1 variance	2568.33	2413.75		2413.81	
Level 2 variance	2085.69	1649.87		1636.03	***
Proportion of Variance explained					
Level 1		6.02%			
Level 2				.84%	

Unstandardized coefficients are shown with robust standard errors in parentheses. Self-confidence of learning science and SES are grand mean centered.
*p < .05. **p < .01. ***p < .001.

Table 7. HLM analyses results of the relationship between three science teaching approaches with the achievements at knowing, applying, and reasoning three levels for African American students

Knowing	Null model	Model 1		Model 2	
Student level variables					
SES		10.04(2.73)	***	13.13 (1.57)	***
Self-confidence		18.27(2.57)	***	24.30 (1.77)	***
Class level variables					
More inquiry				-3.56 (6.10)	
Mix				-1.14 (10.78)	
Practice				-5.65 (7.85)	
Variance components					
Level 1 variance	3049.81	2883.11		2880.95	
Level 2 variance	2447.78	1990.95		1985.36	***
Proportion of Variance explained					
Level 1		5.47%			
Level 2				.28%	
Applying	Null model	Model 1		Model 2	
Student level variables					
SES		8.33 (2.75)	**	13.13 (1.57)	***
Self-confidence		16.14(3.02)	***	24.30 (1.77)	***
Class level variables					
More inquiry				-3.98 (8.67)	
Mix				-1.13 (12.84)	
Practice				9.87 (11.83)	
Variance components					
Level 1 variance	2759.07	2641.76		2637.93	
Level 2 variance	2170.59	1798.70		1786.94	***
Proportion of Variance explained					
Level 1		4.25%			
Level 2				.65%	

Table 7. Continued.

Reasoning	Null model	Model 1		Model 2	
Student level variables					
SES		4.38 (3.05)		4.28 (3.13)	
Self-confidence		15.40 (2.88)	***	15.31 (2.92)	***
Class level variables					
More inquiry				.63 (9.10)	
Mix				-1.32 (11.43)	
Practice				5.41 (11.14)	
Variance components					
Level 1 variance	2677.54	2585.13		2582.92	
Level 2 variance	2131.64	1882.37		1878.31	***
Proportion of Variance explained					
Level 1		3.45%			
Level 2				.22%	

Unstandardized coefficients are shown with robust standard errors in parentheses. Self-confidence of learning science and SES are grand mean centered.
*p < .05. **p < .01. ***p < .001.

Table 8. HLM analyses results of the relationship between three science teaching approaches with the achievements at knowing, applying, and reasoning three levels for Hispanic American students

Knowing	Null model	Model 1		Model 2	
Student level variables					
SES		12.10(1.93)	***	13.13 (1.57)	***
Self-confidence		21.07(2.65)	***	24.30 (1.77)	***
Class level variables					
More inquiry				-5.70 (6.84)	
Mix				25.25 (9.87)	**
Practice				1.67 (8.42)	
Variance components					
Level 1 variance	3427.96	3193.00		3189.77	
Level 2 variance	2749.44	1968.99		1894.58	***
Proportion of Variance explained					
Level 1		6.85%			
Level 2				3.78%	
Applying	**Null model**	**Model 1**		**Model 2**	
Student level variables					
SES		11.46(2.17)	***	11.51 (2.19)	***
Self-confidence		18.36(3.18)	***	18.04 (3.17)	***
Class level variables					
More inquiry				-8.92 (6.42)	
Mix				28.76 (8.94)	**
Practice				-3.67 (7.51)	
Variance components					
Level 1 variance	3004.19	2809.61		2805.76	
Level 2 variance	2316.19	1696.17		1625.32	***
Proportion of Variance explained					
Level 1		6.48%			
Level 2				4.18%	

Table 8. Continued

Reasoning	Null model	Model 1		Model 2	
Student level variables					
SES		7.74 (1.91)	***	7.79 (1.93)	***
Self-confidence		16.21 (2.40)	***	15.95(2.38)	***
Class level variables					
More inquiry				-5.92 (6.64)	
Mix				26.18 (9.72)	**
Practice				-6.11 (7.89)	
Variance components					
Level 1 variance	2809.26	2701.50		2699.38	
Level 2 variance	2556.36	2033.17		1968.38	***
Proportion of Variance explained					
Level 1		3.84%			
Level 2				3.19%	

Unstandardized coefficients are shown with robust standard errors in parentheses. Self-confidence of learning science and SES are grand mean centered.
*p < .05. **p < .01. ***p < .001.

Second, there were no significant relationships found between the more inquiry-based instruction approach with the science content and problem solving achievements of students across three racial groups. As shown in Tables 6, Table 7, and Table 8, the more inquiry-based instruction approach was not significant related to Caucasian, African American, and Hispanic students' performances at knowing (*ps*> .05), applying (*ps*> .05), and reasoning levels (*ps*> .05).

Third, the mixed teaching approach may influence the science content and problem solving achievements of Hispanic American students positively but not those of Caucasian or African American students. As shown in Table 8, the mix teaching approach was significantly related with Hispanic American students' knowing, applying, and reasoning achievement (*p*s< .01). However, it was not significantly associated with Caucasian and African American students' knowing, applying, and reasoning achievement (*p*s< .01) as seen in Table 6 and Table 7.

Finally, the practice teaching approach did not show significant association with the content and problem solving achievements of Caucasian, African American, and Hispanic students. As shown in Table 6, Table 7, and Table 8, the practice based approach was not significant related to knowing, applying and reasoning achievement of any of the three racial and ethnic groups (*p*s> .05).

Students' Self Confidence and SES and Their Content and Problem Solving Performances

Our analysis of the influences of the two controlling variables, students' self confidence in science learning and SES, on their science content and problem solving competence further led us to the following three findings. First, in comparison with three teaching approaches, student SES and self-confidence of learning science explained substantially more variance of the achievement of three groups of students in the study. Based on Table 6, Caucasian students (Table 6), these two control variables at student level together explained 9.96%, 8.52%, and 6.02% variance of Caucasian students' science achievement at knowing, applying, and reasoning level respectively. For African American students as seen in Table 7, the two controlling variables explained 5.47%, 4.25%, and 3.45% variance of science achievement at knowing, applying and reasoning level correspondently. In the case of Hispanic American students as seen in Table 8, 6.85%, 6.48%, and 3.84% variance of science achievement at knowing, applying and reasoning level was explained by these two control variables.

Second, students' self-confidence of science learning was found significantly associated to the content and problem solving achievements of each of the three racial and ethnic groups of students. As shown in Table 6, student self-confidence in science learning significantly and positively associated to the achievement of Caucasian, African American, and Hispanic students at knowing, applying, and reasoning level (*p*s< .001).

Finally, students' SES might also shape the content and problem solving achievement of each of the three groups expect for that it might not influence the achievement of African American students at reasoning level. As shown in Table 6 and Table 8, student SES was positively related to the achievement of Caucasian and Hispanic American students at knowing, applying, and reasoning levels (*p*s< .001). However, for the African American students in Table 7, their SES was only positively associated to student knowing and applying achievement while it had no significant relationship with student reasoning achievement.

Discussion and Implications

This study did have three obvious limitations. First, by using a second-hand database in TMISS 2007, we were unable to conduct any observations in the classrooms about how the teaching approaches were actually used in the classrooms. Thus, the findings of this study need to be verified and extended in future studies based on systematic observations. Second, only some components of inquiry-based and didactic science teaching approaches were surveyed, therefore, other components may be unrepresented and need to be identified using the survey instruments that cover more sciences teaching components of various kinds in the future. Finally, the causal inferences between different science teaching approaches and students' science content and problem solving achievements could not be determined as the experimental study will do since TIMSS study did randomly assign students to treatments. In spite of these limitations, the empirical analysis of this study contributes to our understanding about the two research questions posed in the beginning of the report in several ways.

First, this study indicates that simply measuring what teacher did in the science classrooms does not necessary cover the complexity of sciences teaching practices that may shape students' competence in science content and problem solving in various contexts presumably in the literature (Barrow, 2006; Duschl, Schweingruber, & Shouse, 2007). As shown in this study, the three teaching approaches at classroom level can only explain relatively very small portion of the variances in students' content and problem solving performance. For example, across three racial and ethnic group students, the highest variance of science content and problem solving achievements explained by three teaching approaches was lesson than 4% for the Hispanic American students. This finding suggests that variations of science teaching approaches in the classroom alone might not have important influences on students' science content and problem solving performance (Byrnes & Miller, 2007; White, 1982).

Consequently, more factors of science teaching that potentially influence students' performances should be identified and included in examination and their relationship with teaching approaches in shaping students' performance needs to be empirically explored. However, to conduct such examination, it is important for science education community to identify and conceptualize these factors based on the carefully designed qualitative study or systematic observations of science teaching (Kloser, 2014; Sawada et al., 2002).

The implication of this finding is that the quality of science teaching cannot be simply judged based on the kinds of teaching approaches used in the classrooms such as inquiry based tasks implemented (Pedaste et al., 2015). Instead, a broader definition of teaching practices is necessary for guiding the teachers' changes of their science teaching based on the idea that teaching practices as a system, of which what a teacher does in the classroom is only one part (Kloser, 2014).

Second, the study suggests that the pure didactic teaching practice was not popularly practiced in the science classrooms as assumed (Smerdon, Burkam, & Lee, 1999) while in the science classrooms, various kinds of science teaching approaches may exist. As shown in the study, three related science teaching approaches, more inquiry based, mixed, and practice-based teaching, we identified as popularly practiced in the middle level classrooms. However, none of them fit into exact definitions of the inquiry based and didactic science teaching in the literature (Barrow, 2006; Pedaste et al., 2015). In addition, these three science teaching were actually positively related as shown in the results section.

This finding contributes to the much-needed understanding about the science teaching approaches popularly practiced in the middle level and confirm the assumption that the existing science teaching practices can be multiple and mixed science approaches as suggested (Furtak, Seidel, Iverson, & Briggs, 2012; Flick, 1995). Consequently, it challenges the assumption that the didactic teaching was the most popular science teaching approach practiced in the science classrooms (Hudson et al., 2002; Weiss, Pasley, Smith, Banilower, & Heck, 2003) since the frequency of mixed teaching identified in this study was the highest one in the US classrooms.

The implications of this finding can be twofold. On the one hand, it may suggest that the policy efforts to change teachers' teaching practices towards the inquiry based instruction following the assumption that didactic teaching is the most popular science teaching can be misguided (Capps, Crawford, & Constas, 2012; Keys, Bryan, & Hall, 2001). Over the years, such a policy initiative has been channeling various kinds of resources to change the assumed science teaching practices and relevant teachers' beliefs that may not popularly exist (Capps & Crawford, 2013; Capps, Crawford, & Constas, 2012). Thus, such a policy should not continue especially in the time when both financial and human resources have been limited and decreased for science education improvement, which should be better and thoughtfully used for more important purposes (Berliner, 2009).

While the present study helps understand that the didactic science teaching may not be the most popularly practiced science teaching approach, it is unable to offer sufficient evidence to construct a more realist image of various kinds of science teaching approaches practiced in the science classrooms since only the components of inquiry and didactic science teaching from TIMSS 2007 instrument were used in the our measures of science teaching. Therefore, it is necessary for the research community to construct such an image using the measures involving more components and kinds of science teaching practices. The qualitative design is able to reveal many of these components and kinds of science teaching (Kloser, 2014).

On the other hand, it may suggest that the science teaching reform developed to transform didactic science teaching practice toward the inquiry-based approach over the years could be successful as suggested in the literature (Hudson et al., 2002). However, although this study was able to show that the components of inquiry-based science teaching approaches did popularly present in science classrooms, it cannot verify such a claim directly since we are not sure whether and to what extent such components of inquiry-based teaching were not presented in the science classrooms initially. Therefore, to verify this assumption, it is necessary to examine what kinds of teaching that science teachers used to practice and whether and to what extent they transformed their practices because of the reforms efforts put in the place (Desimone, 2002; Smith, et al., 2007).

Third, it indicates that variations of science teaching approaches practiced in classrooms including the inquiry based teaching may not have any substantial effects on the improvement of students' competence in science content and problem solving no matter their racial/ethnic backgrounds. As shown in the study, the more inquiry-based instruction approach was not significant related to Caucasian, African American, and Hispanic students' performances at knowing, applying, and reasoning levels while the mixed approach was only significantly positively related to the science content and problem solving achievements of Hispanic American students. The practice-based science teaching approach had no significant association with those two kinds of performances across three different racial or ethnical group students either.

This finding is consistent with the concern that minority students may hold their cultural values different from inquiry science teaching style and thus, they might not be able to learn effectively when they are engaged in inquiry-based science teaching classrooms (Lee, Buxton, Lewis, & Leroy, 2006; Meyer & Crawford, 2011). For example, Hispanic American students' cultural values include respecting elder and strong family loyalty and allegiance (Griggs & Dunn, 1995), this might be in conflict with the learning styles of inquiry-based instruction, which encourages students to construct science knowledge by themselves through self- investigation (Snively & Corsiglia, 2001). Therefore, mixed teaching which including some traditional teaching components, such as listening teacher lecture and memorizing, works more effectively for Hispanic American students' science learning.

Therefore, this finding also seems to support the assumption of culturally relevant teaching indirectly that effective teachers needs to carefully consider the cultural values, norms, and styles of learning that various racial and ethnic brought into their classrooms (Ladson-Billings, 1995). However, the present study is not able to sustain such an assumption with sufficient and direct evidence, which require a further examination of the relationship between the values and norms of science learning that Hispanic students have actually honored and developed, the inquiry based science teaching that they are exposed to, and their science performance (Allen & Crawley, 1998; Meyer & Crawford, 2011).

This finding is not consistent with the general findings exist in current literature which showed that inquiry-based instruction positively associated with students' science achievements (Furtak, Seidel, Iverson, & Briggs, 2012; Minner, Levy, & Century, 2010). In those studies, the inquiry based teaching is mostly examined without substantial attention to different racial and ethnic groups nor differentiating student performance in science content and problem solving areas (Akkus, Gunel & Hand, 2007; Odom, Stoddard, & LaNasa, 2007; Wilson, Taylor, Kowalski, & Carlson, 2010; Taraban, Box, Myers, Pollard, & Bowen 2007). Therefore, this finding of our study problemizes the assumed relationship between inquiry based teaching and science content and problem solving achievement of students across different racial and ethnic groups in the existing literature (Kahle, Meece, & Scantlebury, 2000; Lynch, Kuipers, Pyke, & Szesze, 2005).

Nevertheless, this study is not able to sustain the challenge with sufficient and direct evidences as it only measured the frequencies of inquiry-based teaching components used in the science classroom instead of the quality of the inquiry tasks were implemented (NGSS Lead States, 2013). Thus, it is important to examine how inquiry-based teaching are implemented the classroom with diverse student populations using observation data and explore the effects of such teaching implementation on students' competence in using science knowledge in solving problems across different racial and ethnic groups as suggested (Chinn & Malhotra, 2002).

Finally, this study suggests that the successful reform of science teaching cannot simply rely on the reform of teaching alone (Fogleman, McNeill, & Krajcik, 2011; Lavonen & Laaksonen, 2009). Substantial attention also needs to be paid to the complex relationships between students' performances and teaching practices to other social, economic, cultural, and historical contexts in which such teaching and curriculum practices are situated (Berliner, 2009; Sykes, Bird, & Kennedy, 2010). As shown repeatedly in the history, the reform efforts to change the teaching and curriculum alone in order to solve social problems often prove to be futile (Labaree, 2008). Maybe that is why the variations of teaching approaches are not found strongly associated with student performances, especially when large database and diverse students are involved (Schmidt, Burroughs, Zoido, & Houang, 2015) while the effects of students' SES and self-confidence on their performance have been consistently identified as influential on students performances in the large data based studies such as this one and others (Byrnes & Miller, 2007; Schmidt, Burroughs, Zoido, & Houang, 2015). Therefore, it is important to explore how the teaching approaches related with non-teaching factors in shaping students performance across different racial groups as suggested (Ngololo, Howie, & Plomp, 2012; Wang & Lin, 2005).

Disclosure statement

No potential conflict of interest was reported by the authors.

Notes on contributors

Su Gao holds a PhD in science education and now is an associate professor at University of Central Florida, Florida, USA.

Jian Wang holds a PhD in science education and now is professor at Texas Tech University, Lubbock, USA.

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