AERA Open
July-September 2019, Vol. 5, No. 3, pp. 1–17
DOI: 10.1177/2332858419867653
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Inquiry-Based Instruction in Science and Mathematics in Middle School Classrooms: Examining Its Association With Students' Attitudes by Gender and Race/Ethnicity

Catherine Riegle-Crumb
University of Texas at Austin
Karisma Morton
University of North Texas
Ursula Nguyen
University of Texas at Austin
Nilanjana Dasgupta
University of Massachusetts, Amherst

Utilizing a nationally representative sample of middle school students, this article focuses on whether students who report experiencing more inquiry-based instruction in science and mathematics classrooms have more positive attitudes toward these subjects. Results of multilevel, multivariate regression analyses revealed that, net of the inclusion of control variables for student, teacher, and school characteristics, a higher frequency of inquiry-based instruction is significantly associated with greater interest, perceptions of utility, and self-efficacy for science and mathematics. Furthermore, although there is some evidence indicating that compared with female students, male students' perceptions of science utility are higher in relation to more inquiry-based instruction, overall, the weight of evidence clearly leans toward the conclusion that the attitudes of students from different gender and racial/ethnic backgrounds are similarly associated with greater exposure to inquiry-based instruction in both their science and mathematics classrooms.

Keywords: *mathematics, science, attitudes, gender, race/ethnicity*

Science and mathematics are foundational subjects in students' educational trajectories, as their successful engagement in these subjects in the K–12 years strongly predicts entry into college as well as entry into science, technology, engineering, and mathematics (STEM) college majors that typically lead to in-demand and economically lucrative jobs in the global economy (Burkam & Lee, 2003; National Research Council [NRC], 2010; Wang, 2013). As such, there is a vast research literature focusing on understanding the factors that promote students' achievement in these subjects, primarily centered on standardized test performance and, to a lesser extent, enrollment in advanced high school courses (Maltese & Tai, 2010; Xie & Shauman, 2003). While much has been learned through the concerted attention to science and mathematics performance and course-taking, importantly, such outcomes are necessary but not sufficient predictors of students' motivation to pursue and succeed in future STEM trajectories.

Specifically, social psychological research has provided strong evidence that young people's confidence in their abilities (or self-efficacy), interest, and beliefs about the usefulness of science and mathematics strongly shape their decisions to pursue these subjects in the future (Correll, 2001; Dasgupta & Stout, 2014; Eccles & Wang, 2015). And while children begin formal schooling with highly favorable attitudes regarding science and mathematics, their positivity wanes as they move through middle school, such that many students enter high school lacking confidence in their ability in these subjects, perceiving them as boring and not particularly relevant for their future (Shapiro & Sax, 2011; Whalen & Shelley, 2010). Moreover, students who decide that science and mathematics are not "for them" in middle school are unlikely to change their mind as they progress through high school and beyond, and they choose to opt out of science and mathematics classes and activities whenever possible (Morgan, Gelbgiser, & Weeden, 2013; Xie & Shauman, 2003). Therefore, the middle school years represent a key period to intervene and potentially turn the tide by bolstering students' positive attitudes and beliefs about science and mathematics.

In this article, we focus on inquiry-based instruction in science and mathematics classrooms as a potential catalyst that might promote students' positive attitudes toward these subjects. Inquiry-based pedagogy is based on students' active

involvement in the learning process, where they pose and answer questions, evaluate evidence, and assess and propose explanations (Furtak, Seidel, Iverson, & Briggs, 2012; NRC, 2000). This is often accomplished via collaborative work with fellow students and a focus on real-life problems or driving questions in a field (Kanter & Konstantopoulos, 2010; Lee, Hart, Cuevas, & Enders, 2004; Marx et al., 2004). Reform-based efforts in science emphasize inquiry-based instruction as instrumental in promoting not just science understanding but also the motivation to learn science. Likewise, similar reform efforts highlight how the benefits of inquiry-based learning also extend to other subjects, including mathematics (National Governors Association Center for Best Practices, 2010). Of course, educational theorists and researchers have long recognized the value of inquiry-based approaches to instruction for promoting both students' learning and engagement (Dewey, 1997; Piaget, 1977; Vygotsky, 1980); in comparison, the reform efforts to move toward this type of instruction in schools on a national scale are relatively new.

In the present study, we seek to make three important new contributions. First, using a large and nationally representative sample of middle school students, we investigate whether more frequent use of classroom activities consistent with the notion of inquiry-based instruction, as reported by the students who experience them, is associated with greater self-efficacy regarding one's ability, greater interest, and more perceived utility of these subjects. While a few studies have found evidence suggesting that inquiry-based instruction in both science and mathematics promotes positive attitudes toward each subject, past research is limited by the use of small samples and a focus on specific curricular interventions (e.g., S. W. Brown, Lawless, & Boyer, 2013; Jiang & McComas, 2015). Additionally, the literature on this topic is far from conclusive, particularly given that other studies find evidence of student resistance to this mode of instruction (e.g., Finelli et al., 2018; Seidel & Tanner, 2013). Second, our study bridges the typically separate research literatures focusing on science and mathematics to consider whether the relationship between inquiry-based instruction and students' attitudes is similar or different across both subjects.

Third, our study sheds light on the potential benefits of inquiry-based instruction on students who have been traditionally underrepresented in STEM fields. Female, Black, and Hispanic youth face many obstacles to participating in STEM fields, including the pervasive presence of negative stereotypes casting doubt on their ability, and experiences of bias and exclusion in classrooms (Beasley & Fischer, 2012). Some research suggests that inquiry-based instruction might be an effective remedy that counters negative stereotypes and prior exclusionary experiences of female and minority youth in science and mathematics classes (Brotman & Moore, 2008; Laughter & Adams, 2012) and, thus, be a stronger predictor of positive attitudes for underrepresented students compared with their majority White and male peers. Alternatively, it is also possible that inquiry-based instruction is associated with more positive attitudes for all students regardless of gender or race/ethnicity (i.e., no extra boost for female students or students of color) because while inquiry-based techniques are designed to facilitate the inclusion and engagement of all students, they do not explicitly confront larger social issues of inequality.

In sum, our study investigates the following research questions: (1) Is more frequent use of inquiry-based instruction associated with more positive attitudes, in terms of higher levels of student interest, greater self-efficacy, and greater feelings of personal utility attached to these subjects? (2) Is the association of such classroom instruction with students' attitudinal outcomes similar or different for science and mathematics? (3) Is the association similar or different across student gender and race/ethnicity? To address these questions, we utilize rich data from a national sample of eighth graders in the United States from the 2007 Trends in International Mathematics and Science Study (TIMSS 2007; https://timss.bc.edu/TIMSS2007/intl_reports.html). As the most recent national data set that includes student reports of classroom instructional activities in science and mathematics, it is ideal for capturing students' own views about what they experience in their daily classrooms in these two subjects. Furthermore, the data set includes other detailed information on characteristics of students, teachers, and their schools to serve as controls and, importantly, also includes a sufficient representation of both Black and Hispanic students to enable us to consider potential racial/ethnic differences (as well as gender differences) in the relationship between inquiry-based instruction and students' attitudes.

Background

Inquiry-Based Instruction in Science

Educational theorists have long argued that the best way to promote students' science learning is to actively engage them in the process of constructing knowledge via scientific inquiry (Dewey, 1997; Piaget, 1977; Vygotsky, 1980), such that students are authentically involved in scientific practice to make sense of the world around them via active investigation and collaboration (Furtak et al., 2012; Minner, Levy, & Century, 2010; NRC, 1996, 2000). While definitions of inquiry-based science pedagogy vary and the word "inquiry" itself can be a contested term among researchers (Buck, Bretz, & Towns, 2008), most working definitions within the research literature are generally consistent with the instructional principles outlined by the NRC (2000): (1) learners are engaged by scientifically oriented questions; (2) learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions; (3) learners formulate explanations from this evidence; (4) learners evaluate their explanations in light of alternative explanations, particularly those reflecting conceptual understanding; and (5) learners communicate and justify their proposed explanations. Furthermore, instruction aligned with these standards is also notable for emphasizing

collaboration with fellow students to create shared meaning and to foster a community of science learners and for focusing on driving questions related to the real-world applications of science (Kanter & Konstantopoulos, 2010; Lee et al., 2004; Marx et al., 2004; Minner et al., 2010; NRC, 1996, 2000). And while the *New Framework for K–12 Science Education* (NRC, 2012) provides a detailed list of recommended science practices that go further than the previously recommended components of inquiry-based instruction (including argumentation and modeling for example) and articulates the need for integration of practices with core disciplinary ideas and cross-cutting concepts, nevertheless the principles for learners outlined above, as well as an emphasis on collaboration with peers, connecting to students' life experiences and studying real-world phenomena, continue to be recognized as important to the field (J. C. Brown, 2018; Furtak & Penuel, 2019; NGSS Lead States, 2013; Siry & Wilmes, 2018).

Reform efforts to emphasize inquiry in science classrooms are supported by research which finds that as students actively grapple with scientific concepts and evidence and become more authentically engaged in the process of discovery, they learn more. For instance, Minner et al. (2010) synthesized 138 studies and concluded that the majority of studies showed that students in classrooms with inquiry-based instruction outperformed students in the comparison groups on learning outcomes. A meta-analysis by Furtak et al. (2012) found similarly positive results of inquiry-based instruction on students' performance in science. Yet as we discuss in more detail later, empirical research on the possible benefits of such instruction for students' science attitudes is relatively sparse and in need of more attention.

Inquiry-Based Instruction in Mathematics

Within mathematics, standard-based or reform-based teaching practices can be viewed as falling under the umbrella of inquiry-based instruction (Goos, 2004). Specifically, the standards articulated by the National Council of Teachers of Mathematics (NCTM) several decades ago (NCTM, 1989, 1991) state that teachers should guide students to investigate solutions to complex problems, to create their own mathematics knowledge, to apply their new knowledge to real-world problems, to make connections to other disciplines and everyday experiences, and to regularly participate in classroom discourse. Researchers and practitioners who advocate for reform-based or standards-based mathematics argue that K–12 mathematics classrooms should involve the active engagement of learners, often in small cooperative groups (McCaffrey et al., 2001; Riordan & Noyce, 2001; Senk & Thompson, 2003). In short, classrooms using standards-based or reform-based techniques are intended to foster students' habits of mathematical inquiry, allowing students to become authentic practitioners of mathematics (Goos, 2004; NCTM, 1989, 1991; Senk & Thompson, 2003).

Relatedly, there is a robust body of research finding that students learn more when participating in mathematics classrooms with more inquiry-based instruction (Billstein & Williamson, 2003; Cain, 2002; Cichon & Ellis, 2003; Mac Iver & Mac Iver, 2009; Riordan & Noyce, 2001). Some studies find evidence of differential effects based on the type of learning outcome, such that exposure to inquiry-based mathematics may not improve students' performance on procedural or computational questions but does improve their understanding as measured by conceptual questions (Balfanz, Mac Iver, & Byrnes, 2006; Tarr et al., 2008; Thompson & Senk, 2001). Overall, these studies have yielded promising results in terms of the benefits of inquiry-based classrooms on performance in mathematics. Yet similar to the limitations observed within the science education literature, there is comparatively little empirical research on the potential benefits of inquiry-based classrooms for students' mathematics attitudes.

Possible Benefits of Inquiry-Based Instruction for Students' Attitudes

In this article, we argue that the benefits of inquiry-based instruction likely extend to the attitudes that young people hold regarding science and mathematics (NRC, 2007). Generally speaking, inquiry-based instruction requires students to actively engage in the learning process, giving them the opportunity for both individual ownership and more collaboration with peers. As such, students may find the process of learning more enjoyable and develop more confidence in their abilities. Furthermore, as inquiry-based classrooms are organized around compelling questions linked to the real world, this is likely to foster interest as students see the relevance of these subjects to their lives. And given that students' interest, self-efficacy, and perceptions of utility are known to be powerful predictors of their pursuit and persistence in STEM fields in college and beyond (Eccles & Wang, 2015), to the extent that inquiry-based instruction promotes more favorable attitudes toward science and mathematics than traditional instruction, it could represent a major catalyst in increasing levels of STEM participation nationwide.

There is a small body of research that supports the idea that inquiry-based instruction promotes positive attitudes among students. A few recent studies provide suggestive evidence of effects of inquiry-based instruction on student attitudes toward science at the secondary level, finding evidence that it promotes students' interest in science or their self-efficacy (S. W. Brown et al., 2013; Gibson & Chase, 2002; Jiang & McComas, 2015; Taraban, Box, Myers, Pollard, & Bowen, 2007; Wolf & Fraser, 2008). Similarly, for mathematics, a separate body of literature has considered students' mathematics attitudes as the outcome of interest, finding that inquiry-based mathematics increases students' interest, as well as their confidence in their mathematics ability (Billstein & Williamson, 2003; Cain, 2002; Cichon & Ellis, 2003; Hilberg, Tharp, & DeGeest, 2000).

Yet studies in this area are limited in several ways. First, most of this research focused on a specific curricular intervention or professional development attended by a teacher that were intended to change classroom practice, yet whether students subsequently experienced more inquiry-based instruction in the classroom was not measured (e.g., Billstein & Williamson, 2003; Gibson & Chase, 2002; Hilberg et al., 2000; Mataka & Kowalske, 2015; Taraban et al., 2007; Wolf & Fraser; 2008). Second, students' attitudes were typically measured directly proximate to a specific short-term intervention or teacher training rather than assessed in relation to the typical classroom practice that students experience throughout the year. Third, these studies raise questions about generalizability in that they are limited to small samples and specific small regions of the United States (e.g., S. W. Brown et al., 2013; Cain, 2002; Cichon & Ellis, 2003; Gibson & Chase, 2002; Taraban et al., 2007).

Additionally, some studies find that students resist inquiry-based learning. Because such instruction requires substantial activity and effort on the part of students, and may also deviate from typical K–12 instruction to which they have become accustomed, students may react adversely to such expectations (Finelli et al., 2018; Seidel & Tanner, 2013; Shekhar et al., 2015). For example, a recent study of precalculus classrooms reported that students preferred more highly teacher-directed instruction to inquiry-based instruction where they were required to take on a more active role (Cooper, Bailey, Briggs, & Holliday, 2017). As such, it is important to acknowledge that students may not always respond positively to inquiry-based instruction.

In sum, while there is some promising evidence that inquiry-based instruction may promote positive attitudes toward each subject, it is far from conclusive. We seek to advance this timely and important topic in several ways. First, we move past the limitations of small targeted samples, utilizing a large sample of nationally representative data on eighth-grade students to investigate whether more frequent use of inquiry-based instruction in classrooms, as reported by the students who experience it, is associated with more positive attitudes. Second, in doing so, we bridge what has been traditionally two separate research literatures—to consider inquiry-based instruction in science and in mathematics in the same study. And finally, as described in detail below, a major focus of this study is an exploration of whether inquiry-based instruction has a similar or stronger link with science and mathematics attitudes for students from traditionally underrepresented groups in STEM fields compared with White male students.

Inquiry-Based Instruction and Underrepresented Youth

Differences in Science and Mathematics Attitudes by Gender and Race/Ethnicity. A gender gap in science and mathematics attitudes favoring males has been well documented in the research literature (Dasgupta, 2011; Dasgupta & Stout, 2014; Eccles, 1994; Eccles & Wigfield, 2002; Riegle-Crumb, Moore, & Ramos-Wada, 2011). Building on the work of Eccles and her colleagues, among others, researchers have found consistent evidence that compared with their male peers, female students on average report lower levels of interest and self-efficacy in science and mathematics. Additionally, girls are often less likely to perceive science and mathematics as useful to their lives (Eccles & Wigfield, 2002). Thus, despite the fact that girls' performance in these subjects is comparable to that of their male peers, their attitudes toward these subjects lag behind their male peers (Xie & Shauman, 2003). These disparities typically emerge in early adolescence as gender role norms and expectations become salient in young people's lives and become larger in magnitude in high school, with related consequences in shaping choice of college majors and STEM related occupations (Correll, 2001; Xie & Shauman, 2003).

Regarding racial/ethnic differences in attitudes toward science and mathematics, past research has found that on average Hispanic youth have less favorable attitudes toward science and mathematics than their White peers, while Black youth have comparable or more positive attitudes than their White peers (Hanson, 2006; Hurtado, Eagan, & Chang, 2010; Riegle-Crumb et al., 2011; Xie, Fang, & Shauman, 2015). Yet even though minority youth do not always trail their White peers in terms of their confidence or interest in science and mathematics, they are more likely to confront stubborn stereotypes that disparage their intellectual ability, particularly in the areas of science and mathematics (Beasley & Fischer, 2012; Schmader, Johns, & Barquissau, 2004). Relatedly, research has documented strong evidence of bias, discrimination, and exclusionary experiences directed toward racial/ethnic minority youth in STEM fields (Beasley & Fischer, 2012; McGee & Martin, 2011), suggesting that a strong bent in favor of these subjects is likely necessary to weather such deterrents. In sum, given the continued relative scarcity of both women and racial/ethnic minorities among STEM degree earners and among STEM occupations, there is a clear imperative to identify factors that may help boost their inclination toward science and mathematics during the early adolescent years.

Possible Benefits of Inquiry-Based Instruction for Female and Minority Students. In this article, we address the following question: Is exposure to more frequent use of inquiry-based science and mathematics instruction associated with more positive attitudes of female and racial/ethnic minority youth compared with their White male peers? Some educational theory and empirical evidence suggest that might be the case. First, there is a strong alignment between inquiry-based instruction and what scholars refer to as gender inclusionary strategies, which include hands-on, problem-solving activities and projects that draw on students' interests and experiences, emphasize real-life contexts and the social relevance of science, and encourage collaboration with peers

(Brotman & Moore, 2008; Patrick, Mantzicopoulos, & Samarapungavan, 2009). Furthermore, there is a similar alignment of inquiry-based instruction with elements of culturally responsive pedagogy (Brown, 2018; Kanter & Konstantopoulos, 2010; Laughter & Adams, 2012), given that both pedagogies place a high value on empowering students' agency and ownership of their learning, acknowledging students' ideas in the classrooms as well as their experiences and the knowledge they bring with them from outside the classroom.

Specifically, in a classroom where students are actively engaging with their peers in the process of investigation and discovery on meaningful topics, stereotypes about science and mathematics ability and traditional norms about who belongs in these fields may fade into the background (Fennema, Peterson, Carpenter, & Lubinski, 1990; Patrick et al., 2009). In other words, in inquiry-based classrooms, girls might begin to see themselves as scientists and mathematicians (Carlone, 2004) and as part of a larger community. Relatedly, inquiry-based instruction might provide a crucial opportunity for minority youth to see themselves as belonging in science and mathematics. Sheth (2018) argues that as inquiry-based instruction prompts students to take more ownership and agency in the classroom, it might help "overcome the impacts of stereotypes or cultural dissonance from dominant conceptions of who is capable of science and who belongs in science" (Sheth, 2018, p. 2). It stands to reason that this might be the case in mathematics as well as in science. Furthermore, inquiry-based instruction may be comparatively less important in promoting more positive attitudes among White male students than their female and racial/ethnic minority peers, as the former already feel a sense of belonging and inclusion in STEM classrooms and do not have to contend with negative stereotypes in this domain.

A few studies offer support for this claim. Regarding gender, some research points to more positive science attitudes among girls than boys in the context of inquiry-based instruction (Mataka & Kowalske, 2015; Patrick et al., 2009). For example, Billstein and Williamson (2003) found that in middle school mathematics classrooms that used an inquiry-based curriculum, gender gaps in attitudes such as the perceived relevance of mathematics disappeared over the course of the year, suggesting that girls' attitudes benefited more than boys. Only a handful of studies have focused on how inquiry-based science instruction relates to minority students' attitudes in either science or mathematics (Kahle, Meece, & Scantlebury, 2000; Kanter & Konstantopoulos, 2010). For instance, a study of minority students in eight middle schools found that those in science classes characterized by more frequent use of inquiry-based activities had higher levels of interest in science and self-efficacy and viewed science as more valuable (Kanter & Konstantopoulos, 2010). In sum, there is reason to expect that inquiry-based instruction holds significant promise for shaping science and mathematics attitudes for those who belong to underrepresented groups.

Alternatively, it is also possible that these benefits may "lift all boats" and may not differ across gender and racial/ethnic groups. First, while inquiry-based instruction aligns with key elements of both gender-inclusive pedagogy and culturally responsive pedagogy, it may also diverge from these equity-focused pedagogies because it does not explicitly emphasize the role of societal inequality and stereotypes in shaping student outcomes. As Laughter and Adams (2012) argue, culturally relevant teaching includes a sociopolitical consciousness that extends beyond the classroom, and in so doing, goes beyond "a neutral, apolitical stance . . . (to) actively address oppression" (p. 1114). Feminist scholars make similar claims regarding gender inclusion (Brotman & Moore, 2008). In other words, while inquiry-based instruction may generally encourage inclusion of all students in learning, without conversations and activities that call attention to social inequality and how it might impact relationships in the classroom, the status quo may continue uninterrupted (Sheth, 2018). From this perspective, positive attitudes that accrue from inquiry-based instruction are likely to be similar for White and for male students compared with their female and racial/ethnic minority peers. Given the limited extant empirical research on this topic, our study aims to provide important new information regarding whether or not experiences of inquiry-based instruction are associated with more positive attitudes for underrepresented students relative to their White and male peers.

Data and Method

This study utilizes data from a national sample of eighth-grade students in the United States from the TIMSS (2007). Although there are more recent cohorts of U.S. TIMSS students, we utilize the 2007 data set because it is the most recent one to include questions about classroom pedagogical practices (Williams et al., 2009). See the online Appendix for more details on the data set.

Variables

Our focal *independent variables* measure the frequency of *inquiry-based instruction* in students' classrooms as reported by students themselves (see the online Appendix for a more detailed discussion). Beginning with science, we constructed a scale that is highly consistent with that used in previous research on inquiry-based instruction (Jiang & McComas, 2015; Kanter & Konstantopoulos, 2010) and includes the following items: (1) We make observations and describe what we see, (2) we design or plan an experiment or investigation, (3) we conduct an experiment or investigation, (4) we watch the teacher demonstrate an experiment or

investigation, (5) we work in small groups on an experiment or investigation, (6) we relate what we are learning in science to our daily lives, and (7) we give explanations about what we are studying. The response categories for all items were on a 4-point scale ranging from 1 = *never*, 2 = *some lessons*, 3 = *about half the lessons*, and 4 = *every or almost every lesson*. Our scale of inquiry-based instruction is the average of these items ($\alpha = .86$), with a mean of 2.80.

Similarly, for mathematics, we created a scale that was also consistent with previous scales of inquiry-based or reform-based math instruction (Balfanz et al., 2006; Hamilton & Martinez, 2007; Jacobs et al., 2006). It is constructed by averaging the following items ($\alpha = .65$): (1) We decide on our own procedures for solving complex problems, (2) we explain our answers, (3) we relate what we are learning in mathematics to our daily lives, (4) we work together in small groups, and (5) we interpret data in tables, charts, or graphs. As with science, students reported that inquiry-based techniques were occurring on average in slightly less than half of their lessons (mean = 2.77).[1]

The *dependent variables* are three scales to capture different aspects of students' attitudes toward science and mathematics. Beginning with science, the first scale captures students' *self-efficacy*, which is an average of four items ($\alpha = .82$), including "I usually do well in science" (see the online Appendix for a full list of items in all scales). Each statement had the following response categories: 1 = *disagree a lot*, 2 = *disagree a little*, 3 = *agree a little*, and 4 = *agree a lot*, so that a high score captured greater confidence. We created a parallel measure to capture students' self-efficacy in mathematics ($\alpha = .84$).

Our second outcome variable captures students' *interest* in science and mathematics. Beginning with science, students were asked to indicate their agreement with four items, such as "I enjoy learning science." Responses were averaged for each student ($\alpha = .88$). Parallel items were asked for students' mathematics interest, which were also averaged ($\alpha = .86$). Last, we created scales to capture students' perceptions of the *utility* of science and mathematics. For science, we averaged responses to four items ($\alpha = .82$), such as "I think learning science will help me in my daily life." Parallel items were asked regarding mathematics and were averaged into a scale ($\alpha = .73$). See Table A.3 in the online Appendix for correlations between the dependent variables.

Control Variables. We control on a host of potentially confounding factors, as shown in Table 1. First, we include a measure to capture the *socioeconomic status* of students' families. This variable is a scale ($\alpha = .60$) created by averaging a measure of parental education, the number of books students had at home, and a variable that sums across ownership of other resources in the home (e.g., having a computer, desk/table, dictionary, video game system). Analyses also include a measure to capture students' nativity, where 0 = *born in the United States*, and 1 = *not born in the United States*.

TABLE 1
Descriptive Statistics: Control Variables

	Mean	*SD*
Student characteristics		
Socioeconomic status	−0.01	0.77
Not born in the United States	0.09	
Affect toward school	2.86	0.91
Science test score	517.34	84.05
Math test score	505.17	76.27
Enrolled in algebra	0.34	
Teacher characteristics		
Female	0.62	
Years teaching science	12.99	9.61
Years teaching math	13.71	10.28
Science expertise	0.78	
Math expertise	0.22	
School characteristics		
Public	0.93	
Urbanicity		
City	0.32	
Suburb	0.34	
Town	0.16	
Rural	0.18	
Region		
Northwest	0.15	
Midwest	0.25	
South	0.34	
West	0.26	
Percent minority	0.35	0.34
N	5,846	

Note. SD = standard deviation.

We include three additional variables to capture aspects of students' educational experiences. First, to ensure that students' views toward science or mathematics are not conflated with general pro-school attitudes, we include students' reports of how much they *like school*, coded on a scale from 1 = *disagree a lot* to 4 = *agree a lot*. Second, we control on students' score on standardized science or mathematics exams.[2] To account for whether the student is in advanced academic classes, we include a dichotomous measure of whether the student was enrolled in eighth-grade algebra (1 = *enrolled* and 0 = *not enrolled*).

Furthermore, our analyses also control on teacher and school characteristics that might be related to classroom pedagogical practices as well as students' attitudes. Teacher characteristics include the numbers of years teaching either science or mathematics, and teachers' content expertise (coded 1 if the major area of study was science or mathematics for science and math teachers, respectively, and 0 if it

TABLE 2
Descriptive Statistics: Attitudinal Outcomes in Science and Mathematics

			Gender				Race/ethnicity					
	Pooled		Males		Females		White		Black		Hispanic	
	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*
Science self-efficacy	2.96	0.77	3.03	0.75	2.89^{M}	0.78	3.04	0.77	2.90^{W}	0.78	2.80^{WB}	0.73
Science interest	2.80	0.88	2.86	0.87	2.73^{M}	0.89	2.83	0.88	2.76	0.90	2.71^{W}	0.87
Science utility	2.89	0.77	2.89	0.78	2.87	0.76	2.91	0.76	2.84^{W}	0.79	2.82^{W}	0.77
Math self-efficacy	2.88	0.81	2.96	0.80	2.80^{M}	0.81	2.95	0.80	2.86^{W}	0.82	2.72^{WB}	0.79
Math interest	2.52	0.87	2.53	0.88	2.51	0.87	2.48	0.87	2.74^{W}	0.86	2.50^{B}	0.86
Math utility	3.38	0.59	3.37	0.61	3.40^{M}	0.56	3.37	0.59	3.47^{W}	0.54	3.37^{B}	0.61
N	5,846		2,867		2,979		3,520		818		1,508	

Source. TIMSS 2007.
Note. "M" indicates that the mean for female is statistically significantly different from that for males ($p < .05$). Similarly, "W" and "B" indicate means that are statistically significantly different from that of White and Black students, respectively ($p < .05$). *SD* = standard deviation.

was not). Teacher gender distinguishes between female (1) and male (0). School characteristics include sector (coded as 1 = *public* and 0 = *private*), urbanicity, and region. Finally, percent minority is a continuous variable measuring the percentage of Black and Hispanic students at the school. See Table A.2 in the online Appendix for a table of correlations between all independent variables.

Analytic Plan

As recommended by the National Center for Education Statistics, all analyses utilize the student-level weight that captures the probability of student selection, conditional on school selection (Williams et al., 2009). Missing data were imputed via multiple imputation in Stata. We utilize multilevel multivariate analyses to address our research questions, where the school is Level 3, classrooms are Level 2, and students are at Level 1. We perform a series of regression models for each of our six outcome variables, with results for the three science outcomes in Table 3 and mathematics outcomes in Table 4. Tables 5 and 6 display the results of models that include interactions between racial/ethnic and gender groups and inquiry-based instruction to test whether the association between such instruction and science and mathematics attitudinal outcomes may vary across groups.

Results

Descriptive Results

Table 2 displays means and standard deviations for the six outcome variables, overall and disaggregated by gender and racial/ethnic group. Please see the online Appendix for a detailed discussion. Here we note that overall these descriptive results indicate that disparities in attitudes favoring male students and White students are generally more apparent in science than in mathematics. Also consistent with past research using national data (Hanson, 2006; Riegle-Crumb et al., 2011), Black students exhibit comparatively high levels of math interest and math utility.

Predicting Students' Science Attitudes

Table 3 displays the results of models predicting students' science attitudes. Beginning with *science efficacy*, as seen in Model 1, there is a positive and significant baseline association between inquiry-based instruction and students' feelings of efficacy in science. Specifically, as students' reports of the frequency of inquiry-based instruction increase by 1 point on the scale, students' science self-efficacy increases by .2 points, or about one fourth of a standard deviation. Model 2 adds all control variables, including students' social and academic background as well as characteristics of their teachers and their schools. The coefficient for inquiry-based instruction is slightly reduced (and post hoc tests confirm that it is smaller compared with Model 1, $p < .05$). Nevertheless, the positive association between inquiry and self-efficacy remains robust.

Also in Table 3, models predicting both *science interest* and *science utility* reveal a parallel pattern. Namely, a higher frequency of inquiry-based science instruction is positively and significantly associated with higher levels of science interest and higher perceptions of science utility. As with the models predicting science self-efficacy, post hoc tests confirm that with addition of all control variables, the coefficient in Model 2 is smaller than in Model 1 ($p < .001$). Nonetheless, inquiry-based instruction remains a robust predictor of science interest and science utility, such that as students' reports of frequency of inquiry-based instruction increase by 1 point, students' science interest and utility increase by approximately 0.3 points, or one third of a standard deviation. Finally,

TABLE 3
Association Between Students' Reports of Inquiry-Based Science Instruction and Their Attitudes

	Science self-efficacy		Science interest		Science utility	
Variables	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
Frequency of inquiry-based instruction in science class	0.170*** (0.019)	0.146*** (0.021)	0.300*** (0.022)	0.258*** (0.024)	0.344*** (0.021)	0.301*** (0.020)
Student characteristics						
Race (ref = White)						
Black		0.091 (0.076)		0.029 (0.067)		0.026 (0.073)
Hispanic		0.049 (0.058)		0.058 (0.078)		0.060 (0.052)
Female		−0.123*** (0.035)		−0.198*** (0.040)		−0.109*** (0.029)
Socioeconomic status		0.126*** (0.018)		0.104*** (0.024)		0.141*** (0.024)
Born outside the United States (ref = U.S. born)		0.014 (0.049)		0.037 (0.063)		0.079 (0.058)
Affect toward school		0.041* (0.016)		0.199*** (0.034)		0.174*** (0.019)
Science test score		0.003*** (0.000)		0.002*** (0.000)		0.001*** (0.000)
Enrolled in algebra (ref = no algebra)		0.031 (0.060)		−0.073 (0.046)		−0.025 (0.038)
Teacher characteristics						
Female		−0.007 (0.029)		0.010 (0.043)		−0.014 (0.029)
Years teaching science		−0.001 (0.002)		0.002 (0.003)		0.000 (0.002)
Science expertise		−0.041 (0.056)		−0.107~ (0.060)		−0.097* (0.045)
School characteristics						
Public (ref = private)		0.114 (0.076)		0.077 (0.094)		−0.006 (0.072)
Urbanicity (ref = city)						
Suburb		−0.035 (0.069)		0.054 (0.086)		0.121 ~ (0.070)
Town		−0.068 (0.097)		0.069 (0.114)		0.218* (0.099)
Rural		−0.003 (0.087)		−0.004 (0.115)		0.145 (0.095)
Region (ref = Northwest)						
Midwest		0.151~ (0.086)		−0.059 (0.102)		−0.025 (0.060)
South		0.165* (0.078)		−0.038 (0.100)		−0.021 (0.055)
West		0.005 (0.080)		−0.273* (0.126)		−0.191* (0.092)
Percent minority		0.049 (0.137)		0.002 (0.155)		0.148 (0.146)
Constant	2.516*** (0.066)	0.582** (0.200)	1.976*** (0.074)	0.775** (0.246)	1.930*** (0.060)	0.860*** (0.168)
Random effects parameters						
Level 3 variance component estimate	0.013 (0.010)	0.043 (0.010)	0.051 (0.013)	0.055 (0.011)	0.029 (0.012)	0.030 (0.007)
Level 2 variance component estimate	0.078 (0.014)	0.031 (0.008)	0.028 (0.009)	0.016 (0.007)	0.020 (0.006)	0.003 (0.004)
Residual variance	0.486 (0.016)	0.429 (0.015)	0.654 (0.025)	0.595 (0.030)	0.493 (0.014)	0.451 (0.013)
Wald chi-square	83.23***	744.57***	181.92***	766.83***	260.99***	1237.05***

Source. TIMSS 2007.
Note. Coefficients are from multilevel linear regression models; N = 5,846 students (Level 1), 476 classrooms (Level 2), and 225 schools (Level 3); robust standard errors are in parentheses.
~$p < .10$. *$p < .05$. **$p < .01$. ***$p < .001$.

TABLE 4
Association Between Students' Reports of Inquiry-Based Mathematics Instruction and Their Attitudes

	Math self-efficacy		Math interest		Math utility	
Variables	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
Frequency of inquiry-based instruction in mathematics class	0.168*** (0.032)	0.147*** (0.028)	0.317*** (0.029)	0.232*** (0.029)	0.257*** (0.025)	0.208*** (0.024)
Student characteristics						
Race (ref = White)						
Black		0.167** (0.057)		0.151* (0.077)		0.099~ (0.054)
Hispanic		−0.011 (0.058)		0.048 (0.056)		0.074~ (0.042)
Female		−0.091* (0.037)		−0.049 (0.032)		−0.027 (0.025)
Socioeconomic status		0.055* (0.023)		0.016 (0.032)		0.088*** (0.018)
Born outside the United States (ref = U.S. born)		0.074 (0.062)		0.132* (0.057)		−0.043 (0.047)
Affect toward school		0.078*** (0.020)		0.297*** (0.019)		0.140*** (0.014)
Math test score		0.007*** (0.000)		0.004*** (0.000)		0.001*** (0.000)
Enrolled in algebra (ref = no algebra)		−0.126*** (0.035)		−0.068 (0.048)		0.020 (0.037)
Teacher characteristics						
Female		0.025 (0.025)		−0.002 (0.038)		−0.007 (0.026)
Years teaching math		0.002 (0.002)		0.003 (0.002)		−0.000 (0.001)
Math expertise		−0.129** (0.041)		−0.140** (0.049)		−0.069 (0.042)
School characteristics						
Public (ref = private)		0.098~ (0.055)		0.105 (0.082)		−0.072 (0.051)
Urbanicity (ref = city)						
Suburb		0.039 (0.059)		−0.028 (0.068)		0.105~ (0.055)
Town		0.118~ (0.068)		0.089 (0.099)		0.214** (0.066)
Rural		0.054 (0.069)		0.006 (0.080)		0.221** (0.068)
Region (ref = Northwest)						
Midwest		−0.040 (0.067)		−0.052 (0.104)		−0.069~ (0.040)
South		−0.113~ (0.065)		−0.172~ (0.094)		−0.062 (0.043)
West		−0.090 (0.074)		−0.169~ (0.092)		−0.150~ (0.077)
Percent minority		0.331*** (0.082)		0.389*** (0.098)		0.198* (0.092)
Constant	2.422*** (0.098)	−1.266*** (0.170)	1.672*** (0.085)	−1.004*** (0.262)	2.663*** (0.077)	1.963*** (0.136)
Random effects parameters						
Level 3 variance component estimate	0.023 (0.010)	0.123 (0.006)	0.033 (0.012)	0.019 (0.009)	0.014 (0.010)	0.008 (0.005)
Level 2 variance component estimate	0.068 (0.015)	0.024 (0.007)	0.064 (0.018)	0.037 (0.012)	0.010 (0.005)	0.007 (0.005)
Residual variance	0.568 (0.016)	0.429 (0.010)	0.646 (0.022)	0.540 (0.020)	0.304 (0.013)	0.281 (0.011)
Wald chi-square	26.94***	2168.18***	118.98***	880.76***	109.53***	592.15***

Source. TIMSS 2007.
Note. Coefficients are from multilevel linear regression models; N = 5,846 students (Level 1), 476 classrooms (Level 2), and 225 schools (Level 3); robust standard errors are in parentheses.
~$p < .10$. *$p < .05$. **$p < .01$. ***$p < .001$.

TABLE 5
Interaction Effects Between Students' Reports of Inquiry-Based Science Instruction and Their Gender and Race/Ethnicity

	Science self-efficacy		Science interest		Science utility	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
Interactions						
Black × Inquiry	−0.037 (0.050)	−0.052 (0.057)	0.097 (0.066)	0.076 (0.063)	0.036 (0.051)	0.016 (0.047)
Hispanic × Inquiry	−0.037 (0.053)	−0.060 (0.053)	0.079 (0.070)	0.051 (0.072)	0.049 (0.038)	0.032 (0.038)
Female × Inquiry	0.026 (0.038)	0.035 (0.040)	0.007 (0.046)	0.026 (0.047)	−0.087* (0.041)	−0.073~ (0.040)
Main effects						
Frequency of inquiry-based instruction in science class	0.174*** (0.029)	0.150*** (0.029)	0.267*** (0.036)	0.221*** (0.035)	0.373*** (0.031)	0.329*** (0.030)
Race (ref=White)						
Black	−0.032 (0.172)	0.238 (0.189)	−0.343~ (0.207)	−0.179 (0.209)	−0.177 (0.172)	−0.022 (0.177)
Hispanic	−0.057 (0.146)	0.219 (0.153)	−0.322~ (0.177)	−0.087 (0.174)	−0.222~ (0.124)	−0.033 (0.134)
Female	−0.207~ (0.120)	−0.220~ (0.125)	−0.169 (0.145)	−0.268~ (0.148)	0.177~ (0.107)	0.093 (0.107)
Student characteristics		✓		✓		✓
Teacher characteristics		✓		✓		✓
School characteristics		✓		✓		✓

Source. TIMSS 2007.
Note. Coefficients are from multilevel linear regression models; N = 5,846 students (Level 1), 476 classrooms (Level 2), and 225 schools (Level 3); robust standard errors are in parentheses.
~p < .10. *p < .05. **p < .01. ***p < .001.

TABLE 6
Interaction Effects Between Students' Reports of Inquiry-Based Mathematics Instruction and Their Gender and Race/Ethnicity

	Math self-efficacy		Math interest		Math utility	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
Interactions						
Black × Inquiry	0.008 (0.081)	0.000 (0.072)	−0.046 (0.073)	−0.057 (0.076)	−0.044 (0.077)	−0.055 (0.068)
Hispanic × Inquiry	0.037 (0.057)	0.047 (0.049)	−0.038 (0.077)	−0.019 (0.070)	−0.014 (0.052)	−0.013 (0.050)
Female × Inquiry	−0.034 (0.057)	−0.045 (0.047)	−0.014 (0.050)	0.008 (0.050)	−0.041 (0.043)	−0.028 (0.039)
Main effects						
Frequency of inquiry-based instruction in mathematics class	0.180*** (0.038)	0.158*** (0.039)	0.338*** (0.048)	0.241*** (0.046)	0.284*** (0.030)	0.232*** (0.030)
Race (ref = White)						
Black	−0.151 (0.240)	0.167 (0.214)	0.188 (0.225)	0.313 (0.220)	0.168 (0.255)	0.253 (0.228)
Hispanic	−0.327~ (0.179)	−0.140 (0.161)	0.071 (0.242)	0.102 (0.215)	0.024 (0.159)	0.110 (0.154)
Female	−0.005 (0.147)	0.033 (0.122)	0.047 (0.148)	−0.070 (0.149)	0.126 (0.128)	0.051 (0.116)
Student characteristics		✓		✓		✓
Teacher characteristics		✓		✓		✓
School characteristics		✓		✓		✓

Source. Trends in International Mathematics and Science Study (2007).
Note. Coefficients are from multilevel linear regression models; N = 5,846 students (Level 1), 476 classrooms (Level 2), and 225 schools (Level 3); robust standard errors are in parentheses.
~p < .10. *p < .05. **p < .01. ***p < .001.

additional post hoc tests reveal that while inquiry-based instruction positively and significantly predicts all three science outcomes, the association is stronger for science interest and utility compared with self-efficacy (p < .01).

Beyond the results for the focal variable of inquiry-based instruction, many of the *control variables* were significant predictors. As seen in Model 2 for each outcome, female students remain significantly lower than their male peers; these patterns echo the descriptive results in Table 2, but here disparities remain even when student, teacher, and school characteristics are taken into account. In contrast, net of other student characteristics in the model, there are no racial/ethnic differences in science attitudes. Additionally, socioeconomic status is a positive and significant predictor of all three outcomes, as is science test score and students' affect toward school. Students with a teacher who majored in science report lower science interest and utility; further analyses reveal that this is due to the simultaneous inclusion of test score and advanced course-taking; when only one is included, the effect of teacher expertise is no longer negative and significant. Students attending schools in suburbs and towns perceive science as more useful than those in urban areas. Finally, students in the Midwest and South report higher science self-efficacy than those in the Northwest, while students in the West report significantly lower science interest and utility than those in the Northwest.

Predicting Students' Mathematics Attitudes

Table 4 displays the results of parallel models for outcomes in mathematics. Beginning with models predicting *mathematics self-efficacy*, the results reveal a positive and significant association between the frequency of inquiry-based classroom activities in eighth-grade mathematics classrooms and students' level of self-efficacy in mathematics. With the inclusion of student, teacher, and school controls in Model 2, post hoc tests reveal that the coefficient is slightly but significantly attenuated ($p < .01$) but remains robust. We observe a similar pattern from models predicting students' *math interest* and *math utility*. Specifically, there is a positive and significant association between inquiry-based instruction and both outcomes at the baseline (Model 1). For both outcomes, the coefficient is significantly reduced in Model 2 ($p < .001$) but, nevertheless, remains robust with the addition of student, teacher, and school characteristics.

Additionally, as we found in models predicting science attitudes, post hoc tests reveal that the coefficients for inquiry-based instruction predicting both mathematics interest and utility are significantly larger in Model 2 than the coefficient predicting mathematics self-efficacy in Model 2. As such, while inquiry-based instruction positively predicts all three mathematics outcomes, the association is weaker for self-efficacy than interest and utility. Finally, regarding across-subject comparisons, we conducted post hoc tests to compare the effect of inquiry in mathematics classrooms (from Table 4) with science classrooms for the same outcome (Table 3). Results revealed that the coefficients for inquiry-based instruction predicting self-efficacy in both subjects were statistically equivalent ($p > .05$). However, the effect of inquiry-based instruction was marginally larger for science interest than for math interest ($p < .10$) and significantly larger for science utility than for math utility ($p < .01$).

Regarding the effects of *student characteristics* in mathematics, we observe some similar patterns as we did for science. First, for all three outcomes, net of other student characteristics, Black students report higher levels of self-efficacy, interest, and utility than their White peers. This pattern is more pronounced for mathematics self-efficacy and interest, with smaller and borderline coefficients for math utility. Hispanic students also report marginally higher levels of mathematics interest and perceptions of mathematics utility compared with their White peers. A significant male advantage is present only for mathematics self-efficacy.

Turning to other *control variables*, socioeconomic status is a significant and positive predictor of mathematics self-efficacy and utility, and students born outside the United States report higher levels of interest. As we saw for science, higher test scores and positive attitudes toward school in general predict higher scores on all three mathematics outcomes. Additionally, students taking algebra in eighth grade reported significantly lower levels of self-efficacy; however, this is due to inclusion of both course-taking and achievement, as the association is significant and positive when students' math test score is not included. Similar to science outcomes, students with a teacher who has a degree in mathematics report significantly lower levels of self-efficacy, interest and utility net of other controls in the model. As before, this effect is due to the inclusion of both students' test scores and algebra placement. Students attending public schools have marginally higher levels of efficacy, while those in urban schools report that mathematics is less useful and also report marginally lower levels of self-efficacy than students who live in towns. Students in the Northwest generally report less favorable mathematics attitudes than their peers in other regions. Finally, the percentage of minority students in the school is a positive predictor of all attitudinal outcomes in mathematics, again speaking to a general pattern of more favorable mathematics attitudes among minority youth compared with their White peers.

Considering Gender and Racial/Ethnic Interactions

Finally, Tables 5 and 6 present the results of models that included interaction terms to test the possibility that the association between inquiry-based instruction and attitudes toward science and mathematics might differ across gender and racial/ethnic groups. Beginning with Table 5, there are no significant interactions between racial/ethnic group and inquiry-based instruction for any of the three science outcomes. There is one significant interaction between

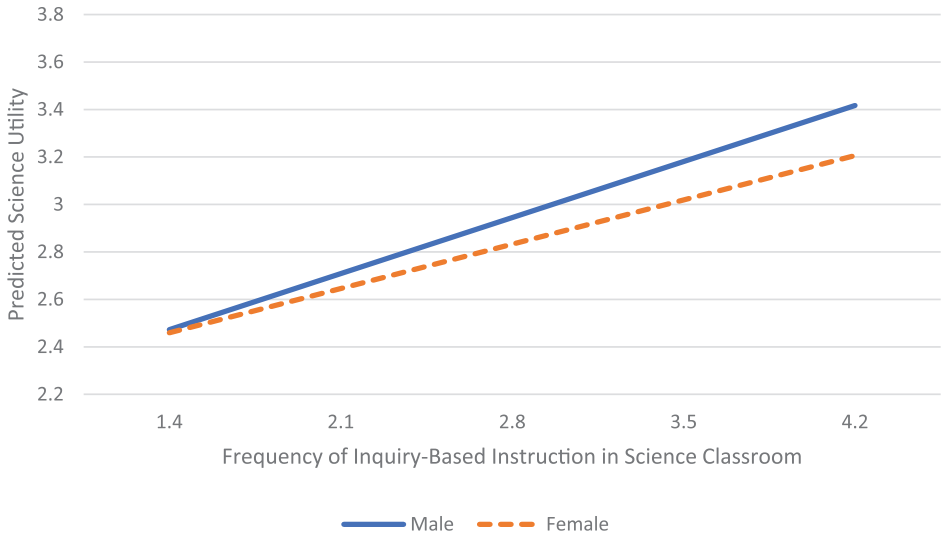

FIGURE 1. *Association of inquiry-based instruction with perceptions of science utility by gender.*

inquiry-based instruction and gender that is negative in direction predicting science utility; this effect becomes marginally significant with the addition of student, teacher, and school controls in Model 2. This means, compared with the reference group of male students, the positive effect of inquiry-based instruction on science utility is marginally weaker for female students.

To better illustrate this pattern, we calculated predicted levels of science utility based on different frequencies of inquiry-based instruction for both male and female students holding all other variables in the model to the mean. As shown in Figure 1, as the frequency of inquiry-based instruction increases from 2 standard deviations below the mean to 2 standard deviations above the mean, males' perceptions of utility increases from 2.5 to 3.4, or an increase of .90. In contrast, female students' perceptions of utility increases from 2.5 to 3.2, an increase of .70. The relatively steeper slope representing the increase in perceptions of utility for male students results in the emergence of a gender gap. Put differently, in classrooms with low levels of inquiry-based instruction, there are no gender differences in perceptions of science utility. As inquiry-based instruction increases in frequency, both male and female students perceive science as more useful. However, at the highest reported levels of inquiry-based instruction, male students view science as more useful than do female students.

Finally, as shown in Table 6, there are no significant interactions between inquiry-based mathematics instruction and race/ethnicity, nor between inquiry-based mathematics instruction and gender. Therefore, as the frequency of inquiry-based instruction increases, self-efficacy, interest, and perceptions of mathematics utility are significantly higher for all students, and not differentially for female students and students of color compared with their male or White peers.[3]

Discussion and Conclusion

Using data from a large nationally representative sample of students at the critical period of middle school, in this study, we sought to expand the limited research on the possible benefits for inquiry-based instruction for promoting adolescents' attitudes. Therefore, our first research question posed whether more frequent use of such instruction predicts higher levels of student interest, greater self-efficacy, and greater feelings of personal utility. In doing so, we also sought to bridge the often-separate literatures in science education and mathematics education; therefore, our second research question posed whether the association between inquiry-based instruction and attitudinal outcomes was similar or different across subjects. Additionally, our study contributes to the limited literature on the potential benefits of inquiry-based instruction for underrepresented groups in STEM fields by investigating our third research question, whether the relationship between inquiry-based instruction and attitudes is similar or different across gender and race/ethnicity.

Regarding our first research question, results of multilevel, multivariate regression analyses revealed a significant and positive association between inquiry-based instruction and students' attitudes, net of a host of control variables for student, teacher, and school characteristics. In reference to our second research question, our results also reveal extremely consistent patterns across both subjects. As seen in Tables 3 and 4, respectively, a higher frequency of inquiry-based instruction predicted higher levels of self-efficacy and student interest in both science and mathematics, as well as greater perceptions of the relevance of both subjects. Comparing patterns across subjects, the strength of association for each outcome was similar, with the exception being

a larger effect of inquiry-based instruction on perceptions of science utility than perceptions of math utility. However, as seen in Table 2, students on average report that math is very useful and that science is less so; thus, there was more room on average for exposure to inquiry-based instruction to move the needle on science utility.

Furthermore, in both subjects, the strength of the association between inquiry-based instruction and interest and utility is substantially stronger than the parallel association for self-efficacy. We speculate that the relatively weaker association with self-efficacy may be due to some of the known challenges of inquiry-based learning. Specifically, inquiry-based instruction takes away the "comfort" of there being only one right answer that the teacher will ultimately supply (Hmelo-Silver, 2004; Trautmann, MaKinster, & Avery, 2004; Wolf & Fraser, 2008). Instead, students are put in the role of posing their own questions, designing their own investigations, and explaining their thinking. While this may be an empowering process in many regards, it is also cognitively demanding and may introduce some uncertainty via "productive struggle" (Barron & Darling-Hammond, 2010; Edelson, Gordin, & Pea, 1999; Hmelo-Silver, 2004; Trautmann et al., 2004; Wolf & Fraser, 2008), therefore perhaps tempering the association between inquiry-based instruction and students' beliefs that they are capable of doing well in mathematics and science. Yet at the same time, we also caution that although the attitudinal outcomes were all measured using the same scale, we cannot be certain that students' interpretation of different concepts is completely comparable; for example, strongly agreeing with items measuring math self-efficacy may not mean the same as strongly agreeing with items measuring math interest.

Overall, in response to our first two research questions, we conclude that our results provide strong empirical evidence that a higher frequency of inquiry-based instruction (as reported by students themselves) is associated with higher levels of interest, perception of utility, and self-efficacy, and similarly for science and mathematics. As all three outcomes are known to be strong predictors of aspirations to major in STEM in college, as well as students' involvement and proclivity toward science- and mathematics-related domains more generally (Eccles & Wang, 2015), our results suggest that inquiry-based instruction could be a decisive factor in keeping young people positively engaged in science and mathematics.

Additionally, our third research question considered whether inquiry-based instruction was a stronger predictor of positive attitudes for students from gender and racial/ethnic backgrounds that have been traditionally underrepresented in STEM fields. Here we found slightly divergent results across subjects. For mathematics, there was no evidence that inquiry-based instruction was associated with more positive attitudes among females or students of color relative to their male and White peers. For science, we found evidence of a gender interaction predicting perceptions of science utility, but in the opposite direction than we anticipated. Specifically, while inquiry-based instruction was a positive predictor of science utility for both genders, unexpectedly, the impact was greater for male students than for female students. While our analyses cannot unpack this particular pattern, we suggest that future research could explore the extent to which male students may dominate or monopolize class time and space in science classes, even in those with inquiry-based instruction. While group activities and authentic investigations can engage all students, if gender stereotypes are salient or go unchecked, then female students may receive less benefit from such instruction as males (Stout, Dasgupta, Hunsinger, & McManus, 2011). Alternatively, it is also possible that compared with boys, girls may be somewhat less likely to "take up" inquiry activities due to concerns about not being academically successful in a classroom setting where the path to getting the right answer is not laid out by the teacher (Carlone, 2004), while boys may be more receptive to such activities if they already view themselves as scientists consistent with traditional gender narratives (Eccles & Wigfield, 2002). Yet such explanations for this finding fail to explain why we do not see a similar result for other attitudinal outcomes.

Overall then, the weight of evidence clearly leans toward the conclusion that positive attitudes of students from different gender and racial/ethnic backgrounds are similarly associated with more frequent experiences of inquiry-based instruction in their science and mathematics classrooms. Regarding race/ethnicity, consistent with other prior research using national data (e.g., Hanson, 2006; Hurtado et al., 2010; Riegle-Crumb et al., 2011), our results find no evidence of racial/ethnic differences in science attitudes net of control variables (see Table 3), and even more important, reveal *more favorable* mathematics attitudes among Black students than among their White (and Hispanic) peers (see descriptive statistics in Table 2 and results net of controls in Table 4). From this lens, the comparatively positive mathematics attitudes of Black youth appear regardless of how frequently inquiry-based instruction occurs.

Unfortunately, we lack data about other classroom norms or practices that might be particularly relevant in promoting the math and science attitudes of both female students and minority students. For example, some teachers may have more training and experience with culturally relevant instruction and/or greater familiarity and comfort in bringing explicit attention to countering traditional narratives about White male students being "innately suited" to those fields. TIMSS surveys do not include questions that allow us to distinguish such teachers or measure students' perceptions of classroom practices or norms that facilitate inclusion of all identities to better understand how such factors might promote the attitudes of female and minority youth in conjunction with, or independently of, inquiry-based activities.

In addition to the limitations already discussed, our data are cross-sectional in nature. While we were careful to attend to many potential confounding variables, our study is not able to make causal claims. Longitudinal data would be more ideal in this regard, particularly long-term panel data that capture exposure to inquiry-based activities throughout their educational career, not just in one grade, and also capture students' prior math and science attitudes. We cannot, for example, completely rule out the possibility that the students who began the school year already inclined toward math and science are more engaged in the classroom and, thus, pay attention and report instructional activities more accurately. Additionally, while we think that student reports of inquiry-based instruction are highly relevant as they capture students' perceptions of their daily experiences (Balfanz et al., 2006; Jiang & McComas, 2015), they are still by definition subjective. Therefore, observations by trained observers, in addition to self-reports by both students and teachers, would shed light on whether and how perceptions diverge from actual classroom practice and what matters most for promoting student attitudes. Furthermore, while we contend that our measures of inquiry-based instruction are a good proxy for inquiry, and are consistent with prior research on this topic (Kanter & Konstantopoulos, 2010; McCaffrey et al., 2001; Riordan & Noyce, 2001), we acknowledge that they do not capture some elements, such as students being asked to generate their own questions and hypotheses.

Finally, while a major strength of our study is the use of national data, more recent data would be better suited to capture the use of inquiry-based instruction in current classrooms across the country, which may have increased due to the push of educational reform movements. In particular, as noted earlier, the new framework developed by the NRC (2012) outlines a more detailed set of recommended science practices that go further than the previously recommended components of inquiry-based instruction (including modeling, computational thinking, and argumentation) and call direct attention to the need to integrate these practices with cross-cutting concepts and disciplinary core ideas. While our data cannot capture either the implementation or potential benefits of these recommendations, research designed explicitly to do so would certainly add important knowledge to the field. For instance, new large-scale surveys should ask explicit questions about the use of argumentation or applications of computational thinking. And as the framework includes an explicit focus on equity as one of its guiding principles, future research should view research questions regarding whether and how these new standards are reaching and affecting all students, particularly those from groups typically underrepresented in STEM fields, as absolutely essential to the field.

Thus, the above limitations notwithstanding, this study makes an important new contribution to research on the potential benefits of inquiry-based instruction by providing robust empirical evidence at the national level linking students' reports of such instruction in the domains of both mathematics and science to greater self-efficacy, interest, and perceptions of utility among students across gender and racial/ethnic groups. As our analyses focus on students completing middle school and at the precipice of high school entry, results suggest that inquiry-based instruction might hold great promise for bolstering students' attitudes at a critical point in their educational trajectories. We look to future research to build on the findings presented here to better understand whether and how such instruction, when enacted across grade levels and on a large scale, might improve the national landscape of students' feelings toward and perceptions of science and mathematics.

Acknowledgments

This research was supported by grant (5 R24 HD042849, *Population Research Center*) awarded to the Population Research Center at The University of Texas at Austin by the Eunice Kennedy Shriver National Institute of Health and Child Development and also by a grant from the National Science Foundation (NSF HRD-1348789) (principal investigator Nilanjana Dasgupta, co–principal investigator Catherine Riegle-Crumb). Opinions reflect those of the authors and do not necessarily reflect those of the granting agencies.

Notes

1. In exploratory analyses, we created parallel measures of inquiry-based instruction using teacher reports. Consistent with some past research (e.g., Hamilton & Martinez, 2007), the correlations with student reports were very weak (.1 to .2). Furthermore, we found that teacher reports did not significantly predict students' attitudes and that the coefficients for students' reports of inquiry-based instruction remained unchanged with the inclusion of teacher reports. Results are available from the authors on request.

2. Although the focus of this article is on students' attitudes as important outcomes of interest, readers might wonder whether inquiry-based instruction predicts students' achievement. Exploratory analyses revealed that such instruction in either mathematics or science did not significantly predict students' scores on the standardized tests administered by TIMSS in the corresponding subject. This is not necessarily surprising given that the TIMSS data lack longitudinal measures of student performance that are typically used when modeling achievement outcomes and, furthermore, that research on inquiry-based instruction tends to find effects on learning outcomes that are conceptual and problem based, with less evidence for large-scale tests of general knowledge and procedures as typically measured in national (and international) exams (Balfanz et al., 2006; Hamilton & Martinez, 2007; Kahle et al., 2000).

3. We conducted additional analyses to determine if the effects of inquiry in science and mathematics varied by other student, teacher, or school characteristics. Specifically, we tested whether science and math inquiry had differential effects for students in an advanced course-taking track (enrolled in eighth-grade algebra) versus those who were in a lower track, differential effects by students' test score, differential effects by teacher gender, or

differential effects based on school percent minority. None of these variables had a significant interaction effect with inquiry-based instruction for any of the six outcomes.

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Authors

CATHERINE RIEGLE-CRUMB is an associate professor of STEM education and sociology at the University of Texas at Austin.

KARISMA MORTON is an assistant professor of math education in the Department of Teacher Education and Administration at the University of North Texas.

URSULA NGUYEN is a graduate student in STEM education at the University of Texas at Austin.

NILANJANA DASGUPTA is a professor of psychological and brain sciences at the University of Massachusetts at Amherst.