Student and Teacher Characteristics on Student Math Achievement

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Abstract
Using data from the Programme for International Student Assessment (PISA), this study implements two statistical analyses to investigate the effects of student and teacher characteristics on students’ mathematical achievement. First, the authors conduct an exploratory factor analysis to explore the factor structure for the various student and teacher variables of interest in this study. Second, they perform hierarchical linear modeling to analyze students’ and teachers’ multilevel structure in a school. The results suggest that student characteristics such as mathematics interest, instrument motivation, mathematics self-efficacy, mathematics anxiety, mathematics self-concept, and out-of-school study time predicted 39.9% of mathematical achievement variance. The results also suggest that mathematics self-efficacy had the largest effect on mathematical achievement. Teacher characteristics such as teacher-directed instruction, cognitive activation, teacher support, classroom management, and student–teacher relations predicted 34.9% of mathematical achievement variance. This study’s results have implications for educators in fostering a positive learning environment to increase students’ mathematics interest and self-efficacy, and focus on specific teacher characteristics to increase students’ mathematical achievement.

Keywords
Mathematical achievement, multilevel, PISA data, student characteristics, teacher characteristics

Increasing students’ mathematical achievement is of national concern. Results from international comparison studies such as the Programme for International Student Assessment (PISA) suggest that 15-year-old U.S. students continually score lower on standardized mathematical achievement tests than 15-year-old students in other countries (OECD, 2012). Moreover, within the United States, the nation’s report card revealed that 42% of fourth-graders, 35% of eighth-graders, and 26% of twelfth-graders were placed at or above the proficient levels for their respective grades, where proficient indicates that students demonstrated competency with challenging subject matter (Kena et al., 2015). Given these statistics, there is a critical need to understand the factors influencing students’ mathematical achievement and address this achievement gap between U.S. students and their international counterparts.

There has been a plethora of empirical research focusing on the student characteristics and teacher characteristics that influence students’ mathematical achievement scores. In terms of student characteristics, the extant literature suggests a number of factors, including students’ mathematics interests, motivation, mathematics self-efficacy, mathematics anxiety, mathematics self-concept, and out-of-school study time, influence academic achievement (Beaton et al., 1996;...
Else-Quest et al., 2013; Fast et al., 2010; Lee, 2009; Marsh & Martin, 2011; Pajares & Miller, 1994; Stevens et al., 2004). In terms of teacher characteristics, there has been research suggesting that teacher-directed instruction, cognitive action, teacher support, classroom management, and student–teacher relations influence students’ mathematical achievement (Baumert et al., 2010; Dever & Karabenick, 2011; Hochweber et al., 2014; Hughes et al., 2011; Levpscek & Zupancic, 2009). These student- and school-level factors have been demonstrated to increase students’ college and career opportunities, as well as their future income prospects (National Mathematics Advisory Panel, 2008).

**Conceptual Framework**

Students’ mathematical achievement scores have been widely used as indicators of students’ academic performance in school. However, there is much debate as to which factors influence students’ mathematical achievement and how they vary across countries. Previous studies have provided empirical evidence for the effects of student- and school-level factors on U.S. students’ mathematical achievement. However, most studies have examined only one or some of these characteristics as predictors of mathematical achievement, but not yet explored various student and teacher characteristics simultaneously. Thus, based on the existing theoretical and empirical research, this study utilizes a conceptual framework that student academic outcome (i.e., mathematical achievement in this study) is explained by various student- and school-level factors. The conceptual model is depicted in Figure 1.

**Student-Level Variables**

The previous literature has identified several student-level variables that explain mathematical achievement. Specifically, these student characteristics include mathematics self-efficacy (i.e., perceived confidence in mathematics; Fast et al., 2010; Lee, 2009; Pajares & Kranzler, 1995; Pajares & Miller, 1994, 1995; Stevens et al., 2004), mathematics self-concept (i.e., a self-evaluation of one’s own general ability in mathematics; Lee, 2009; Marsh & Martin, 2011; Pajares & Miller, 1994), mathematics anxiety (i.e., a feeling of worry or discomfort toward mathematics that impedes performance; Bandalos et al., 1995; Lee, 2009; Ma, 1999; Schulz, 2005), mathematics interest (i.e., interest in learning and achievement in mathematics; Else-Quest et al., 2013), mathematics motivation (i.e., the extent to which individuals embrace challenges and are motivated to perform well in mathematics; Gottfried et al., 2013; Stevens et al., 2004), and out-of-school study time (i.e., the amount of time spent studying outside school; Beaton et al., 1996). These characteristics may act as primary determinants of students’ mathematical achievement.

Although many existing studies have supported the positive impacts of selected student characteristics, some studies have provided mixed results. For instance, Pajares and Miller (1994, 1995) found that mathematics self-efficacy and mathematics self-concept were positively related to mathematical achievement among U.S. undergraduate students. However, Lee’s (2009) study used the PISA 2003 data to study how mathematics self-efficacy, mathematics self-concept, and mathematics anxiety related to students’ mathematical performance and found different results across countries. Specifically, students in Asian countries, such as Korea and Japan, tended to have low mathematics self-efficacy, low mathematics self-concept, and high mathematics anxiety, yet had high mathematical achievement. Conversely, students in western countries such as Finland, the Netherlands, and Liechtenstein, tended to have high mathematics self-efficacy and mathematics self-concept and low mathematics anxiety, yet had high mathematical performance. Mathematics anxiety has often been negatively associated with mathematical achievement (e.g., Tomasetto, 2020), but some studies have found a positive association between them (e.g., Hunt et al., 2017). These results suggest that mathematics self-efficacy and self-concept may be differentially related to mathematical achievement across countries.

![Figure 1. Conceptual Framework.](image-url)
Many studies have reported positive relations between mathematics interest and mathematical achievement (e.g., Aunola et al., 2006; Fisher et al., 2012). Interest in a particular subject can be accompanied by attention and concentration (Hidi, 2006). However, mixed results have been reported on the effect of mathematics interest on achievement. For example, some researchers have found a significant positive relationship between mathematics interest and achievement (Liu, 2009; Singh et al., 2002), while others have reported insignificant or inconsistent results (Koller et al., 2001; Marsh et al., 2005). There have also been some mixed reports on the effects of out-of-school study time on mathematical achievement. Cheema and Sheridan (2015) found that time spent on homework outside of school had a significant impact on mathematical achievement. However, Beaton et al.’s (1996) study, which used Trends in International Mathematics and Science Study (TIMSS) data, suggested that the highest mathematical achievement was associated with students who studied a moderate amount outside of school (i.e., 1 to 3 hours per day). More study time outside of school did not necessarily relate to increases in mathematical achievement scores. Students who have academic difficulties may need additional time to study outside of school to catch up.

These mixed results on the associations between student characteristics and mathematical achievement indicate that student characteristics may not play a consistent role in mathematical achievement for all students, suggesting the need to examine their relations among U.S. students specifically. Furthermore, mathematics motivation has been consistently positively associated with mathematical achievement (e.g., Areepattamannil et al., 2011; Zhu & Leung, 2011), but there are limited studies that have examined mathematics motivation with other various student characteristics simultaneously as achievement predictors. Thus, this study will use selected student-level variables to understand their effects on U.S. students’ mathematical achievement. The study also aims to include teacher-level variables to understand how student- and teacher-level variables relate to students’ mathematical achievement.

**School-Level Variables**

Based on an extensive literature review, several teacher characteristics were identified as primary school-level variables contributing to mathematical achievement. These teacher characteristics include teachers’ support (i.e., perceived psychological and practical support from teachers; Levpuscek & Zupancic, 2009), classroom management (i.e., methods and strategies a teacher uses to maintain a positive classroom environment; Hochweber et al., 2014), student–teacher relationships (i.e., students’ perception of the closeness with teachers; Hughes et al., 2011), cognitive activation (i.e., encouraging students to think more deeply to find solutions and reach the answer, rather than focusing on the answer itself; Baumert et al., 2010), and teacher-directed instruction (i.e., instruction in which teachers are primarily communicating mathematics to students; National Mathematics Advisory Panel, 2008).

Perceived teacher support and positive student–teacher relationships facilitate student learning as teachers are the primary organizers of classroom activities (Patrick et al., 2007; Simons-Morton & Chen, 2009). They help students to develop academic capacities within their classroom (Bedeck, 2015) and to concentrate on academic tasks better (Ryan & Patrick, 2001). The existing literature provided mixed empirical evidence of the impacts of teacher support and student–teacher relationships on mathematical achievement. For example, some studies have found positive relations between perceived teacher support and student–teacher relationships and mathematical achievement scores (e.g., Klem & Connell, 2004; Paulo et al., 2007), but others have reported inconsistent or no significant relations (e.g., Rueger et al., 2010; Valiente et al., 2019).

Teachers’ use of cognitive activation as a teaching strategy has also been linked to higher mathematical achievement (e.g., Burge et al., 2015). Examples of cognitive activation tasks include having classroom discussions, encouraging students to explain and validate their solutions, and prompting students to discover multiple solutions to a problem (Baumert et al., 2010). Cognitive activation has been found to mediate teachers’ pedagogical content knowledge and students’ progress in mathematical performance, indicating the importance of cognitive activation on the path to mathematical achievement (Baumert et al., 2010). Additionally, classroom management, defined as teachers’ ability to create a functioning learning environment (Hochweber et al., 2014), helps students stay on task and enables teachers to better monitor students’ progress (Blair & Dennis, 2010). Children in well-managed classrooms have shown higher mathematical achievement than those in ineffectively managed classrooms (Stronge et al., 2011). However, Blazar (2015) found no significant classroom management impact on mathematical achievement when other classroom variables were examined simultaneously, suggesting the need to further examine various classroom effects on mathematical achievement.

Although there is no doubt that teachers play a significant role in students’ academic achievement, there has been an ongoing debate on which instructional
style is effective for students’ mathematical achievement (National Mathematics Advisory Panel, 2008). More specifically, there have been mixed results as to whether a teacher-directed instructional approach effectively improves students’ mathematical performance. Teacher-directed instruction is focused on the teacher and ranges from highly scripted direct instruction to interactive lecture styles. Similar to other teacher variables, there have been mixed results about the impacts of teacher-directed instruction on academic achievement. Morgan et al. (2015) reported that teacher-directed instruction was significantly associated with the mathematical achievement of students with mathematics difficulties. Other studies, however, have indicated that too much teacher-directed instruction might slow the development of students’ conceptual understanding (Hiebert, 1999; Woodward & Howard, 1994).

Since the legislation of No Child Left Behind, a large body of research has been conducted to identify factors related to students’ academic achievement. Previous studies have attempted to divide variables into school and student levels to extract school effects and student effects (Kang et al., 2005; Lee & Chung, 2011; Muñoz & Chang, 2007). We conducted a multilevel analysis to address the data’s nested structure, where students are nested within schools. Statistically, mixing school-level variance with student-level variance can generate misleading results. Therefore, the research design needs to be multilayered, with student and teacher characteristics in the same school. This will reveal whether students’ academic achievement varies depending on the teachers or their teaching abilities. Thus, the present study aims to investigate the effects of student and teacher characteristics on students’ academic achievements through multilevel analysis.

Method

Data and Sample

This study used the fifth PISA survey, which tested 15-year-olds on reading, mathematics, and science in 2012. Specifically, this study investigated the relation of these student-level variables and school-level variables to students’ mathematical achievement using a U.S. sample drawn from the PISA 2012 data. The U.S. sample contains 4,978 students and 162 schools.

Measures

Outcome Variable. The outcome variable measuring mathematical achievement was based on a total of 85 mathematics test items distributed over 13 booklets. The balanced incomplete block design was used to maximize subject-matter coverage, which meant that no student had the opportunity to attempt all mathematics items during the 2-hour assessment. The scaled achievement scores took the form of five plausible values for each student, where each was generated as a random draw from an estimated ability distribution of students with similar item response patterns and backgrounds (OECD, 2012). For all measures, we used Cronbach’s α to assess the reliability of a set of scale or test items. The reliability coefficient for the mathematical assessment scores (i.e., five plausible values) was .985.

Student-Level Variables

Mathematics Interest. Mathematics interest measures the degree to which students think about their views on mathematics, such as enjoying reading about mathematics, looking forward to mathematics lessons, enjoying mathematics, and being interested in learning in mathematics (Organisation for Economic Co-operation and Development, 2013). The mathematics interest variable included four items, where students responded to the items on a 4-point Likert scale that ranged from 1 = strongly agree to 4 = strongly disagree. These responses were reverse-coded so that higher scores indicate a higher interest related to mathematics. The reliability coefficient for mathematics interest was .910.

Instrumental Motivation. Instrumental motivation measures the degree to which students are motivated to learn mathematics because they perceive mathematics as being useful to them and to their future studies and careers (Organisation for Economic Co-operation and Development, 2013). The instrumental motivation variable was measured by four items, including students’ perception of mathematics as worthwhile for work, worthwhile for their career chances, important for future study, and helping them to get a job. Students had the option to respond on a 4-point Likert scale that ranged from 1 = strongly agree to 4 = strongly disagree. These responses were reverse-coded so that higher scores indicate higher instrumental motivation. The reliability coefficient for instrumental motivation was .910.

Mathematics Self-Efficacy. Mathematics self-efficacy measures the degree to which a student believes in their ability to successfully perform or accomplish a particular mathematical task or problem (Hackett & Betz, 1989). Mathematics self-efficacy was measured using eight items with response options on a 4-point Likert scale ranging from 1 = very confident to 4 = not at all confident. These responses were reverse-coded so that higher scores indicate higher mathematics self-efficacy. The reliability coefficient for mathematics self-efficacy was .852.
Mathematics Anxiety. Mathematics anxiety measures the degree to which a student feels helpless or emotional stress when dealing with mathematics (Schulz, 2005). The mathematics anxiety items were measured using five items with response options on a 4-point Likert scale ranging from 1 = strongly agree to 4 = strongly disagree. These responses were reverse-coded so that higher scores indicate higher anxiety about mathematics. The reliability coefficient for mathematics anxiety was .877.

Mathematics Self-Concept. Mathematics self-concept measures the degree to which a student evaluates their own self-worth related to mathematics (Pajares & Schunk, 2001). Mathematics self-concept was measured using five items on a 4-point Likert scale ranging from 1 = strongly agree to 4 = strongly disagree. These responses were reverse-coded so that higher scores indicate a higher self-concept of mathematics. The reliability coefficient for the mathematics self-concept variable was .898.

Out-of-School Study Time. The out-of-school study time variable indicates the number of hours per week that a student spends on out-of-school study time for all school subjects. Out-of-school study time was measured using six items: homework, guided homework, personal tutor, classes organized by a commercial company, study with a parent or other family member, and online lessons. Students had the option to freely indicate how many hours per week they spent on each out-of-school study activity. The reliability coefficient for out-of-school study time was .618.

School-Level Variables

Teacher-Directed Instruction. The teacher-directed instruction variable measures students’ perceptions of their teacher’s directed mathematics instruction. There were five items used to measure students’ perceptions of teacher-directed instruction, including the extent to which the teacher sets clear goals; encourages thinking and reasoning; checks understanding; summarizes previous lessons; and informs about learning goals. Students had the option to respond on a 4-point Likert scale: 1 = every lesson, 2 = most lessons, 3 = some lessons, and 4 = never or hardly ever. The values were reverse-coded so that higher scores indicate a higher frequency of a student’s perceptions of teacher-directed instruction. The reliability coefficient for teacher-directed instruction was .763.

Cognitive Activation. Cognitive activation measures the degree to which students perceive how often their mathematics teacher incorporates cognitive activation tasks in class, such as having classroom discussions, encouraging students to explain and validate their solutions, and prompting students to discover multiple solutions to a problem (Baumert et al., 2010). Cognitive activation was measured using nine items, including the extent to which a student perceives that their mathematics teacher encourages them to reflect on a problem; gives problems that require students to think for an extended period of time; asks students to use their own procedures; presents problems with no obvious solutions; presents problems in different contexts; helps students learn from their mistakes; asks for explanations; presents problems that require students to apply what they have learned; and gives problems with multiple solutions. Students had the option to respond using a 4-point Likert scale ranging from 1 = always or almost always to 4 = never or rarely. These values were reverse-coded so that higher scores indicate higher cognitive activation by mathematics teachers in the classroom. The reliability coefficient for mathematics cognitive activation was .869.

Teacher Support. Teacher support measures the degree to which students perceive that their mathematics teacher provides support. Four teacher support items measured students’ perception of the extent to which their mathematics teacher lets students know they have to work hard; provides extra help when needed; helps students with learning; and gives students opportunities to express opinions. Students responded to these items on a 4-point Likert scale ranging from 1 = strongly agree to 4 = strongly disagree. The values were reverse-coded so that higher scores indicate a more positive student perception of teacher support. The reliability coefficient for the mathematics teacher support variable was .840.

Classroom Management. Classroom management measures the degree to which students perceive how their mathematics teacher manages the classroom. The classroom management variable was measured using four items, including the extent to which students perceive their teacher gets students to listen; keeps the class orderly; starts lessons on time; and has to wait a long time for students to quieten down. Students responded to four items using a 4-point Likert scale ranging from 1 = strongly agree to 4 = strongly disagree. All of the items except for one (i.e., the teacher has to wait a long time for students to quieten down) were reverse-coded. The reliability coefficient for classroom management was .746.

Student–Teacher Relationship. Student–teacher relationship measures the degree to which a student perceives their relations with teachers at their school. Five student–teacher relationship items measured the extent
to which students perceive their teacher gets along with most students; is interested in students’ well-being; listens to students; helps students; and treats students fairly. Students responded to these items on a 4-point Likert scale ranging from 1 = strongly agree to 4 = strongly disagree. The items were reverse-coded so that higher scores indicate students’ perception of more positive relationships with teachers. The reliability coefficient for student–teacher relationship was .833.

**Data Analysis**

Two statistical analyses were carried out: exploratory factor analysis and multilevel analysis. For the data handling and descriptive analysis, SPSS 16.0 was used. Correlations among the variables were examined to verify the descriptive statistics and model. Multilevel analysis was conducted using hierarchical linear modeling. We conducted hierarchical linear modeling to address the nested structure of the data, where students are nested within schools. Statistically, mixing school-level variance with student-level variance can generate misleading results. Student and teacher characteristics from the same school are not independent of one another and therefore their responses do not meet the independence assumption for regression analysis. The estimates thus reduce the statistical variance and yield more liberal results in significant tests (Bryk & Raudenbush, 1992; Salvucci & Weng, 1995).

We built three models, starting with a one-way analysis of variance model, which allowed for partitioning of the total variance in overall mathematical achievement into within-school and between-school variances. The second model—regression with the means-as-outcomes model—incorporated the student-level characteristics. The third model incorporated the school-level characteristics. Our results are presented in the following section.

**Results**

**Descriptive Statistics**

We implemented a correlation analysis to assess the relations between student characteristics, teacher characteristics, and students’ mathematical achievement. As shown in Table 1, there are significant correlations between student and school characteristics with varying levels of significance, except for the relations of out-of-school study time to mathematical anxiety, mathematics self-concept, and classroom management. The mathematical achievement score was significantly associated with all student and teacher characteristics.

**Exploratory Factor Analysis**

A robust weighted least squares estimation was used with a promax rotation. Empirical approaches, such as examining a scree test and patterns of the factor loading, were considered within a theoretical framework and the extant literature to confirm that the final factor selection was interpretable and substantively plausible. Through this process, an 11-factor model emerged as the most meaningful and parsimonious model. The 5-factor solution yielded a root mean square error of approximation of .06 and standardized root mean square residual of .04, which is considered acceptable (Hu & Bentler, 1999). Table 2 displays the factor loadings of the 11 different factors obtained from the exploratory factor analysis, and the Cronbach’s $\alpha$ and intercorrelations for these factors.

**Multilevel Analysis**

We conducted hierarchical linear modeling to identify mathematical achievement predictors by examining student and teacher characteristics in their respective schools (see Table 3). First, we implemented a null

| Table 1. InterCorrelation Matrix for Study Variables. |
|-----------------------------------------------------|
| 1. Mathematics score | 2. Mathematics interest | 3. Instrumental motivation | 4. Mathematics self-efficacy | 5. Mathematics anxiety | 6. Mathematics self-concept | 7. Out-of-school study time | 8. Teacher-directed instruction | 9. Cognitive activation | 10. Teacher support | 11. Classroom management | 12. Student-teacher relationship |
|-----------------------|--------------------------|-----------------------------|-----------------------------|------------------------|---------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|
| 1. Mathematics score  | 1.00***                  |                             |                             |                        |                           |                             |                             |                             |                             |                             |                             |
| 2. Mathematics interest | .140***                  | 1.00***                     |                             |                        |                           |                             |                             |                             |                             |                             |                             |
| 3. Instrumental motivation | .153***                  | .607***                     | 1.00***                     |                        |                           |                             |                             |                             |                             |                             |                             |
| 4. Mathematics self-efficacy | .569***                  | .407***                     | .361***                     | 1.00***                |                           |                             |                             |                             |                             |                             |                             |
| 5. Mathematics anxiety | -.418***                 | -.440***                    | -.305***                    | -.466***               | 1.00***                   |                             |                             |                             |                             |                             |                             |
| 6. Mathematics self-concept | .414***                  | .636***                     | .452***                     | .548***                | -.776***                  | 1.00***                     |                             |                             |                             |                             |                             |
| 7. Out-of-school study time | .085***                  | .132***                     | .110***                     | .139***                | -.001                     | .040                        | 1.00***                     |                             |                             |                             |                             |
| 8. Teacher-directed instruction | .041*                    | .332***                     | .309***                     | .270***                | -.187***                  | .233***                     | .091***                     | 1.00***                   |                             |                             |                             |
| 9. Cognitive activation | .053***                  | .279***                     | .275***                     | .276***                | -.137***                  | .217***                     | .109***                     | .617***                   | 1.00***                   |                             |                             |
| 10. Teacher support    | .057***                  | .278***                     | .295***                     | .219***                | -.182***                  | .208***                     | .065*                       | .548***                   | .593***                   | 1.00***                   |                             |
| 11. Classroom management | .214***                  | .231***                     | .252***                     | .287***                | -.229***                  | .233***                     | .035                        | .412***                   | .414***                   | .569***                    | 1.00***                   |
| 12. Student-teacher relationship | .150***                  | .283***                     | .316***                     | .274***                | -.213***                  | .243***                     | .129***                     | .403***                   | .411***                   | .460***                   | .391***                    |

*p < .05. **p < .01. ***p < .001.
Table 2. Factor Loadings of Items Used for This Study.

| Items                                                                 | Factor loading |
|-----------------------------------------------------------------------|----------------|
| Mathematics interest (Cronbach’s α = .910)                           |                |
| 1. Enjoy reading                                                      | .840           |
| 2. Look forward to lessons                                            | .899           |
| 3. Enjoy mathematics                                                  | .913           |
| 4. Interested                                                        | .894           |
| Percentage of variance explained                                       | 78.677         |
| Instrumental motivation (Cronbach’s α = .906)                        |                |
| 1. Worthwhile for work                                                | .871           |
| 2. Worthwhile for career chances                                      | .886           |
| 3. Important for future study                                         | .893           |
| 4. Helps to get a job                                                 | .884           |
| Percentage of variance explained                                       | 78.051         |
| Mathematics self-efficacy (Cronbach’s α = .852)                      |                |
| 1. Using a <train timetable>                                          | .682           |
| 2. Calculating TV discount                                            | .750           |
| 3. Calculating square meters of tiles                                 | .775           |
| 4. Understanding graphs in newspapers                                 | .730           |
| 5. Solving Equation 1                                                 | .609           |
| 6. Distance to scale                                                 | .717           |
| 7. Solving Equation 2                                                 | .645           |
| 8. Calculate petrol consumption rate                                  | .700           |
| Percentage of variance explained                                       | 49.419         |
| Mathematics anxiety (Cronbach’s α = .877)                            |                |
| 1. Worry that it will be difficult                                   | .826           |
| 2. Get very tense                                                    | .841           |
| 3. Get very nervous                                                  | .831           |
| 4. Feel helpless                                                      | .803           |
| 5. Worry about getting poor <grades>                                  | .805           |
| Percentage of variance explained                                       | 67.456         |
| Mathematics self-concept (Cronbach’s α = .898)                       |                |
| 1. Not good at mathematics<sup>b</sup>                               | .836           |
| 2. Get good <grades>                                                 | .805           |
| 3. Learn quickly                                                     | .885           |
| 4. One of best subjects                                              | .863           |
| 5. Understand difficult work                                          | .837           |
| Percentage of variance explained                                       | 71.483         |
| Out-of-school study time (Cronbach’s α = .618)                       |                |
| 1. Homework                                                           | .437           |
| 2. Guided homework                                                   | .729           |
| 3. Personal tutor                                                    | .685           |
| 4. Commercial company                                                | .598           |
| 5. With parent                                                       | .727           |
| 6. Computer                                                          | .644           |
| Percentage of variance explained                                       | 41.538         |
| Teacher-directed instruction (Cronbach’s α = .763)                   |                |
| 1. Sets clear goals                                                  | .768           |
| 2. Encourages thinking and reasoning                                  | .714           |
| 3. Checks understanding                                              | .754           |
| 4. Summarizes previous lessons                                        | .664           |
| 5. Informs about learning goals                                       | .698           |
| Percentage of variance explained                                       | 51.928         |
| Cognitive activation (Cronbach’s α = .869)                           |                |
| 1. Teacher encourages to reflect on problems                         | .747           |
| 2. Gives problems that required to think                              | .714           |

Table 2. Continued.

| Items                                                                 | Factor loading |
|-----------------------------------------------------------------------|----------------|
| 3. Asks to use own procedures                                         | .663           |
| 4. Presents problems with no obvious solutions                        | .575           |
| 5. Presents problems in different contexts                            | .752           |
| 6. Helps learn from mistakes                                          | .732           |
| 7. Asks for explanations                                              | .691           |
| 8. Apply what we learned                                              | .733           |
| 9. Problems with multiple solutions                                   | .697           |
| Percentage of variance explained                                       | 49.337         |
| Teacher support (Cronbach’s α = .840)                                 |                |
| 1. Lets us know we have to work hard                                  | .772           |
| 2. Provides extra help when needed                                    | .862           |
| 3. Helps students with learning                                       | .877           |
| 4. Gives opportunity to express opinions                              | .789           |
| Percentage of variance explained                                       | 68.255         |
| Classroom management (Cronbach’s α = .746)                            |                |
| 1. Students listen                                                    | .850           |
| 2. Teacher keeps class orderly                                        | .886           |
| 3. Teacher starts on time                                             | .777           |
| 4. Wait long to <quiet down><sup>b</sup>                              | .524           |
| Percentage of variance explained                                       | 59.627         |
| Student–teacher relationship (Cronbach’s α = .833)                    |                |
| 1. Get along with teachers                                           | .868           |
| 2. Teachers are interested                                           | .797           |
| 3. Teachers listen to students                                       | .817           |
| 4. Teachers help students                                            | .782           |
| 5. Teachers treat students fairly                                     | .787           |
| Percentage of variance explained                                       | 60.113         |

<sup>a</sup>Standardized factor loadings from exploratory factor analysis (factor loading > .30). <sup>b</sup>A reversed item.

The results from Model 2 show that the test language conducted in English (β = 11.926, p < .001) positively affected mathematical achievement scores. Students’ gender, parental education, and economic wealth did not significantly affect mathematical achievement scores. Mathematics interest (β = 6.351, p < .001) and mathematics self-efficacy (β = 10.118, p < .001) had a statistically significant positive effect on mathematical achievement, whereas mathematics anxiety (β = –7.180, p < .001) had a significant negative effect on mathematical achievement.

Third, Model 3 added teacher characteristics to Model 2 to assess the school-level effects on student model (Model 1), which provided information regarding the partitioned total variance in overall mathematical achievement scores into within-school and between-school variances. The intra-class correlation was .24, indicating that 24% of the variance in overall mathematical achievement scores is between school-level characteristics.

Second, Model 2 included student characteristics to examine their effects on mathematical achievement.
mathematical achievement. The results from Model 3 show that among all of the school-level variables, teacher-directed instruction \( (\beta = -12.931, p < .05) \) and teacher support \( (\beta = -36.615, p < .01) \) negatively predicted mathematical achievement scores. On the other hand, cognitive activation, classroom management, and student–teacher relationship were significant positive predictors of student mathematical achievement scores. Student–teacher relationship \( (\beta = 39.319, p < .001) \) was the strongest predictor of the achievement outcome, followed by classroom management \( (\beta = 28.447, p < .01) \) and cognitive activation \( (\beta = 8.540, p < .05) \).

The effect of the conditional model is shown in the accumulated explained variance \( (R^2) \). The student-level model (Model 2) explained 39.9% of the variance in mathematical achievement among classrooms and the school-level model (Model 3) explained 34.9% of the variance in mathematical achievement among schools. The accumulated variance explained by all the predicting variables included in this analysis was 12% of the variance.

Discussion

The current study aimed to investigate factors that predict student mathematical achievement by evaluating student- and school-level factors. The hierarchical linear modeling analysis found that student variables predicted 39.9% of students’ mathematics achievement and the teacher variables predicted 34.9%. Specifically, among the student variables, mathematics interest and mathematics self-efficacy had positive impacts on mathematical achievement, whereas mathematics anxiety had a negative effect. Among the teacher variables, teacher-directed instruction and teacher academic support had negative effects on students’ mathematical achievement, while cognitive activation, classroom

### Table 3. Multilevel Analysis Results for Mathematics Achievement.

| Model 1: Null model | Model 2: Student level | Model 3: School level |
|---------------------|------------------------|-----------------------|
| \( \beta \) (SE)    | \( \beta \) (SE)       | \( \beta \) (SE)       |
| Control variables   |                        |                       |
| Intercept           | 481.012*** (3.746)     |                       |
| Gender (Female = 1) | 1.533 (2.134)          | 1.431 (2.131)         |
| Mother’s school     | -0.205 (1.538)         | -0.236 (1.537)        |
| Father’s school     | 2.200 (1.396)          | 2.054 (1.393)         |
| Wealth              | 1.388 (1.061)          | 1.206 (1.071)         |
| Language (English = 1) | 11.926*** (3.347)     | 11.859*** (3.350)     |
| Effect of student characteristics |       |                       |
| Mathematics interest| 6.351*** (0.617)       | 6.368*** (0.616)      |
| Instrument motivation| -0.341 (0.554)        | -0.339 (0.554)        |
| Mathematics self-efficacy| 10.118*** (0.438)    | 10.128*** (0.438)    |
| Mathematics anxiety | -7.180*** (0.590)     | -7.187*** (0.590)     |
| Mathematics self-concept | 0.735 (0.541)       | 0.736 (0.541)         |
| Out-of-school study time | 0.087 (0.140)   | 0.091 (0.141)         |
| Effect of teacher characteristics |       |                       |
| Teacher-directed instruction | -12.931* (5.820) |                       |
| Cognitive activation | 8.540* (4.230)        |                       |
| Teacher support     | -36.615** (10.612)    |                       |
| Classroom management| 28.447* (7.913)       |                       |
| Student–teacher relationship | 39.319*** (6.310)  |                       |
| Variance            |                        |                       |
| School level        | 1938.130               | 1894.976              |
| Student level       | 6087.792               | 3656.817              |
| Total               | 8025.922               | 5551.793              |
| Intra-class correlation | 0.241           | 0.341                 |
| Accumulated variance explained \( (R^2) \) |       |                       |
| School level        | 0.022                  | 0.349                 |
| Student level       | 0.399                  | 0.000                 |
| Total               | 0.308                  | 0.119                 |

*\( p < .05 \). **\( p < .01 \). ***\( p < .001 \).
management, and student–teacher relationship had positive results.

**Student Characteristics and Mathematical Achievement**

First, mathematics interest significantly influenced mathematical achievement, which is consistent with previous studies (e.g., Fisher et al., 2012). For example, Singh et al. (2002) provided empirical evidence for the impact of mathematics interest on mathematical achievement among 24,599 middle school and high school students collected by the National Center for Education Statistics. The current study also reports that mathematics interest positively predicted academic achievement. These results suggest that students who are interested in mathematics are more immersed and invest more time in studying mathematics, leading to higher achievement.

Second, although mixed results exist, many previous studies have reported the positive effect of mathematics self-efficacy on mathematical achievement. For example, self-efficacy has been shown to be more strongly associated with mathematical performance than English and writing (e.g., Pajares, 1996). Another study, conducted by Shores and Shannon (2007), also found that self-efficacy was a significant variable that increased mathematical achievement among 761 fifth- and sixth-graders. Similarly, Yum and Park (2011) studied the relation between mathematics self-efficacy and mathematical achievement among seventh- to ninth-graders through a 3-year latent growth model. They reported a continuous positive effect of mathematics self-efficacy on mathematical achievement. The current study supports these previous results by showing that mathematics self-efficacy had the largest impact on mathematical achievement among all the student variables, suggesting the importance of improving students’ perceived confidence in mathematics to improve their mathematical performance.

Third, this study’s findings support mathematics anxiety’s adverse impact on mathematical achievement. Previous studies have reported inconsistent results on the relation between mathematics anxiety and mathematical achievement. For instance, Ma’s (1999) meta-analysis of 26 studies indicated a significant negative correlation between anxiety and academic achievement. Similarly, Shim’s (2000) study of 219 high school students showed that mathematics anxiety was negatively correlated with mathematical achievement. Shim (2000) argued that negative emotions, such as anxiety, interfere with learning, and negatively affect achievement. The present study reveals comparable findings, where mathematics anxiety had a statistically significant negative effect on mathematical achievement. Given that mathematics anxiety may interfere with manipulating numbers and solving mathematical problems (Richardson & Suinn, 1972), mathematics interventions could incorporate the means to reduce students’ mathematics anxiety to improve their mathematical performance.

**Teacher Characteristics and Mathematical Achievement**

The student–teacher relationship was the strongest predictor of students’ mathematical achievement at the school level, followed by teacher support, classroom management, teacher-directed instruction, and cognitive activation. Specifically, the student–teacher relationship, classroom management, and cognitive activation positively predicted mathematical achievement, whereas teacher support and teacher-directed instruction negatively predicted mathematical achievement.

First, our results provide additional empirical support to the existing literature for student–teacher relationships’ positive influence on students’ mathematical achievement (e.g., Croninger & Lee, 2001). The quality of the student–teacher relationship plays a primary role in students’ cognition and academic achievement (Kim & Lee, 2015). The current study suggests that the student–teacher relationship has the most considerable effect on mathematical achievement—more than other student or teacher characteristics—emphasizing the critical role of a positive student–teacher relationship in improving students’ mathematical achievement.

Second, teacher support had a negative relation to mathematical achievement. It is important to note that this does not necessarily imply that more academic support from teachers results in decreased mathematical achievement scores. Instead, we interpret this finding as students who had lower mathematical achievement needed more support from teachers. Given that previous studies have reported mixed results on teacher support and mathematical achievement (e.g., Klem & Connell, 2004; Rueger et al., 2010), more research is needed to understand this relationship.

Third, this study shows that teachers’ classroom management positively predicted students’ mathematical achievement. Our finding provides additional support for the positive impacts of classroom management on mathematical achievement (Kim, 2000; Stronge et al., 2011), suggesting that better organized and managed classrooms enable students to perform to the best of their ability and promote academic achievement.

Fourth, this study shows the negative effect of teacher-centered classes on students’ mathematical achievement. This result contributes to the existing literature by supporting the findings of previous studies (e.g., Hiebert, 1999; Woodward & Howard, 1994) that
teacher-centered classes, or teacher-directed instruction, might hinder students’ voluntary learning and thus negatively influence mathematical achievement. However, Morgan et al. (2015) noted that students who are struggling with mathematics benefit from teacher-directed instruction more than student-centered instruction. Thus, more research is needed to understand which type of instruction works better for students depending on their mathematical performance level. Lastly, cognitive activation positively influenced mathematical achievement, supporting previous findings (Burge et al., 2015; Lampert, 2001; Sizmur et al., 2015) that classes emphasizing students’ cognitive activities could help students construct their knowledge and show improved mathematical performance.

This study’s results contribute to the existing literature by using a large nationally representative data set of 15-year-old students across the United States to examine student and teacher factors related to student mathematical achievement. The study emphasizes the importance of student mathematics interest, student mathematics self-efficacy, the student–teacher relationship, teacher cognitive activation, and classroom management, providing implications for educators. Specifically, interventions designed to improve students’ mathematics interest and mathematics self-efficacy may promote students’ mathematical achievement. We have found that teacher characteristics had the most effect on students’ mathematical achievement, especially the student–teacher relationship. It is widely acknowledged that teachers are an essential component in education (Driel et al., 2001) and determine the class (Borich, 2000). Building positive relationships with students, using cognitive activation, and more student-centered instruction are suggested to improve mathematical performance. This can come from inquiry-based activities that are student-centered and challenge students’ mathematical thinking while listening to and encouraging students (Savery, 2006). Fostering these student and teacher characteristics can be the first step in improving U.S. students’ mathematical achievement and, ultimately, rankings in international mathematical achievement comparisons.

Limitations and Future Directions

The findings of this study should be interpreted with consideration of the study’s limitations. The study examined the influence of teacher and student characteristics on student mathematical achievement. Although the student characteristics mostly focused on mathematics-related factors, out-of-school study time was the amount of time spent studying any subject. Out-of-school study time specific to mathematics may have more substantial impacts on mathematical achievement. In future studies, researchers need to investigate other factors that might influence mathematical achievement, such as cognition, metacognition, and motivation.

Future studies could also expand on the current findings by using various achievement scores (i.e., reading and science) and including family and peer characteristics. Additionally, the present study relied on students’ self-reported data. Although it is arguably a unique source of information regarding student and teacher characteristics, it is possible that variables related to student perceptions of teacher characteristics may be underreported or overreported by the students. The present study was also limited to only teacher-related factors at the school level and did not examine other contextual variables such as peer factors. Despite these limitations, however, this study’s results contribute to our understanding of various student and teacher characteristics and their impacts on student mathematical achievement.

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