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A Multi-Level Analysis of Students' Teacher and Family Relationships on Academic Achievement in Schools

Ozden Sengul *
Bogazici University, TURKEY

Xiaoyun Zhang
Georgia State University, USA

Audrey J. Leroux
Georgia State University, USA

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Abstract: By using multi-level modeling, this study explores the impact of students' perception of the quality of the teacher-student relationship and family structure on student achievement after controlling for socioeconomic status (SES), school urbanicity, and school control. The data from 750 schools and 17,000 10th grade students were analyzed. Family structure and student's perception of teacher-student relationship, and SES were student-level; school urbanicity and school control were school-level variables. The findings indicated that students, who had a positive perception about their relationship with their teachers, came from families including two biological parents, and had high SES and high math achievement. Students' SES and attending public school in urban areas were found to be significantly related to students' math achievement. The math score for public school students was lower than students from private and Catholic schools. The further research should have a design addressing the impact of these variables in a longitudinal term.

Keywords: *Student achievement, teacher-student relationship, family structure.*

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Introduction

Student achievement in all grade levels is considered as an important educational objective and outcome. Studies have measured student achievement in different ways through addressing school, family, and community connections including the teacher performance, students' language skills and academic performance, attitudes, and healthy development (Epstein, 2018). Student achievement can be influenced by the individual-level, school-level, teacher-level or parent-level factors. At the individual-level, students' interactions with the adults such as the relationships with the family members and the perception of student-teacher relationships can be linked to their academic performance (e.g. Dearing, Kreider, & Weiss, 2014; Short, 2017; McGrath & Van Bergen, 2015; Ralo, 2016; Mikk, Krips, Säälik, & Kalk, 2016; Stronge, 2018; Wu, Schimmele, Hou, & Ouellet, 2012; Wubbels, Brekelmans, Mainhard, den Brok, & van Tartwijk, 2016). The studies also indicated that family structure can have positive or negative impact on students' academic performance; students living with two biological parents, single parent or other guardians may experience school adjustment in different ways (Ralo, 2016; Wu et al., 2012). In addition, studies documented significant associations between students' perception of teacher-student relationship and their emotional, behavioral, and academic skills such as attitudes towards school, motivation to learn, and academic achievement (e.g. Mikk etal., 2016; Roorda, Koomen, Spilt, & Oort, 2011; Stronge, 2018; Wubbels et al., 2016). Teachers' academic, social, and emotional competence also had a role on the development of the quality of teacher-student relationships.

In addition, the impact of students' socioeconomic status (SES) is a substantial factor on students' achievement (Gustaffson, Nilsen, & Hansen, 2018; Kyriakides, Creemers, & Charalambous, 2018; Thomson, 2018). For example, Kyriakides et al. (2018) found that low-SES led to lower academic achievement aligning with the lack of resources and family support. Moreover, school-level factors can be related to the students' achievement (e.g. Carbonaro & Covay, 2010; Northrop & Kelly, 2018; Perry & McConney, 2010). These previous studies investigated the influence of these individual-level and school-level factors on student achievement separately. No paper addressed how these factors at the individual level (such as family structure, students' perception of teacher-student relationship, and SES) and at the school level (such as school urbanicity and school control) influence student achievement in the same study. Research-based evidence is needed to provide resources and strategies to enhance student achievement and address the design of future studies. This study aims to present the

* **Corresponding Author:**
Ozden Sengul, Bogazici University, Istanbul, TURKEY.
✉ ozden.sengul@boun.edu.tr

base-year results (ELS: 2002) of a longitudinal study to understand the impact and relationship of these individual-level and school-level factors on student achievement. Our purpose is to investigate the school urbanicity, which may influence the relationship between student achievement and socioeconomic status (SES), as well as the association between student achievement and interpersonal relationships including family members and teacher-student relationship. We try to understand the moderation of school urbanicity on the relationship between students' interpersonal relationships and socioeconomic status with student achievement. The research questions of this study are:

1. What is the relationship between student achievement and perceived student-teacher relationship after controlling for SES and school-level factors?
2. What is the association between student achievement and family structure after controlling for SES and school-level factors?
3. What is the main effect of the interaction between perceived student-teacher relationship and family structure?

Literature Review

The Influence of Teacher-Student Relationship on Student Achievement

Research on students' social and cognitive development suggests that students' perceptions of student-teacher relationship influences their school performance and academic success (e.g. McGrath & Bergen, 2015; Mikk et al., 2016; Stronge, 2018). Teachers can have impact on the quality of social and intellectual experiences of students. Teachers can provide a classroom climate to enhance students' motivation to learn; they can have a regulatory function for the development of emotional, behavioral, and academic skills (Roorda et al. 2011; Stronge, 2018). Teachers' responsiveness to students' needs can promote students' academic learning and their social interactions. For example, students' levels of emotional closeness, conflict, and dependency and teachers' mediation of peer relationships can be associated with the students' perceptions of teacher-student relationships and the development of the academic and social skills (Allen et al., 2013; Wubbels et al., 2016).

Teachers have a significant role in creating supportive instructional contexts. Teachers' actions and beliefs and their interaction within the instructional context influences their relationships with their students and can be a factor to enhance students' motivation to learn. Teachers' beliefs about the nature of schooling, knowledge, and learning can be linked to the quality of student participation in class activities and enhance their interaction with the students and the instructional material (Ferguson & Braten, 2018). In short, teachers' beliefs influence the quality of instruction and the interaction with the students. Furrer, Skinner, and Pitzer (2014) suggests that teachers can enhance the quality of the relationship between students and teachers through developing appropriate tasks to support student autonomy, recognition, and collaborative work. Teachers can promote a sense of belonging to the school through addressing students' needs and encouraging students' use of appropriate learning strategies (Furrer et al., 2014; Stronge, 2018).

Teachers' knowledge about students' conceptions and learning processes can help them focus on students' understanding during the instruction through making connections between the course materials and students' thinking. Lee and Hannafin (2016) suggested that learner-centered approach could enhance the quality of teacher-student relationships through promoting students' voices, thinking, and learning and enhancing their sense of ownership in their own learning process through collaboration. Additionally, instructional support for learning can predict students' achievement. Teachers' use of classroom time effectively, explicit instruction, modeling, scaffolding, and providing sufficient feedback during the learning process can contribute to students' learning.

The research about the importance of social and relational constructs argues that children's sense of relatedness, belongingness, pedagogical caring, and positive teacher-student relationship can be contributing factors to students' academic success (e.g. Roorda et al., 2011; Short, 2017). Positive teacher-student relationships can provide children with the emotional security necessary to promote social interactions between students and teachers, enculturate them in their own learning process and scaffold the development of social, behavioral, and self-regulatory competencies in the school environment (Prewett, Bergin, & Huang, 2019; Wubbels et al., 2016). The students' emotional security can serve as a mediator between teacher support and students' engagement in learning tasks (Roorda et al., 2011). However, the conflict between students and teachers or students' dependency on teacher during the learning process can influence their academic success in negative ways (McGrath & Van Bergen, 2015).

Students' impressions of teacher support influence their motivation to learn. When teachers can effectively apply interpersonal skills during the instruction, they can nurture a friendship among students and help students have positive feelings about their learning environments. Teachers can promote a sense of connectedness with the school and classroom environment and a sense of involvement to explore new ideas in the learning process (Wang, Hatzigianni, Shahaeian, Murray, & Harrison, 2016). In this process, students' perceptions of the teacher-student relationship can highly influence their approach to learning; teachers' friendly professional relationship with students can stimulate and motivate students to learn. For example, a study by Short (2017) investigated the relationship between teacher-student relations and students' academic performance of high school students. The participants were 14 eleventh or twelfth grade

students from southwest of United States. The data collected through semi-structured interviews. Participants thought that the healthy interpersonal relationship between students and teacher enhanced the productivity and achievement as teacher prepared the student for success and inspired them for learning. However, students also indicated that if their teacher did not care, help, and connect with students, they would feel disconnected with the teacher and school, and they would not experience positive teacher-student relationship. The study suggested that teachers needed to prepare learning tasks and environments that addressed students' learning needs and guided them during the learning experiences. Teachers should choose appropriate instructional approaches and effective classroom management techniques to enhance students' academic achievement, motivation, and engagement in the classroom and take responsibility of their learning.

Roorda et al. (2011) made the case for the role of student, teacher, study methods, and other characteristics on the student-teacher relationships. Their meta-analysis about the relationship between teacher-student relationships and student achievement suggested that younger students were more strongly influenced by their relationships with teachers than the older students since the latter could be influenced by their peers easily. In terms of the gender of students, they found that boys and girls interacted with their teachers differently, which could influence students' learning in different ways. Girls tended have more close relationships with their teachers aligned with the friendlier relationships, but boys seemed to be at risk of school failure due to their conflict-related behaviors. The authors also argued that teacher-student relationships influenced the learning outcomes of students-at-risk such as ethnic minority students and students with low SES. Teacher ethnicity and teaching experience could also be effective factors in the establishment of teacher-student relationships. Furthermore, the research literature argued that the quality of teacher-student relationships could influence the students' drop-out rate (e.g. Furrer et al., 2014; McDermott, Donlan, & Zaff, 2018). Positive relationships including support from the teacher could promote students' interests for learning and contribute to prolonging the time students stayed in schools (McDermott et al., 2018).

The literature review on the influence of teacher-student relationships on student achievement argues that teachers can enhance students' social and cognitive experiences in schools through creating a responsive and caring environment and promoting students' voices, thinking, and learning. The positive relationship between teacher and student can contribute to student's motivation to learn and academic success. As the purpose of the study, we are interested in the influence of both student's perception of teacher-student relationships and family structure on academic achievement and their interaction to examine our assumption that students, who had lack of support from their parents could benefit from their positive relationship with their teachers. Therefore, next, we will discuss the published literature on the influence of family structure on students' academic success.

The Influence of Family Structure on Student Achievement

Research indicates that family structure can facilitate or limit the ways that family members can have impact on students' academic performance (Ralo, 2016; Wu et al., 2012). Few research studies have explored the influence of family structure on student achievement. Most published literature have addressed the family structure as two-parent families, single-parent families, and stepchildren; in other words, the literature separated the children, who were reared by both biological parents from children who were not (Wu et al., 2012).

Wu and colleagues (2012) explored the relationship between family structure and university enrollment and completion through collecting longitudinal data (2000-2010) from a representative sample of Canadian youth via Canadian Youth in Transition Survey (YITS). The family structure addressed six types of family arrangements: married biological-parent (inact) families, cohabiting biological-parent families, married stepfamilies, cohabiting stepfamilies, single-parent families, and other living arrangements such as with grandparents, other relatives, or in foster care. The study indicated that youth from fragile families including cohabiting biological-parent families, married stepfamilies, cohabiting stepfamilies, single-parent families, and other living arrangements have lower influence in the university enrollment than youth living with the married biological-parent families. The results showed that family structure influenced the educational attainment, and there was a difference between intact and fragile families.

Lamie (2014) investigated the factors influencing the math achievement of high school students. The author looked at the factors including attendance, family structure, socioeconomic status, special education status, students who are English language learners (ELL), and gender. The family structure was defined as two parent families and one parent families. Data was collected from a public-school system including 412 ninth grade students over a 10-year period (starting from their kindergarten period). The results indicated that students from two-parent families had higher scores on math test than the students from single-parent families.

The published literature on the influence of family structure on students' academic achievement indicates that students, who are living with two biological parents (intact families), have higher academic performance than students, who are living with a single biological parent or stepparents (fragile families). Next, we are interested in exploring how published literature discusses the influence of other significant factors as control variables that may moderate the association with the students' perception of teacher-student relationship and family structure and influence the students' academic achievement in the individual- and school-level.

Other Significant Factors on Student Achievement

Several research studies have focused on the factors that could influence the student achievement. Gustaffson, Nilsen, and Hansen (2018) indicated that SES had a substantial impact on student achievement. They defined SES in relation to the combination of parental education level, occupation and income or free/ reduced lunch status, the number of siblings, family structure, and ethnicity at the individual level. Bumgarner and Brooks-Gunn (2013) also stated that there were multiple factors indicating the influence of SES on students' academic achievement such as parental education, parenting, health, instructional strategies, and environmental conditions. Perry and McConney (2010) examined the influence of school-level SES on academic achievement in Canada and Australia with different educational systems. They found that regardless of students' individual SES, as the SES of school increased, students' math and reading performances enhanced. Educational system in Australia had high-level of social segregation that led schools with high SES to have more resources and increase the achievement gaps between Australia and Canada.

Studies also connect the school location to students' SES. In a comprehensive meta-analysis, White (1982) found that SES and student achievement were strongly correlated, but the relationship was depended on the unit of analysis. The National Center for Education Statistics (NCES) explored the impact of school urbanicity on students' achievement and argued that urban schools included high number of students with low socio-economic status than non-urban counterparts. Students in urban schools had low family backgrounds, less desirable school experiences, and less successful educational achievement outcomes, such as difficulty in speaking English than students in non-urban schools. Sirin (2005) also investigated the linkage between the school urbanicity and SES across studies through conducting a meta-analysis of published studies between 1990-2000. The results indicated that the relation between SES and academic achievement was stronger for students in suburban schools than for students in rural or urban schools; this relationship was the weakest for urban schools as compared to non-urban schools.

The issue of school control is another important factor in students' academic achievement. A study by Carbonaro and Covay (2010) examined the influence of school sector in student learning. The data for 10th grade student achievement was collected through math assessment, which was compared to students in four different sectors including public, Catholic, private-secular, and private-other religious. The study indicated that mathematics achievement for students in Catholic and private-secular schools was higher than that of other public-school students due to their rigorous academic curriculum.

Summary

The aforementioned studies separately addressed the influence of students' perception of the quality of teacher-student relationship, family structure, and other significant factors at the individual- and school-level on students' academic achievement. No study has been done so far to investigate the influence of students' perception of the quality of teacher-student relationship and family structure on students' academic performance in one study. This study aims to address these relationships together (the influence of family structure and students' perceptions of teacher-student relationships) and the main effect of the interaction between them. In addition to the primary of the interest, SES at the student-level could be another factor to influence students' achievement. Although the previous studies made clear connection between students' SES and their achievement as the purpose of the study, no study has been utilized SES as the control variable to investigate the influence of teacher-student relationships and family structure on students' academic achievement. In addition, although the published literature indicated that school-level variables including school urbanicity and school control might have impact on students' academic achievement, no study has explored how school urbanicity and school control can moderate on the student-level variables, teacher-student relationships and family structure. This study aims to address the influence of students' perception of the quality of teacher-student relationships and family structure on their math achievement after controlling for SES, school urbanicity, and school control.

Methods

This study utilized data from the Educational Longitudinal Study of 2002 (ELS: 2002), which aimed to collect data from a national sample of students as they progressed from 10th grade to postsecondary education (Lauff & Ingels, 2014). We used the publicly available data (restricted version of ELS: 2002). The data from ELS: 2002 study had a multi-level characteristic. The participants were students, their parents, math teachers, and schools, and each unit had repeatedly been surveyed over time. The participants were 750 schools and over 17,000 10th-grade students in Spring 2002, and data from all participants were included in the study. In the first stage, schools were selected, and then 10th-grade students were randomly selected within schools. School types involved the public, private and Catholic schools from urban, suburban, and rural areas; students were from upper, middle, and lower socioeconomic status and had different racial/ethnic groups with different family backgrounds.

Instruments

ELS: 2002 was a longitudinal study that utilized various data collection methods. The students completed cognitive tests in reading and mathematics; parents, teachers, and school administrators completed surveys and questionnaires. For this intended study, the priority was given to the variables that would be useful to answer the research questions. The study aimed to explore the influence of family structure and students' perception of student-teacher relationship

on students' math achievement after controlling for school urbanicity, school control, and SES. Therefore, students' math achievement scores, family structure, students' perception of student-teacher relationship, SES, school urbanicity, and school control were the variables of interest.

Math achievement was assessed through math tests that were developed for the National Educational Longitudinal Study (NELS) and included items to assess students' skill/knowledge, understanding/comprehension, and problem-solving. The test provided accurate measurement of the status of each participating student at each given time. The 10th grade tests were administered in two stages to increase the accuracy of the measurement. The first stage was a routing test and included 15 multiple-choice mathematics questions. The second stage included both open-ended and multiple-choice items. The scores were represented as a continuous variable, and they were based on the Item Response Theory (IRT) to be able to compare the scores across different test forms (Embretson & Reise, 2013).

One of the *student-level variables* was "student's perception of teacher-student relationships in the school" from the student base-year questionnaire on a four-point Likert-scale. This scaled variable represented student's perception of the quality of teachers as a continuous variable. To investigate the relationship between student achievement and the support from the family, family structure was chosen as the second predictor in the student-level, which was from the parent questionnaire. We divided family structure into three categories: two biological parents (mother and father), single biological parents (mother and male guardian, father and female guardian, mother only, father only), and others as guardians (two guardians, female guardian only, male guardian only, lives with student less than half time). Socioeconomic status (SES) was also included as a control variable, which was scaled as a continuous variable based on father and mother's educational attainment, occupational prestige, and family income derived from parent and student questionnaire.

School-level variables were also control variables related to school urbanicity and school control. These two categorical variables were taken from the school file for all sample schools. Urban, suburban, and rural were three categories of sampling school urbanicity that effects coding was applied. Public, Catholic, and other private schools were the three categories of sampling school control that dummy coding was applied.

Table 1 represents the variables of interest, type of the variables, and sample items or categories for each variable.

Table 1. Variables of interest, type of the variables, and sample items or categories for each variable

Variable	Type	Sample items or category
Dependent Variable- Math achievement	Continuous	
Independent Variables Individual (student) Level	Continuous	**Base-year Student Questionnaire**
• Students' perception of teacher-student relationships in school (BYTEAQUA)		• Students get along well with teachers • The teaching is good • Teachers are interested in students
• Family structure (F1COMP)	Categorical (Effects coding was applied)	**Base-year Parent Questionnaire** Two biological parents (2BIOPAR) 1- Mother and father (-1) Single biological parents (SINGBIOPAR) 2- Mother and male guardian (1) 3- Father and female guardian (1) 4- Mother only (1) 5- Father only (1) Others as guardians (GUARDIANS) 6- Two guardians (0) 7- Female guardian only (0) 8- Male guardian only (0) 9- Lives with student less than half time (0)
• Socioeconomic status (BYSES1)	Continuous	**Parent and Student Questionnaire** • SES is based on equally weighted, standardized components: father's/ guardian's or mother's/ guardian's education, family income, father's/ guardian's or mother's/ guardian's education

Table 1. Continued

Variable	Type	Sample items or category
School Level • School Urbanicity (BYURBAN)	Categorical (Effects coding was applied)	**Sampling Data** 1. Urban (1) 2. Suburban (-1) 3. Rural (0)
• School Control (BYSCTRL)	Categorical (Dummy coding was applied)	**Sampling Data** 4. Public (1) 5. Catholic (0) 6. Private (0)

Data Analysis

This study utilized multilevel modeling for the analysis due to the hierarchical nature of the data, in which students were nested within schools (Raudenbush & Bryk, 2002). The data analysis was conducted using the HLM 7 software with restricted maximum likelihood estimation. The two-level model was formed in multiple steps. The null model was firstly estimated to see whether the study needed the level-2 model by calculating the intra-class correlation coefficient (ICC). The equation of the unconditional model was shown in equation (1).

(1) **Level-1:** $MATH_{ij} = \beta_{0j} + r_{ij}$
Level-2: $\beta_{0j} = \gamma_{00} + u_{0j}$

Secondly, only student-level variables were added into the model including socioeconomic status (SES), family structure, and student's perception of teacher-student relationships in the school. The family structure was a categorical variable, so the effects coding was utilized; a student living with two biological parents was coded as "-1" as the reference group; a student living with a single biological parent was coded as "1," and student living with guardian(s) was coded as "0." In addition, the study assumed that students, who did not have a complete family, might benefit from the relationship with the teacher. To check this assumption, an interaction was also constructed between the effects-coded family structure variables including single biologic parent (SINGBIOPAR) and guardians (GUARDIANS) and the student's perception of teacher-student relationships. The equation for the second step was shown in equation (2).

(2) **Level-1:** $MATH_{ij} = \beta_{0j} + \beta_{1j}*(BYSES1_{ij}) + \beta_{2j}*(BYTEAQUA_{ij}) + \beta_{3j}*(SINGBIOPAR_{ij}) + \beta_{4j}*(GUARDIANS_{ij}) + \beta_{5j}*(SINGBIOPAR_{ij} * BYTEAQUA_{ij}) + \beta_{6j}*(GUARDIANS_{ij} * BYTEAQUA_{ij}) + r_{ij}$

Level-2: $\beta_{0j} = \gamma_{00} + u_{0j}$
$\beta_{1j} = \gamma_{10}$
$\beta_{2j} = \gamma_{20}$
$\beta_{3j} = \gamma_{30}$
$\beta_{4j} = \gamma_{40}$
$\beta_{5j} = \gamma_{50}$
$\beta_{6j} = \gamma_{60}$

Next, the Likelihood Ratio Test was examined to check whether the model fit significantly different from a model including a random slope. In a multilevel model, the intercept and the slopes for each level-1 variables can randomly vary across the level-2 units (McCoach, 2010). The equation for the third step indicating that a random slope was added for BYSES1 predictor was shown in equation (3). In this equation, we allowed the SES slope to randomly vary across schools; in other words, we specified a model that represented the relation between math achievement and SES to be different for different schools. Random effect was tested through adding a slope for each predictor at a time to check whether individual-level slopes significantly vary across schools.

(3) **Level-1:** $MATH_{ij} = \beta_{0j} + \beta_{1j}*(BYSES1_{ij}) + \beta_{2j}*(BYTEAQUA_{ij}) + \beta_{3j}*(SINGBIOPAR_{ij}) + \beta_{4j}*(GUARDIANS_{ij}) + \beta_{5j}*(SINGBIOPAR_{ij} * BYTEAQUA_{ij}) + \beta_{6j}*(GUARDIANS_{ij} * BYTEAQUA_{ij}) + r_{ij}$

Level-2: $\beta_{0j} = \gamma_{00} + u_{0j}$
$\beta_{1j} = \gamma_{10} + u_{1j}$
$\beta_{2j} = \gamma_{20}$
$\beta_{3j} = \gamma_{30}$
$\beta_{4j} = \gamma_{40}$
$\beta_{5j} = \gamma_{50}$
$\beta_{6j} = \gamma_{60}$

In addition, this study was interested in the within-school relation of three level-1 variables (SES, family structure, and student's perception of teacher-student relationships), so they were group-mean centered (Enders & Tofighi 2007). The equation for the third step was shown in equation (4).

(4) **Level-1:**
$$MATH_{ij} = \beta_{0j} + \beta_{1j} * (BYSES1_{ij} - \overline{BYSES1}_{.j}) + \beta_{2j} * (BYTEAQUA_{ij} - \overline{BYTEAQUA}_{.j}) + \beta_{3j} * (SINGBIOPAR_{ij} - \overline{SINGBIOPAR}_{.j}) + \beta_{4j} * (GUARDIANS_{ij} - \overline{GUARDIANS}_{.j}) + \beta_{5j} * (SINGBIOPAR_{ij} * BYTEAQUA_{ij}) + \beta_{6j} * (GUARDIANS_{ij} * BYTEAQUA_{ij}) + r_{ij}$$

Level-2:
$$\beta_{0j} = \gamma_{00} + u_{0j}$$
$$\beta_{1j} = \gamma_{10} + u_{1j}$$
$$\beta_{2j} = \gamma_{20}$$
$$\beta_{3j} = \gamma_{30}$$
$$\beta_{4j} = \gamma_{40}$$
$$\beta_{5j} = \gamma_{50}$$
$$\beta_{6j} = \gamma_{60}$$

Thirdly, as the school-level variables, school urbanicity was coded using effects coding, in which suburban schools were coded as "-1" as a reference group; urban schools were coded as "1," and rural schools were coded as "0." And, school control was dummy-coded, in which public schools were coded as "1," whereas private and Catholic schools were coded as "0." The study was also interested in both within and between school relations for public schools in urban and rural areas, so school urbanicity and school control were grand-mean centered. Then, the cross-level interaction was also included to model the interaction between the student-level variable, SES, and school urbanicity. The equation for the fourth and last step was shown in equation (5). Finally, assumptions were evaluated using SPSS software to check whether the level-1 predictors were independent of the level-1 residuals, level-2 predictors are independent of every level-2 residual, both level-1 and level-2 residuals are normally-distributed, and the correlation between the predictors at each level and residuals at the other level.

(5) **Level-1:**
$$MATH_{ij} = \beta_{0j} + \beta_{1j} * (BYSES1_{ij} - \overline{BYSES1}_{.j}) + \beta_{2j} * (BYTEAQUA_{ij} - \overline{BYTEAQUA}_{.j}) + \beta_{3j} * (SINGBIOPAR_{ij} - \overline{SINGBIOPAR}_{.j}) + \beta_{4j} * (GUARDIANS_{ij} - \overline{GUARDIANS}_{.j}) + \beta_{5j} * (SINGBIOPAR_{ij} * BYTEAQUA_{ij}) + \beta_{6j} * (GUARDIANS_{ij} * BYTEAQUA_{ij}) + r_{ij}$$

Level-2:
$$\beta_{0j} = \gamma_{00} + \gamma_{01} * \left(PUBLIC_j - \overline{PUBLIC}_{.}\right) + \gamma_{02} * \left(URBAN_j - \overline{URBAN}_{.}\right) + \gamma_{02} * \left(URBAN_j - \overline{URBAN}_{.}\right) + \gamma_{03} * \left(RURAL_j - \overline{RURAL}_{.}\right) + u_{0j}$$

$$\beta_{1j} = \gamma_{10} + \gamma_{11} * \left(URBAN_j - \overline{URBAN}_{.}\right) + \gamma_{12} * \left(RURAL_j - \overline{RURAL}_{.}\right) + u_{1j}$$
$$\beta_{2j} = \gamma_{20}$$
$$\beta_{3j} = \gamma_{30}$$
$$\beta_{4j} = \gamma_{40}$$
$$\beta_{5j} = \gamma_{50}$$
$$\beta_{6j} = \gamma_{60}$$

Results

Descriptive statistics for individual-level and school-level variables included in the analysis were provided on Table 2. The first step in the multi-level analysis was to check the unconditional two-level model to see whether the study needed the level-2 model. The amount of variability within schools (σ^2) and between schools (τ_{00}) were 76.07 and 22.50, respectively. The ICC value was calculated as 0.23, so the study needed the level-2 model. The results indicated that the expected math score of a randomly selected 10th grade student from a randomly selected school was 50.61, and the proportion of variance in the math scores between schools was 23%. The results for the first model were displayed on Table 3.

Table 2. Descriptive statistics for individual- and school-level variables

	N	Mean	SD	MIN	MAX
Dependent Variable- MATH	15892	50.71	9.91	19.38	86.68
Individual Level					
BYSES1	15244	0.04	0.74	-2.11	1.82
BYTEAQUA	13975	0.07	1.01	-3.72	2.35
SINGBIOPAR	15325	-0.23	0.95	-1.00	1.00
GUARDIANS	15325	-0.55	0.58	-1.00	1.00
SINGBIOPAR * BYTEAQUA	13975	-0.08	0.96	-4.66	2.92
GUARDIANS * BYTEAQUA	13975	-0.04	0.65	-4.66	2.92
School Level					
URBAN	751	- 0.15	0.89	-1.00	1.00
RURAL	751	- 0.29	0.76	-1.00	1.00
PUBLIC	751	0.77	0.42	0.00	1.00

The second step in the multi-level model analysis was to build the level-1 predictors related to individual-level variables as the predictors of math achievement. The results of model testing at the individual-level were presented on Table 3. Since the level-1 model was interested in the within school level relation, individual-level predictors were added to the model through group-mean centering. The level-1 model included the family structure as single biological parent (SINGBISOPAR) and guardian(s) and student's perception of teacher-student relationship as the predictors of math achievement and SES as the control variable. To check the main effect of the interaction between the variables of family structure and student's perception of teacher-student relationship, their interaction was also included as other predictors. Then, the random effects were examined for all level-1 predictors to decide whether we needed to eliminate any random effects that were non-significant. In other words, we wanted to statistically test the different fit from a fixed-effect-only model through testing random-effects; we tested the random effects for level-1 predictors through adding one slope at a time across level-2 units.

The findings indicated that during the model-building process, SES was the individual-level control predictor of math achievement, and the SES slope could randomly vary across schools. However, when other predictors such as student's perception of teacher-student relationship (BYTEAQUA), students living with single biological parent (SINGBIOPAR) or guardians were included once at a time at the school-level model as the predictors of math achievement slope, random effects were not statistically significant. Therefore, we eliminated the level-1 slopes across level-2 clusters except the slope of SES as the control variable at the individual level. The results of this analysis were presented on Table 5.

Random effect of all the predictors including student's perception of teacher-student relationship (BYTEAQUA), family structure (SINGBIOPAR and GUARDIANS), and the interaction between BYTEAQUA and predictors of family structure were non-significant except SES as the control variable. There was a significant variation across schools in the slopes for socioeconomic status. Next, we conducted the Likelihood Ratio Test to test whether the model fits significantly different from a model with a random slope of all predictors. The results of likelihood ratio test indicated that a model with a random slope for socioeconomic status was significantly different ($p< 0.001$) from a model with fixed slope for all predictors; in other words, the influence of socioeconomic status on students' math achievement within schools was different across schools. Therefore, we only included random effect in the model for only socioeconomic status as control variable at the individual level. The equation (3) indicated the model for formula for random effect of the socioeconomic status, and Table 4 presented the results of the analysis at the individual level.

We also examined the assumptions related to the level-1 and level-2 models. The findings showed that no assumptions were violated. The level-1 predictors were not related to level-1 residuals since the correlations between level-1 predictors and level-1 residuals were statistically significant at $p= 0.01$ level. The assumption of normality at individual and school levels also indicated that level-1 and level-2 residuals were normally distributed.

Among four variables at individual level, student's perception of teacher-student relationship, family structure including students' living with guardian(s) and socioeconomic status were significantly related to students' math achievement. Although there was a positive correlation between SES, students' perception of teacher-student relationship, and math achievement, the correlation between a family structure for students' living with guardian(s) was negative. The results indicated that students, who had higher socioeconomic status ($\gamma_{10}= 3.86$, $p< 0.001$) and positive perception of teacher-student relationship ($\gamma_{20}= 0.68$, $p< 0.001$), had higher performance in math. However, there was an inverse relationship between family structure and math achievement. Students, who were living with guardian(s), had lower academic achievement ($\gamma_{40}= -1.24$, $p< 0.001$) than students living with two biological parents. There was also non-significant relationship between students' living with a single biological parent and students' math achievement ($\gamma_{30}= -0.13$, $p= 0.392$).

Furthermore, the study assumed that the family structure and students' perception of teacher-student relationship interact in their effect on students' math achievement at 10th grade. The interaction effect between students living in a single biological parent and students' perception of teacher-student relationship on math achievement was significant

(γ_{50}= -0.81, SE= 0.23, p< 0.001). The interaction effect between students living with guardian(s) and students' perception of teacher student relationship on math achievement was 0.35 (SE= 0.14, p= 0.013). The findings indicated that students, who had positive perception about their relationship with their teachers, came from families including two biological parents, and had high SES as the control variable, had high math achievement. Student-level characteristics accounted for about 10% of the within school variance in math achievement.

In the level-2 analyses, the combined effects of the Level-2 and Level-1 predictors were examined. Two school-level predictors were examined: school control and school urbanicity. Since the study was interested in both within- and between-level school variables, the variables at level-2 related to school urbanicity and school control were grand-mean centered. School control was dummy coded, in which public was coded as "1," and private and Catholic schools were coded as "0." In addition, school urbanicity was effect coded, in which suburban schools were selected as the reference group and coded as "-1," and urban schools were coded as "1" and rural schools were coded as "0." As the study assumed that there was a significant relationship between school urbanicity and math achievement after controlling for SES, cross-level interaction was modelled to examine the relationship between SES as an individual-level variable and school urbanicity on student math achievement. In other words, the interaction effect between socioeconomic status and school urbanicity for urban and rural schools on students' math achievement was examined. The results of the analysis were presented on Table 3 as the Level-2 analysis.

Table 3. Multi-level modeling of individual-level and school-level variables on 10th grade students Math achievement

	Model 1: Unconditional			Model 2: Individual-level			Model 3: School-level		
Variable	Coefficient	SE	p	Coefficient	SE	p	Coefficient	SE	p
Intercept1 (β_{0j})									
Intercept2 (γ_{00})	50.61	0.19	<.001	50.75	0.20	<.001	50.79	0.18	<.001
PUBLIC (γ_{01})	-	-	-	-	-	-	-5.03	0.45	<.001
URBAN (γ_{02})	-	-	-	-	-	-	-1.26	0.27	<.001
RURAL (γ_{03})	-	-	-	-	-	-	0.55	0.31	0.080
Slope on BYSES1 (β_{1j})									
Intercept2 (γ_{10})	-	-	-	3.86	0.13	<.001	3.86	0.13	<.001
URBAN (γ_{02})	-	-	-	-	-	-	-0.85	0.19	<.001
RURAL (γ_{03})	-	-	-	-	-	-	0.43	0.23	.062
Slope on BYTEAQUA (β_{2j})									
Intercept2 (γ_{20})	-	-	-	0.68	0.11	<.001	0.72	0.11	<.001
Slope on SINGBIOPAR (β_{3j})									
Intercept2 (γ_{20})	-	-	-	-0.13	0.15	0.39	-0.13	0.15	0.396
Slope on GUARDIANS (β_{4j})									
Intercept2 (γ_{20})	-	-	-	-1.24	0.25	<.001	-1.23	0.25	<.001
Slope on SINGBIOPAR * BYTEAQUA (β_{5j})									
Intercept2 (γ_{20})	-	-	-	0.35	0.14	0.013	0.28	0.14	0.048
Slope on GUARDIANS * BYTEAQUA (β_{6j})									
Intercept2 (γ_{20})	-	-	-	-0.81	0.23	<.001	-0.65	0.23	0.05
Random Effects	Estimation	SD	p	Estimation	SD	p	Estimation	SD	p
Variance in intercepts or between schools (τ_{00})	22.50	4.74	<.001	24.51	4.95	<.001	20.09	4.48	<.001
Variance in BYSES1 slope (τ_{11})	-	-	-	2.49	1.58	<.001	2.33	1.53	<.001
Variance within schools (σ^2)	76.07	8.72	-	68.61	8.28	-	68.63	8.28	
Model Fit	Deviance	df		Deviance	df		Deviance	df	
	115395.39	2		100401.14	4		100261.91	4	

Table 4. Random effects for individual-level predictors

	Model 1			**Model 2**			**Model 3**			**Model 4**			**Model 5**			**Model 6**		
Random Effects	**Est.**	**SD**	**p**	**Est.**	**SD**	**p**	**Est.**	**SD**	**p**	**Est.**	**SD**	**p**	**Est.**	**SD**	**p**	**Est.**	**SD**	**p**
Variance																		
between schools (τ_{00})	24.51	4.95	*	24.57	4.96	*	24.60	4.96	*	24.63	4.96	*	23.98	4.90	*	23.81	4.88	*
in BYSES1 slope (u_1)	2.49	1.58	*	2.49	1.58	*	2.67	1.63	*	2.60	1.61	*	2.60	1.61	*	2.63	1.62	.016
in BYTEAQUA (u_2) slope	-	-		.31	.55	.27	.36	.60	.47	.34	.58	.10	.44	.67	.04	.57	.76	.029
in SINGBIOPAR (u_3) slope	-	-		-	-	-	.42	.65	.06	1.76	1.32	.021	1.83	1.35	.07	1.81	1.34	.096
in GUARDIANS (u_4) slope	-	-		-	-	-	-	-	-	6.61	2.57	.004	6.13	2.47	.02	5.94	2.43	.030
in SINGBIOPAR*BYTEAQUA slope (u_5)	-	-		-	-	-	-	-	-	-	-	-	-	-	-	.83	.91	.010
in GUARDIANS*BYTEAQUA slope (u_6)	-	-		-	-	-	-	-	-	-	-	-	.90	.95	.06	2.84	1.69	.155
within schools (σ^2)	68.61	8.28		68.35	8.27		67.91	8.24		67.33	8.21		67.11	8.19		66.98	8.18	

* where p < .001.

The results of the examination of combined effects of Level-2 and Level-1 variables indicated that the overall math score for 10th grade students was 50.79 (SE= 0.18, p< 0.001). The math score for public school students was 5.03 lower than students from private and Catholic schools after controlling for socioeconomic status, family structure, students' perception of the relationship with teachers, and school urbanicity. The math score for urban school students was 1.26 lower than students from suburban and rural schools and for rural school students, it was non-significant and 0.55 higher than students from urban and suburban schools after controlling for socioeconomic status, family structure, students' perception of the relationship with teachers, and school control.

Within school-level, the 10th grade math achievement was expected to increase by 3.86 points for each unit increase in SES after controlling for student perception of relationship with teachers and family structure, whereas the math achievement was expected to increase by 0.72 points for each unit increase in student perception of relationship with teachers after controlling for SES and family structure. In addition, the cross-level interaction indicated that the within-school effect of SES on math score was -0.85 points lower for students in urban schools than students from suburban and rural schools and 0.43 points higher for students in rural schools that students from urban and suburban schools.

In terms of family structure, within school, students living with single biological parent scored on average 0.13 points below the grand mean and students living with guardian(s) scored on average 1.23 below the grand mean after controlling for SES and student perception of relationship with teachers. The interaction effect between students living with guardian(s) and students' perception of teacher-student relationship on 10th grade math achievement was significant with γ_{50}= -0.65, SE= 0.23, and p= 0.005. And, the interaction between students living with a single biological parent and students' perception of teacher-student relationship on 10th grade math achievement was insignificant with γ_{60}= 0.28, SE= 0.14, and p= 0.048. The average effect of students' perception of teacher-student relationship was 0.72 across different family structure. Additionally, the initial variance for students' math achievement between schools was 22.50 from the unconditional model, but the level-2 analysis indicated a decrease in students' math scores, and the variance between schools in the conditional level-2 analysis became 20.09. School-level predictors as school urbanicity and school control led to 10% variance in students' math achievement. The interaction between students' perception of the quality of teacher-student relationship and family structure was represented on Figure 1.

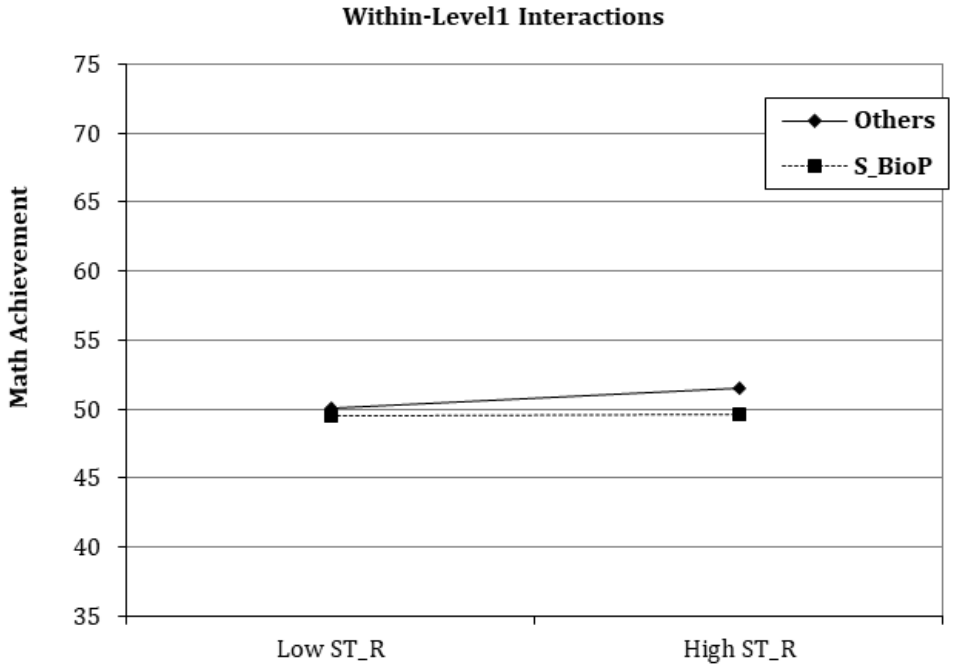

Figure 1. The interaction between students' perception of the quality of teacher-student relationship and family structure

Discussion

The study included the national data from a U.S. 10th grade students to investigate the influence of family structure and student's perception of the quality student-teacher relationship on student achievement after controlling for SES, school urbanicity, and school control. In this section, we discussed how the results of the study were similar to or different from the published literature to explain the relationship between family structure and student's perception of the quality student-teacher relationship on student achievement. We also provided potential implications for future research and limitations of the study.

The results indicated that student's perception of teacher-student relationship was significantly related to students' math achievement, but there was a negative relationship between students' living with guardian(s) and their math achievement after controlling for SES. Students' SES and their perception of the quality of teacher-student relationship were positively

related to their academic achievement. The students, who had higher socioeconomic status and positive teacher-student relationship, had higher performance in math. However, there was an inverse relationship between family structure and math achievement. Students, who were living with guardian(s) and a single parent, had lower academic achievement than students living with two biological parents. These findings indicated that students, who had positive perception about the quality of the relationship with their teachers, came from families including two biological parents and had high SES as the control variable, had high math achievement.

The examination of combined effects of Level-2 and Level-1 variables indicated that there was a positive association between student perception of the quality of the teacher-student relationship and the math achievement after controlling for SES and family structure. In terms of the family structure, students' living with a single biological parent or guardian(s) had lower academic achievement than students' living with two biological parents after controlling for SES and student perception of the quality of the relationship with teacher. The main effect of the interaction between students living with guardian(s) and a single biological parents and students' perception of teacher-student relationship was not high, and the average effect of the students' perception of teacher-student relationship and family structure was 0.72. For the control variables, students' SES and attending public school in urban areas were found to be significantly related to students' math achievement. Within school-level, the 10th grade math achievement was positively related to SES after controlling for student perception of relationship with teachers and family structure. The math score for public school students was lower than students from private and Catholic schools after controlling for socioeconomic status, family structure, students' perception of the relationship with teachers, and school urbanicity. In addition, the math score for students' attending urban schools was lower than students from suburban and rural schools. However, attending rural school was not significantly associated with student achievement. In addition, the cross-level interaction indicated that SES had negative impact on academic achievement in urban schools, but higher impact for students in rural schools than students from urban and suburban schools.

These results were consistent with the previous studies. First, positive teacher-student relationship and pedagogical caring contributed to students' academic success and promoted student learning. This finding is consistent with the results from McGrath and Van Bergen (2015), Mikk et al. (2016), and Wubbels et al. (2016). There is a positive correlation between the quality of teacher-student relationship and student academic achievement for this sample from United States. However, Mikk and colleagues (2016) also argued that cultural context of the country might influence that relationship as they found negative relationship between teacher-student relationship and academic achievement in developing countries.

Furthermore, family structure influenced the educational attainment depending on different factors. Consistent with the previous research, we found that the support from two biological parents could enhance student motivation and academic performance (e.g. Wu et al., 2012), whereas students living with a single biological parent or guardian(s) had lower academic achievement (e.g. Dearing et al., 2014). Wu and colleagues (2012) also suggested that besides the structure of the family, SES of the parent, educational background of the parent, parental involvement, gender of the parent, and student behavior might influence the academic success.

Moreover, we found that public high schools included students with lower academic achievement than private high schools. As suggested by the previous studies (e.g Carbonaro & Covay, 2010), there were differences between public and Catholic schools and private schools in terms of educational opportunities. Catholic and private schools exposed students to more academic curriculum, math in particular, than public schools (Carbonaro & Covay, 2010). These results were specific to high schools; but school control may have different influence on students' academic achievement in elementary and middle school levels as found in an earlier study of Carbonaro (2006).

We also found that the relation between students' SES and academic achievement was stronger for students in suburban schools than for students in rural or urban schools, and this impact was the weakest for urban schools compared to rural schools. Consistent with Sirin (2005), our study found that the relationship between SES and math achievement was stronger for students in rural schools than urban schools.

Implications for future research and practice

We believe our findings have some important implications for future research. The quality of teacher-student relationship influences the cognitive, social, emotional, and academic outcomes of students. Teachers need to develop strategies to provide motivational support, enhance the classroom level interactions (teacher-student and student-student interactions), and improve the quality of the instruction for all students. Further research should measure the influence of other student-level characteristics such as gender, ethnicity, age, disability, and learning difficulty on students' school adjustment and achievement to develop positive perception for student-teacher relationships. Teacher-level factors should also be examined to understand their influence on instructional approaches to address students' needs. Teacher education programs should help prospective teachers learn how to create and maintain supportive learning environments that can promote equal educational opportunities regardless of negative influences. In addition, this study was limited to high-school students. The perception of the quality of teacher-student relationship may change through academic years and influence the drop-out rates. Further research should examine how the teacher-student relationships influence the educational attainment in different grade levels in K-16 education.

This study found that students living with two-biological families had higher academic performance that single-parent families. The study reveals that family structure influences the academic success, but further research is required to examine the influence of the quality of parental involvement in different types of families on students' motivation and attitudes towards school. Moreover, this study found that students in private and suburban schools had higher academic achievement that public and urban schools. Carbonaro and Covay (2010) suggested that this result might be related to the difference in academic curriculum between private and public schools. Private schools follow a rigorous curriculum, so urban schools may need to enhance the quality of the instruction to improve the learning gains through utilizing innovative and research-based strategies (Northrop & Kelly, 2018). These results call for further examination of the quality of the instruction and factors influencing the instruction in different schools and in different grade levels including elementary, middle, high school and college education through longitudinal studies.

Students at risk and with low SES may lack academic and financial support from their parents, which influences their academic performance (Thomson, 2018). However, families with high SES may provide more academic, financial as well as psychological support to promote students' learning and improvement. Schools have important roles in improving students' academic performance. Schools should provide equal opportunities for all students by enhancing the school climate and quality and quantity of instruction (Gustafsson et al., 2018). Educational system of the country and cultural context may also influence the support and resources provided for students' learning. This study investigated the influence of student-level SES on academic performance. Further study is necessary to examine the influence of school-level and country-level SES on the educational opportunities and student achievement.

Limitations

These results provided the research-based evidence about the influence of family structure and student's perception of the quality student-teacher relationship on student achievement after controlling for SES, school urbanicity, and school control. However, there were some limitations. First, only, the base-year data (2002) was accessible online although ELS:2002 was a longitudinal study. The data from 2004 and 2012 were restricted. The further research should have a design addressing the impact of these variables in a longitudinal term. Secondly, teacher-level variables were not accessible. Teacher identification number and variables could be added to the model to examine the influence of teachers' characteristics on student's perception of the quality student-teacher relationship and students' math achievement. Lastly, the study could investigate the impact of other school-level (e.g. school SES), individual-level (e.g. drop out or gender), and teacher-level (e.g. education, gender) variables on student achievement.

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