High Achievers from Low Socioeconomic Backgrounds: The Critical Role of Disciplinary Climate and Grit

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The purpose of this study was to examine whether school disciplinary climate and grit predicted low socioeconomic status (SES) students being high achievers in mathematics and science with a representative sample of 15-year-old students in the United States. Our analysis, using a two-level logistic hierarchical linear model (HLM), indicated both disciplinary climate and grit were significantly associated with low-SES students' high achievement in math and science. Low-SES students who perceived themselves as having a higher level of grit and whose classrooms had better disciplinary climate were much more likely to be high achievers. This finding provided supplemental evidence to the limited number of existing studies which suggest achievement gaps could be narrowed by addressing school climate and student grit. In conclusion, we discussed what implications this study could offer for future educational research and policy.

Introduction

Based on the belief that students deserve equal opportunities to learn and succeed in schools regardless of their racial/ethnic identities and socioeconomic backgrounds, the United States government proposed with the No Child Left Behind Act of 2001 (NCLB) to close achievement gaps through accountability, flexibility, and choice. Many states' policy initiatives, such as the "7-Point Plan: Better Schools for a Better Minnesota" and the "Master Plan to Eliminate the Achievement Gap in Connecticut,"[1] also make closing achievement gaps a priority goal. Yet despite federal and state-level policy efforts, the achievement gap between students from low- and high-income families has been growing over the past few decades (Reardon, 2011). As a consequence, students with low-SES backgrounds are still constrained in their ability to perform well enough for improved opportunities, such as the pursuit of a college education.

Although NCLB and state policies have not led to the desired outcome of closing the SES-based achievement gap at the national or state level (Lee, 2006; Reardon, Robinson, & Weathers, 2015), researchers have suggested multiple approaches to address this gap. They include cultivating transformative leadership at the school level (Brown, 2006; Johnson Jr. & Uline, 2005); providing highly qualified teachers for all students (Borman & Kimball, 2005; Haycock, 1998); improving school climate (Becker & Luthar, 2002); and increasing parental involvement (Lee & Bowen, 2006; Jeynes, 2007). To demonstrate how these approaches work in practice, a few studies based on data from a limited number of schools—such as Golden Spike Schools

[1] See Minnesota plan at http://education.state.mn.us/MDE/about/cmsh/bsbmn/ and Connecticut plan at https://www.cga.ct.gov/ed/tfs/20110708_Achievement%20Gap%20Task%20Force/April%202014%20Taskforce%20Final%20Report.pdf

(McGee, 2003) and the Harlem Children's Zone (Dobbie & Fryer, 2009)—have indicated these approaches do play a critical role in reducing achievement gaps. However, no empirical studies have used national samples to show the general effectiveness of these approaches across states. While the achievement gap discussion continues, it is still unknown what if anything has worked on a large scale to narrow the SES-based gap.

We did not intend to evaluate all the approaches suggested by previous research. Instead we investigated whether school disciplinary climate and student grit might reduce the gap. There are three reasons for this focus. First, a considerable amount of previous research (e.g., Chen & Weikart, 2008; Lee & Bryk 1989; Shin, Lee, & Kim, 2009) has demonstrated that disciplinary climate significantly influences student achievement. Second, a small number of early studies found a safe and orderly school environment to be related to resilience of low-SES students (Borman & Overman, 2004). Third, emerging research on non-cognitive factors and student achievement (Farrington et al., 2012) indicates the importance of grit, suggesting grit might be an essential characteristic for high-achieving students. Most previous quantitative research in school disciplinary climate and grit, however, has largely focused on the overall effect on the achievement of *all* students without specifically exploring populations of disadvantaged students. Therefore, these studies could not suggest disciplinary climate and grit might specifically help low-SES students catch up with their better-off peers within the same context because students from economically disadvantaged families are likely to attend more disruptive schools (Gregory, Skiba, & Noguera, 2010) and show lower levels of grit (Huang, 2015).

In order to overcome the limitations of previous studies, we examined how well school disciplinary climate and student grit predicted the high achievement in mathematics and science of a nationally representative sample of low-SES students. Although low-SES students in general have lower achievement compared to high-SES students, about 10% of socioeconomically disadvantaged children have excelled against the odds to become high achievers (Organization for Economic Co-operation and Development (OECD), 2011). These findings will contribute to the discussion of closing the SES-related achievement gap with empirical evidence from a nationally representative sample.

We adopted Bronfenbrenner's (1979, 1992) ecological systems theory (EST) to understand student achievement with a focus on the influence of school disciplinary climate and student grit. In Bronfenbrenner's view, each child is surrounded by layers of systems from a macro to micro level. Influence from the microsystem of peers, families, neighborhoods, and schools largely determines the development and growth of children. While acknowledging that these environmental settings in the microsystem play a critical role, Bronfenbrenner places individual children at the center of the conceptual framework, suggesting children themselves could also take an active role in their own developmental process. In other words, the development of children is shaped both by their social environments and by the children themselves, which speaks to the social nature of individuals. This conceptualization applies to student achievement, meaning that achievement is subject to the influences of students themselves, their families, and their schools (e.g., Brookover, 1978; Coleman et al., 1966; Farrington, 2012; Hoy & Hannum, 1997; Lee & Bowen, 2006; Lee & Bryk, 1989).

In this article, we first review existing research regarding the influence of student characteristics and social environment factors on student achievement, and provide a brief overview of the SES-related achievement gap and why disciplinary climate and grit might reduce the gap. We then present our research design and model results, and conclude by offering implications for future research and policy.

Overview of Literature

Beginning at the center of Bronfenbrenner's EST, student characteristics that impact achievement include, but are not limited to, grit (Farrington et al., 2012), gender (Campbell & Beaudry, 1998; Ma, 2008), and time spent studying (Singh, Granville, & Dika, 2002).

Grit and Student Achievement

Student achievement is influenced by the interplay of cognitive and noncognitive factors. The current literature is replete with studies that focus on cognitive factors—a student's accumulation of content knowledge and academic skills learned in school, such as the Intelligence Quotient (IQ) (Farrington et al., 2012), and their effects on students' learning outcomes. Recently, however, there has been a rising interest in exploring malleable individual student behaviors and attitudes that can prompt students to push their limits and to achieve at a higher level within educational contexts (Duckworth, Peterson, Matthews, & Kelly, 2007; Farrington et al., 2012).

Defined as perseverance and passion for long-term goals (Duckworth et al., 2007), grit has been recognized as an important noncognitive factors that can lead to academic and life success. Perseverance is a characteristic that keeps individuals from giving up easily when encountering problems and challenges, while passion for long-term goals motivates them to sustain efforts needed to achieve a goal. Individuals higher in grit have the advantage of stamina; they stay on their course despite challenges and failures, which may eventually lead them to surpass even their gifted peers who are lower in grit (Duckworth et al., 2007; Farrington et al, 2012).

In 2007, Duckworth et al. developed a 12-item measurement scale to examine grit among different sample populations. Duckworth and Quinn (2009) later developed an 8-item scale measurement of grit and replicated many of their earlier studies, and they arrived at the same conclusions.

Grit and perseverance are significant predictors across a wide range of populations. They were shown to be related to student grades in elementary school (Bowles & Gintis, 1976); academic performance in higher education (Wolter & Hussain, 2014), including African Americans at predominately White institutions (Strayhorn, 2014); and even academic performance among military cadets (Duckworth et al., 2007; Maddi, Matthews, Kelly, Villarreal, & White, 2012). More specifically, many studies found that grit was positively related to academic achievement, self-control and retention rates (see also Duckworth, et al., 2007), and could serve as a stronger predictor of college grades than high school GPA and all standardized college entrance exams (Wolter & Hussain, 2014).

Gender and Study Time

Gender and time spent studying play an important role in student achievement; however they play a minor role in the current research and usually serve as control variables. Briefly, literature shows that historically boys outperform girls in mathematics and science achievement (Campbell & Beaudry, 1998). This achievement gap has persisted; in 2008 Ma's analysis of Program for International Student Assessment (PISA) data found that 29 countries out of 41 had significant gender gaps in mathematics achievement favoring boys. In the United States, 15-year-old boys' achievement in mathematics was 30 points higher than girls'. Even today, a decade later, gender gap in student achievement is still an issue (e.g., Pargulski & Reynolds, 2017; Speer, 2017).

In terms of time spent on studying, findings by Singh, Granville, and Dika (2002) suggested that study time was positively related to achievement in both mathematics and science. Fan et al.'s (2017) review of research published since 1986 also came to the same conclusion: that time on studying mattered in achievement. Interestingly, time might not have the same impact on achievement for both genders. Campbell and Beaudry's (1998) study of 543 11th graders who participated in the Longitudinal Study of American Youth survey indicated that although girls spent more time on homework, they still achieved significantly lower results. However, some other studies (e.g., Duckworth & Seligman, 2006) showed that female students had better achievement because they are more disciplined, spending more time and effort on learning.

Social Environment Factors and Student Achievement

Within the microlevel of Bronfenbrenner's EST, family backgrounds, including parents' education, SES, and school involvement also affect student achievement (e.g., Bourdieu, 1973; Coleman et al., 1966; Huang & Liang, 2016; Lareau & Weininger, 2003; Lee & Bowen, 2006). In particular, parental SES has become a stable factor not to be neglected in research on student performance. Compared with the role of families, the role of schools in student achievement has undergone more debate. The Coleman Report (Coleman et al., 1966), the first national look at educational opportunities, was widely interpreted as discounting the role of schools in student achievement (Gamoran & Long, 2007); however, more recent research (Konstantopoulos & Borman, 2011) indicated that the school effect was larger than it was estimated in the Coleman Report. Many studies have shown that school size (e.g., Hoxby, 2000), location (e.g., Young, 1998; Lankford, Loeb, & Wyckoff, 2002), teacher quality (e.g., Darling-Hammond, 2000; Borman & Kimball, 2005), and principal leadership (e.g., Hallinger, Bickman, & Davis, 1996; Sebastian & Allensworth, 2012), do, in fact, have a significant impact on student achievement.

Disciplinary Climate and Student Achievement

The importance of school climate in student achievement has been well supported by existing research (e.g., Esposito, 1999; Johnson & Stevens, 2006; Lee & Bryk, 1989; Lubienski, Lubienski, & Crane, 2008; McEvoy & Welker, 2000; O'Reilly, 1975; Sebastian & Allensworth, 2012; Sherblom, Marshall, & Sherblom, 2006; West, 1985) in different disciplines (Anderson, 1982), including but not limited to education, psychology, sociology, gender studies, and health science. Research on school climate covers a wide range of topics including juvenile behavior (e.g., Gaviria & Raphael, 2001), drug use (e.g., Allen, Chango, Szwedo, Schad, & Marston,

2012; Bauman & Ennett, 1996), organizational support of learning (Sweetland & Hoy, 2000), principal leadership and teacher efficacy (Raudenbush, Rowan, & Kang, 1991), and student achievement (e.g., Hanushek, Kain, Markman, & Rivkin, 2003; Schunk & Hanson, 1985). There are also multiple dimensions of school climate, such as students' sense of academic futility (Brookover, Schweitzer, Schneider, Beady, Flood, & Wisenbaker, 1978), organizational health (Hoy & Hannum, 1997), and school culture and structure (Chen & Weikart, 2008). While we acknowledged the comprehensive conceptualization of school climate, our purpose was to discover whether disciplinary climate and grit predict high achievement by low-SES students. We therefore focus on studies that investigated these two measures.

Whereas harsh or too much discipline might discourage students from engaging in school work (Gregory, Skiba, & Noguera, 2010; Skiba & Rausch, 2004), a lack of order in a school can also interfere with student learning (Chen & Weikart, 2008). Large scale research over the years has shown that disciplinary climate is one of multiple factors significantly associated with higher student achievement. For example, using NELS data of eighth graders (n = 24,599; Ma & Willms, 2004), data from Catholic and public high schools in the U.S. (n = 10,000+; Lee & Bryk, 1989), as well as samples from Korea (n = 5,444), Japan (n = 4,707), and the U.S. (n = 5,456; Shin, Lee, & Kim, 2009), researchers have employed hierarchical linear modeling (HLM) to predict overall student achievement.

Although disciplinary climate is significantly related to overall achievement, it might not serve to reduce the gap. The increase in achievement by students from different SES backgrounds could proceed at the same pace and leave the SES-based gap remaining. Furthermore, because these studies aggregated the measure of disciplinary climate at the school level, the findings do not necessarily mean that an individual student in a less disruptive classroom is likely to perform better than a student in a more disruptive classroom. The reason is that the average *school* disciplinary climate might not be directly related to individual students' performance; different classrooms within the same school could have different levels of disciplinary climate. On the individual student relationship between disciplinary climate and student achievement, a more recent study by van de Werfhorst, Bergstra, and Veenstra (2012) found that disciplinary climate (labeled as student misbehavior) "was significantly associated with academic performance, even after holding constant earlier academic achievement" in the Netherlands (p. 218).

SES-Based Achievement Gap

Empirical research has long evidenced the SES-based achievement gap since the publication of the Coleman Report (Equality of Educational Opportunities) in the 1960s (e.g., Sirin, 2005; Gamoran & Long, 2007; Stanfiel, 1973; Walker, Greenwood, Hart, & Carta, 1994; White, 1982). After decades of policy reforms from the War on Poverty to the NCLB[2], both of which featuring an emphasis on helping economically disadvantaged students learn, one might expect that students from low-income/SES communities would be less constrained in performing as well as students with a higher SES background. Quite disappointingly, recent research has shown the opposite is happening. The achievement gap between students from wealthy families and those from economically disadvantaged families has persisted and widened (Reardon, 2011).

[2] War on Poverty was a legislative initiative introduced by President Lyndon Johnson in the 1960s; No Child Left Behind (NCLB, 2001) was a reauthorization of the Elementary and Secondary Education Act.

Comparing the extent of the achievement gap across 19 large samples surveyed over the past 60 to 70 years, Reardon estimated that the gap grew 40 to 50 percent between 1970 and 2001, an increase "from around 0.87 to almost 1.25 standard deviations. One standard deviation is the equivalent of three to six years of learning in secondary schools" (Reardon, 2011, p. 11). In other words, the achievement of students with lower SES was at least 2.6 years behind high SES students in the 1970s, and this gap increased to 3.8 years by 2001.

Research has offered varied solutions to address the growing achievement gap among levels of SES (Becker & Luthar, 2002; Borman & Kimball, 2005; Brown, 2006; Haycock, 1998; Jeynes, 2007; Johnson Jr. & Uline, 2005; Lee & Bowen, 2006). Yet, research has only provided limited empirical evidence, on a small scale, to show the success of these recommended solutions. It is still unknown if any factors could narrow the SES-based achievement gap across the U.S.

Method

Bronfenbrenner's EST, along with existing research, suggests we should address the influence of both school and individual student measures on achievement. In our study, we considered both, with a focus on grit/perseverance and disciplinary climate.

We test two hypotheses:

(1) Disciplinary climate and student grit significantly predict the likelihood of low-SES students' high achievement in mathematics and science.

(2) The association between disciplinary climate, student grit, and high achievement remain significant after controlling for characteristics of students, parents, and schools.

It is critical to focus on low-SES students because 1) SES disadvantaged students still have limited achievement comparably to their wealthier peers, and 2) there is still a considerable knowledge gap in understanding what could be done to promote achievement of low-SES students.

Data and Sample

We use 2012 Program for International Student Assessment (PISA) U.S. data to address the two hypotheses. The OECD has collected PISA data five times—once every three years since 2000—targeting 15-year-old students in more than 60 countries. Mathematics and science assessments as well as survey responses from students, parents, and schools were used to collect student achievement data in the two subject areas, individual student characteristics, family background, and school characteristics such as school size and location. In 2012, 6,111 U.S. students from 161 schools participated in PISA, "representing the 15-year-old U.S. student population of 4,074,457" (OECD, 2014, p. 178). The sample was drawn with a stratified random sampling procedure. The overall student response rate was 88.99% and the school response rate was 77.78% (OECD, 2014). This study is based on 4,978 valid observations—each observation representing an individual student.

Variables

Dependent variables. The two dependent variables (*High Achiever Math* and *High Achiever Science*) are categorical measures constructed by ranking student SES and achievement in mathematics and science into four groups/quartiles from low to high. For the 4,978 valid observations, achievement in mathematics and science had a mean around 500 and standard deviation close to 100, the SES variable being standardized with a mean around zero and standard deviation near one. To illustrate how we created the *High Achiever Math* variable, students with low SES (first quartile) and also low achievement (in the first and second quartile) are coded as "0," and students with low SES but high achievement (third and fourth quartile) are coded as "1" (Table 1). The same criteria and approach were used to generate *High Achiever Science*. This study targets low-SES students who fall in the first quartiles on the SES ranking, so the final sample (n = 1,220) does not include students whose SES ranked in the second, third, or fourth quartiles. Among these 1,220 students 31% of them are high achievers in mathematics, and 30% in science (see Table 3).

Table 1
Dummy Coding Creating the Dependent Variables

	Achievement Level			
SES	Low (1st quartile)	Low (2nd quartile)	High (3rd quartile)	High (4th quartile)
Low (1st Quartile)	0	0	1	1
Low (2nd Quartile)	--	--	--	--
High (3rd Quartile)	--	--	--	--
High (4th Quartile)	--	--	--	--

*Note: the same criteria were used to identify high achievers in both science and math.

By using the two high-achiever dummy variables (one for math, one for science) and limiting the sample to the 1,220 low-SES students, we sought to show what specific variables can predict low-SES students' high achievement in both subjects.

Focus independent variables. In alignment with Bronfenbrenner's EST the independent variables are categorized into three groups—student-related factors, parental factors, and school-related factors. The two focus independent variables are student grit (student-related) and disciplinary climate (school-related) at the classroom and school levels. Parental factors and additional student-related factors are used as control variables. Table 3 provides a complete list of these variables along with correlations.

Item descriptions of the focus independent variables are provided in Table 2. We used two measures for disciplinary climate. The first, "classroom disciplinary climate (CDC)," was derived from five items (OECD, 2012b, p. 21). The second disciplinary climate variable, "school disciplinary climate (SDC)," is a school-level variable derived from a factor analysis of eight items asking principals to rate the extent to which learning was hindered (OECD, 2014, p. 348). Student grit is measured by five items asking how persistent students perceive themselves to be (OECD, 2012a, p. 25). A limitation of our grit measure is that it only captures the perseverance component, not the component measuring passion for long-term goals. We discuss how this limitation affects interpretation of our model results later.

Table 2
Disciplinary Climate Measures

	Item Description (item scales are presented in Appendix A)
Classroom Disciplinary Climate (CDC)	
1	Students don't listen to what the teacher says
2	There is noise and disorder
3	The teacher has to wait a long time for the students to quiet down
4	Students cannot work well
5	Students don't start working for a long time after the lesson begins
School Disciplinary Climate (SDC)	
1	Student truancy
2	Students skipping classes
3	Students arriving late for school
4	Students not attending compulsory school events
5	Students lacking respect for teachers
6	Disruption of classes by students
7	Student use of alcohol or illegal drugs
8	Students intimidating or bullying other students
Student Grit	
1	When confronted with a problem, I give up easily
2	I put off difficult problems
3	I remain interested in the tasks that I start
4	I continue working on tasks until everything is perfect
5	When confronted with a problem, I do more than what is expected of me

Control variables. We included three groups of control variables accounting for confounding factors from students themselves, schools, and parents. The first group includes student gender, SES, immigration background, language spoken at home, time spent in mathematics and science classes per week, and time spent on homework after school each week. The second group includes school average SES, school admission policy, teacher shortage, percentage of teachers who have a teaching certificate, percentage of math teachers holding a math teaching certificate, instructional leadership, enrollment size, school sector (public vs. private), and school location (small town/city/big city). The last group is parental involvement in their children's school. A complete list of the variables is provided in Table 3 and Appendix A. Appendix A also includes a detailed description of each independent variable.

Table 3
Variable Descriptive Statistics and Correlation (n = 1,220)

Variable	Mean	SD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Student-related																										
1 SES	-1.23	0.46																								
2 Gender	0.50	0.50	0.04																							
3 Immigration	0.42	0.49	-0.33	0.00																						
4 Language	0.68	0.47	0.24	0.01	-0.67																					
5 Time Math	4.12	2.22	-0.01	0.03	-0.05	-0.01																				
6 Time Science	4.11	2.31	-0.03	0.03	-0.03	-0.01	0.76																			
7 Out Hours	9.55	7.64	0.04	-0.01	0.11	-0.07	0.05	0.05																		
8 **Grit**	0.13	1.07	0.02	0.01	0.04	-0.01	0.03	0.04	0.12																	
9 **CDC**	-0.13	1.01	-0.01	0.01	0.04	-0.02	-0.11	-0.07	0.12	0.10																
School-related																										
10 **CDC (mean)**	-0.09	0.43	0.03	0.01	0.11	-0.09	-0.04	-0.01	0.09	0.02	0.27															
11 School SES	-1.04	0.20	0.23	0.00	-0.13	0.08	-0.06	-0.07	-0.05	0.02	0.05	-0.05														
12 **SDC**	-0.43	0.86	0.12	0.05	-0.08	0.07	0.04	0.04	0.08	-0.01	0.06	0.11	0.07													
13 Selectivity	0.68	0.47	0.04	0.02	-0.04	0.02	-0.01	-0.02	-0.07	0.14	0.00	0.05	0.30	0.11												
14 Shortage	-0.17	1.03	-0.04	-0.03	-0.01	-0.03	-0.01	-0.06	-0.10	0.02	-0.07	-0.08	0.16	-0.33	0.16											
15 %Certified	0.99	0.08	-0.04	-0.01	0.06	-0.02	-0.04	-0.04	0.03	0.03	-0.05	-0.14	-0.02	-0.09	-0.05	0.06										
16 %Certified Math	0.73	0.44	0.00	0.03	0.06	-0.07	-0.01	-0.04	0.09	-0.02	-0.02	-0.03	-0.13	0.25	-0.03	-0.28	0.12									
17 Leadership	0.88	1.10	0.01	-0.02	0.03	-0.05	-0.02	-0.01	0.05	-0.02	-0.04	0.04	0.07	0.07	0.01	0.02	-0.04	0.23								
18 Private	0.01	0.10	0.04	-0.02	0.03	0.01	-0.03	-0.04	0.02	-0.03	0.01	0.02	0.02	0.19	0.07	-0.01	-0.20	0.03	0.01							
19 Enrollment Size	14.35	9.07	-0.10	-0.06	0.32	-0.27	-0.03	-0.04	0.10	-0.01	-0.03	0.03	-0.09	-0.31	-0.07	-0.03	0.08	-0.05	0.17	-0.10						
20 Locale Small Town	0.24	0.43	0.10	0.03	-0.36	0.25	-0.01	-0.03	-0.08	-0.01	0.02	0.02	0.03	0.07	-0.03	0.09	-0.14	0.01	-0.11	-0.02	-0.50					
21 Locale City	0.64	0.48	-0.07	-0.03	0.26	-0.14	-0.05	-0.03	0.07	0.00	0.00	0.03	-0.08	-0.14	-0.13	-0.22	0.10	0.06	0.13	0.00	0.40	-0.76				
22 Locale Large City	0.12	0.32	-0.02	0.00	0.10	-0.12	0.10	0.09	0.01	0.01	-0.03	-0.06	0.08	0.11	0.23	0.20	0.03	-0.10	-0.05	0.03	0.07	-0.21	-0.48			
Parent-related																										
23 Parental Inv.	15.17	10.06	-0.03	0.02	0.04	-0.02	0.07	0.10	0.08	0.02	0.02	0.12	-0.26	0.30	0.00	-0.15	-0.11	0.03	0.04	0.10	-0.17	0.06	-0.16	0.16		
Percent of high achievers																										
24 Math (%)	0.31	0.46	0.08	0.05	-0.01	0.03	0.08	0.11	0.10	0.14	0.14	0.10	0.05	0.15	0.03	-0.10	-0.02	0.06	0.03	-0.04	-0.01	0.01	-0.04	0.04	0.09	
25 Science (%)	0.30	0.46	0.07	0.03	-0.06	0.09	0.08	0.12	0.06	0.09	0.13	0.08	0.03	0.13	0.01	-0.13	-0.02	0.01	-0.03	-0.04	-0.04	0.03	0.01	-0.06	0.05	0.73

Model and Procedure

We used a logistic hierarchical linear model (HLM) to predict the probability of high achievement in mathematics and science respectively. Logistic HLM is used because the dependent variable is binary and our data have a nested structure, meaning students are nested within schools. Using HLM accounts for the nested structure of PISA data (Raudenbush & Bryk, 2002). The model is illustrated by Equations 1 through 4.

Null Model: Student Level

$$Log\ (High\ Achiever)_{ij} = \beta_{0j} + \delta_{ij} \quad (1)$$

Null Model: School Level

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

No independent variables are included in the null model. The estimation results of a null model provide the baseline for a model with independent variables included. As this study focuses on how disciplinary climate and grit predict the probability of high achievement, we used Model 2 and Model 3 (see Tables 4 and 5) to estimate the likelihood without controlling potential confounding factors. Model 4 is the full model with the focus independent variables and control variables included. See Equations 3 and 4.

Full Model: Student Level

$$Log\ (High\ Achiever)_{ij} = \beta_{0j} + \beta_{ij} * X_{ij} + \delta_{ij} \quad (3)$$

X_{ij} denotes a set of vectors for all student-level variables with β_{ij} as the corresponding coefficients. β_{0j} and δ_{ij} are the student-level intercept and error term respectively.

Full Model: School Level

$$\beta_{0j} = \gamma_{00} + \gamma_{0j} * W_{0j} + \varepsilon_{0j} \quad (4)$$

At the school level, W_{0j} represents all school-level variables with γ_{0j} being coefficients. γ_{00} is the school-level intercept and ε_{0j} the error term.

We prepared data in *SAS 9.4* (recoded variables, imputed missing data, etc.). The imputation was estimated with *PROC MI*. Five sets of imputed data were generated. We conducted the HLM analysis in *Mplus 6.11*. Both student-level and school-level sampling weights were included in the HLM model.

Results

Percentage of Low-SES High Achievers

As shown in Table 3, the percentages of low-SES high achievers in mathematics and science are similar, 31% and 30%, respectively. To put it in a different way, approximately 30% of students whose family SES is in the lowest quartile (1,220 among the 4,978 PISA participating students) had above average achievement. Thus, the overall percentage of high achievers for the 4,978 American students who participated in 2012 PISA is 7.8% (31% divided by 4) for mathematics and 7.5% (30% divided by 4) for science. This percentage is different from the proportion of students that OECD (2011) labeled as "resilient." In the OECD report, due to a different definition, the average percentage of resilient students in the United States is about 10% (p. 88).: We defined low-SES high achievers as students whose achievement is within the top half of performers and whose SES falls in the bottom quartile, while OECD defined this group as students "who fall in both the bottom third of their country's socio-economic background distribution and the top third of their country's performance distribution on the PISA science/mathematics assessment scale" (OECD, 2011, p. 25). It is beyond the scope of this article to identify the difference across countries; however, our finding shows that the current American education system does enable a good percentage of low-SES 15-year-old students to perform well. To be cautious, we do not suggest that this group of students would continue their good performance throughout high school and college. Our data were collected at one point in time and do not indicate achievement growth over years. Some of these high achievers might maintain their favorable achievement, but others might do worse.

Grit and Disciplinary Climate

We further investigated if disciplinary climate and grit predict the likelihood of the low-SES students' high-achieving status. As shown in Model 2 and Model 3 (Tables 4 and 5), classroom disciplinary climate (CDC) and grit are both significantly related to whether a student falls into the category of being a high achiever. The limitation of Models 2 and 3 is that there are potential factors confounding the significance of both CDC and grit. Time spent on study, for instance, could be one of these confounding factors. Without their inclusion in the model, one may argue that we could attribute high achievement to how much time a student spent on each subject. To address this problem, we included a list of control variables which were identified as significant in our literature review and theoretical framework.

Table 4
Model Results, Math

	Model 1	Model 2	Model 3	Model 4
Level One				
Intercept	-0.78 (0.16)**	-0.96 (0.19)**	-1.00 (0.22)**	-1.94 (0.65)**
SES				0.39 (0.27)
Gender				0.20 (0.18)
Immigration				0.77 (0.32)*
Language				0.63 (0.37)
Time Math				0.12 (0.07)
Out Hours				0.01 (0.01)
Grit			0.47 (0.13)**	0.45 (0.16)**
CDC		0.28 (0.11)*		0.26 (0.11)*
Level Two				
CDC (mean)		0.05 (0.37)		0.00 (0.41)
School SES				1.76 (0.57)**
SDC		0.33 (0.18)		0.33 (0.22)
Selectivity				0.02 (0.37)
Shortage				-0.26 (0.16)
%Certified				0.63 (1.38)
%Certified Math				0.86 (0.37)*
Leadership				-0.24 (0.18)
Private				-1.23 (0.99)
Enrollment Size				0.04 (0.03)
Locale Small Town				0.40 (0.46)
Locale City				-0.09 (0.45)
Parental Involvement				0.00 (0.02)
ICC		0.19	0.26	0.16
Fit Statistics				
Log Likelihood	-760.14	-700.86	-684.41	-603.04
AIC	1522.27	1407.73	1378.83	1252.09
BIC	1527.38	1423.03	1404.12	1367.36

* $p \leq .05$, ** $p \leq .01$; $ICC = \tau / \left(\frac{\pi^2}{3} + \tau\right)$

As expected, CDC and grit remained significant in our final model (Model 4) for both math and science even after controlling for other variables. Because the coefficients in Tables 4 and 5 are in logarithmic and difficult to interpret, we transformed them into *odds ratio* presented as percentages in Table 6. On average, the *odds ratio* for students in the bottom quartile by SES to have high achievements status in math and science is 14.4% and 13.4% respectively. A one standard deviation increase in CDC leads to a 29.7% increase in the *odds ratio* for both subjects. A one standard deviation increase in grit is associated with a 56.8% increase of the *odds ratio* in math and 40.5% increase in science. To put it in a different way, the *odds ratio* for an average low-SES student to be a high achiever vs. not a high achiever is 14.4%. If this student is higher in grit by one standard deviation above the mean (0.13), the *odds ratio* would increase by 56.8%.

Table 5
Model Results, Science

	Model 1	Model 2	Model 3	Model 4
Level One				
Intercept	-0.78 (0.15)**	-0.89 (0.18)**	-0.91 (0.20)**	-2.01 (0.71)**
SES				0.42 (0.27)
Gender				0.13 (0.23)
Immigration				0.49 (0.34)
Language				0.70 (0.40)
Time Math				0.19 (0.09)*
Out Hours				-0.01 (0.02)
Grit			0.33 (0.14)**	0.34 (0.16)*
CDC		0.25 (0.12)*		0.26 (0.13)*
Level Two				
CDC (mean)		-0.02 (0.35)		0.00 (0.42)
School SES				1.50 (0.65)*
SDC		0.24 (0.19)		0.38 (0.22)
Selectivity				-0.35 (0.38)
Shortage				-0.41 (0.19)*
%Certified				1.49 (1.47)
Leadership				-0.28 (0.13)*
Private				-0.86 (1.09)
Enrollment Size				0.02 (0.03)
Locale Small Town				0.59 (0.64)
Locale City				0.58 (0.58)
Parental Involvement				-0.02 (0.02)
ICC		0.19	0.24	0.18
Fit Statistics				
Log Likelihood	-759.09	-714.00	-690.87	-608.80
AIC	1520.17	1434.01	1391.75	1261.60
BIC	1525.28	1449.33	1417.05	1371.87

* $p \leq .05$, ** $p \leq .01$; $ICC = \tau / \left(\frac{\pi^2}{3} + \tau\right)$

Interestingly, school disciplinary climate (SDC) is not related to high achievement by low-SES student. We do not suggest that SDC is less important than CDC, given that classrooms are embedded in schools. Without a positive school disciplinary environment, supporting CDC cannot be sustained. However, the findings suggest that we might set CDC as a priority when implementing school-wide policies.

Table 6
Predicted Odds Ratio of Being a High Achiever vs. not a High Achiever

	Math			Science		
	Odds Ratio	95% LCL	95% UCL	Odds Ratio	95% LCL	95% UCL
Intercept	14.4%	4.0%	51.4%	13.4%	3.3%	53.9%
SES	147.7%	250.7%	87.0%	152.2%	258.4%	89.7%
Gender	122.1%	173.8%	85.8%	113.9%	178.7%	72.6%
Immigration	216.0%	115.3%	404.4%	163.2%	317.8%	83.8%
Language	187.8%	387.8%	90.9%	201.4%	441.1%	91.9%
Time Science	112.7%	129.3%	98.3%	120.9%	101.4%	144.3%
Out Hours	101.0%	103.0%	99.0%	99.0%	103.0%	95.2%
Grit	156.8%	114.6%	214.6%	140.5%	102.7%	192.2%
Peer Climate	129.7%	104.5%	160.9%	129.7%	100.5%	167.3%
Peer Climate (mean)	100.0%	223.4%	44.8%	100.0%	227.8%	43.9%
School SES	581.2%	190.2%	1776.4%	448.2%	125.4%	1602.3%
Student Behavior	139.1%	214.1%	90.4%	146.2%	225.1%	95.0%
Selectivity	102.0%	210.7%	49.4%	70.5%	148.4%	33.5%
Shortage	77.1%	105.5%	56.3%	66.4%	45.7%	96.3%
%Certified	187.8%	2807.3%	12.6%	443.7%	7913.9%	24.9%
%Certified Math	236.3%	114.4%	488.0%	--	100.0%	100.0%
Leadership	78.7%	111.9%	55.3%	75.6%	58.6%	97.5%
Private	29.2%	203.5%	4.2%	42.3%	358.4%	5.0%
Enrollment Size	104.1%	110.4%	98.1%	102.0%	108.2%	96.2%
Locale Small Town	149.2%	367.5%	60.6%	180.4%	632.4%	51.5%
Locale City	91.4%	220.8%	37.8%	178.6%	556.7%	57.3%
Parental Involvement	100.0%	104.0%	96.2%	98.0%	101.9%	94.3%

* $p \leq .05$, ** $p \leq .01$; $Confidence\ Interval = exp\{\beta \pm 1.96 * SE(\beta)\}$.

Control Variables and High-achieving Status

Individual student-level SES is not associated with achievement status in our model because we selected a more homogeneous group of students based on their SES. Students with an immigration background are more likely to be high achievers in math. The average SES of a school is still a significant predictor of high achievement by a low-SES student. For a student whose school SES is higher than average (-1.04) by one, the *odds ratio* to have high achievement vs. low achievement is almost five times higher in math and more than three times higher in science. Although this effect is stronger than our focus variables, we are still optimistic that disciplinary climate and grit play a crucial role in low-SES student achievement given school SES and other factors controlled in our analysis.

Discussion

The SES-based achievement gap has been a challenging issue in U.S. education for many decades. Although the federal and some state governments enacted a number of relevant

initiatives such as the NCLB, the gap has remained and has in fact widened in the most recent few decades (Reardon, 2011). In scholarly debates, some researchers even argued that the SES-based achievement gap would not be closed without addressing rising income inequality and poverty first (Berliner, 2013). In this study, however, we identified a small proportion of students with relatively low-SES backgrounds who achieved outstanding performance in math and science, and this group's achievements were comparable to those whose SES was higher than average. CDC and grit were both associated with their high achievement, which offers some hope to reduce the achievement gap through resilience education and improving disciplinary climate in the classroom via interventions and collaborations among educators and families. Programs such as Positive Behavior Interventions and Supports could benefit students and teachers if implemented well (Bradshaw et al., 2008).

Our findings provide strong evidence from a large random sample representing the low-SES (bottom quartile) 15-year-old student population in the U.S. to supplement the existing limited number of case studies (e.g., Dobbie & Fryer, 2009; McGee, 2003) that suggested the achievement gap could be narrowed. According to these case studies and the EST framework (Bronfenbrenner, 1979, 1992), closing the achievement gap necessitates changes to many aspects of the ecological system our education system is rooted in, including principal leadership, teacher quality, parental involvement, school culture and climate, and students' own effort. Previous research describes the significant relationship between overall achievement and all these aspects/factors. Nevertheless, research has failed to provide explicit evidence to show they are related to the SES-based achievement gap. When school leadership, teacher quality, parental involvement, and school climate improve and lead to an increased average achievement for schools, the SES-based gap could still remain if low-SES students and high-SES students improve their achievement at the same pace (Huang & Sebastian, 2015). This present study found that, compared to similar low-SES peers, students who were higher in grit and in classrooms with better disciplinary climates were much more likely to be high achievers.

We do not suggest that CDC and grit are the only solution to the SES achievement gap, although this study provides evidence of the critical importance of these two factors. Taking the holistic view of the EST, we believe that practices designed to increase students' grit and CDC should be only one part of the effort to close the gap. In addition, education and schooling are shaped by local, national, and even global context. School districts in different states might have their own obstacles to overcome to address the achievement gap. Because our study is based on a national representative sample, we cannot offer insights into any particular school facing more urgent problems than disruptive CDC and students perceiving themselves to be lacking grit.

Before we conclude with implications for future research and policy, we acknowledge a few limitations of this study. First, the data we used were collected in one year and do not support a causal relationship. In this case we cannot argue that CDC and grit were causes of high achievement by low-SES students, though they are significantly associated. Second, also due to the lack of longitudinal data, we were not able to track whether the low-SES high achievers continued to excel in high school and college. Third, our measure of grit is only one component of the concept and cannot suggest how much the other component—passion for long-term goals—might affect achievement of low-SES students. Despite these limitations, our study aligns with existing research showing the significance of both CDC (Lee & Bryk, 1989; Ma & Willms,

2004; Shin, Lee, & Kim, 2009; van de Werfhorst, Bergstra, & Veenstra, 2012) and grit/perseverance (Duckworth et al., 2007; Farrington et al., 2012; Strayhorn, 2014), as a component, to overall student achievement. We moved the crucial role of these two factors to a different level by showing their relationship with low-SES student achievement.

Conclusion

Two implications are noteworthy both for future research and school practices or policy. In order for future research to investigate whether grit and CDC continue to be associated with low-SES student achievement in high school and college, longitudinal data following a cohort of students would be needed. The significance of tracing how low-SES students perform in schools over years falls under the broader issue of social mobility and education, because an increase in the percentage of these low-SES high achievers could be an indicator of how well schooling functions as a social ladder. Our estimation of this percentage at one point in time with the PISA U.S. student data joins the discussion of school effect on social mobility. Also, longitudinal data might help to understand how schools might influence student grit over time. Thus, we hope to see empirical studies with longitudinal data to evaluate how much the U.S. schooling system enables economically disadvantaged students to succeed in schools.

Finally, our findings suggest that schools with a large percentage of students from low-income communities should prioritize practices that promote a positive CDC and provide a supportive environment for their students to overcome obstacles to succeed. Among other things, the influence of school leaders (including both principals and teacher leaders) on learning climate is essential (Sebastian et al., 2012). While establishing a positive learning climate, schools might also consider collaborating with parents and communities to provide resilience education. We know from decades of research (Berliner, 2013; Coleman et al., 1966; Sirin, 2005; White, 1982) that a majority of low-SES students have been disadvantaged in schooling. The schools they attend have limited resources because of the neighborhoods in which they are located (Eamon, 2005); they tend to have less involved parents (Lee & Bowen, 2006); they might also have lower aspirations for higher education (Berzin, 2010; McCarron & Inkelas, 2006). Having grit or being resilient cannot solve all these problems, but without it low-SES students will stray further from the American Dream.

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Appendix A
Variable Description

Variables	Details
	Student Level
SES (*Reliability* = 0.70)	Socioeconomic and cultural status of a student. The SES was derived from a factor analysis of parents' highest occupational status, highest education by years, and home possessions (OECD, 2014, p. 352).
Gender	Gender dummy variable with '1' indicating a boy and '0' for a girl.
Immigration	Dummy variable with '1' for students with an immigration background and '0' for those without.
Language	Dummy variable: '1' indicates a student's language spoken at home is the same as the test language, '0' is otherwise.
Out Hours	Hours a student spends on homework after school.
Time Math	Hours in mathematics classes per week.
Time Science	Hours in science classes per week.
Grit (*Reliability* = 0.87)	Students' self-perception of grit. It was derived from five items asking students to rate how well a statement describes them. The items are: '1) When confronted with a problem, I give up easily; 2) I put off difficult problems; 3) I remain interested in the tasks that I start; 4) I continue working on tasks until everything is perfect; 5) When confronted with a problem, I do more than what is expected of me.' 1 = very much like me, 2 = mostly like me, 3 = somewhat like me, 4 = not much like me, 5 = not all like me. (OECD, 2012a, p. 25)
CDC (*Reliability* = 0.89)	Students' rating of how frequent these behaviors occur: '1) students don't listen to what the teacher says; 2) there is noise and disorder; 3) the teacher has to wait a long time for the students to quiet down; 4) students cannot work well; and 5) students don't start working for a long time after the lesson begins.' 1=every class, 2=most classes, 3=some classes, 4=never or hardly (OECD, 2012b, p. 21). A factor analysis was used to combine the items.
	School Level
CDC (mean)	School average peer climate.
School SES	School average of SES.
SDC (*Reliability* = 0.87)	Principal's rating of student behavior. This variable was derived by factor analysis of eight items asking principals the extent to which learning was hindered because of: '1) student truancy; 2) students skipping classes; 3) students arriving late for school; 4) students not attending compulsory school events; 5) students lacking respect for teachers; 6) disruption of classes by students; 7) student use of alcohol or illegal drugs; and 8) students intimidating or bullying other students' (OECD, 2014, p. 348).
Selectivity	Dummy variable: Principals' answer indicating whether admission of a student was based on students' previous 'academic performance and/or recommendation. 1 = selective: considered at least one of the two factors when admitting students; 0 = not selective: did not consider either of the two factors when admitting students' (OECD, 2014, p. 310).
Shortage (*Reliability* = 0.85)	Teacher shortage was derived by factor analysis of four items on principals agreement that instruction was hindered by shortage of '1) qualified science teachers; 2) qualified mathematics teachers; 3) test language teachers; and 4) teachers of other subjects' (OECD, 2014, p. 347).
% Certified Math	Percentage of math teachers who are certified to teach math.
% Certified	Percentage of teachers who hold a teaching certificate.
Leadership (*Reliability* = 0.80)	Instructional leadership was derived from a factor analysis of three items on whether principals '1) promoted teaching practices based on recent educational research; 2) praised teachers whose students were actively participating in learning, and 3) drew teachers' attention to the importance of pupils' development of critical social capacities' (OECD, 2014, p. 346).
Private	Dummy variable: '1' indicates a private school, '0' a public school.
Enrollment Size	Enrollment of the school/100.
Locale Small Town	Dummy variable: if a school's surrounding community has a population less than 15,000, '1' is assigned, otherwise a '0'.
Locale City	Dummy variable: if a school's surrounding community has a population between 15,000 and 1,000,000, '1' is assigned, otherwise a '0'.
Locale Large City	Dummy variable: if a school's surrounding community has a population over 1,000,000, '1' is assigned, otherwise a '0'.
Parental Involvement	Average percentage of parental participation in: 'discussing their child's 1) behavior with a teacher on their own initiative, 2) behavior on the initiative of one of their child's teachers, 3) progress with a teacher on their own initiative, 4) progress on the initiative of one of their child's teachers; volunteering in 5) physical activities, 6) extra-curricular activities, 7) the school library or media center, and 8) the school canteen; assisting 9) a teacher in the school and 10) in fundraising; 11) appearing as a guest speaker; 12) participating in local school government' (OECD, 2012c, p. 19).

* Note: OECD created all the variables used in this study.