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A CRITICAL EXAMINATION OF HOW U.S. SCHOOLS STRUCTURE INEQUALITIES IN SCIENCE LEARNING OPPORTUNITIES BASED ON INTERSECTIONAL STUDENT BACKGROUNDS

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ALISON S. P. WILSON

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A CRITICAL EXAMINATION OF HOW U.S. SCHOOLS STRUCTURE INEQUALITIES IN SCIENCE LEARNING OPPORTUNITIES BASED ON INTERSECTIONAL STUDENT BACKGROUNDS

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Dr. Angela Urick, Chair

Dr. Derek A. Houston

Dr. Kirsten T. Edwards

Dr. Timothy Ford

Dr. Stephanie Burge

DEDICATION

This dissertation is dedicated to Joe, who kept the ship afloat during this journey, and Eleanor, who brought me sunshine every day.

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ABSTRACT

For decades, U.S. education policy has focused on the persistent achievement gap based on race and class in public schools. Within this test-based accountability context, math and reading achievement have been prioritized, and students have experienced inequitable access to rigorous science learning opportunities. Some scholars have drawn on cultural reproduction theory to examine the relationship between student background and achievement without accounting for the role of U.S. schools in structuring differential access to learning opportunities. This study aims to fill a gap in the literature by employing a critical quantitative lens and intersectional framework to examine how school structures, norms, and instructional practices contribute to stratification and systematic inequality in schools based on student background, shifting the focus from the achievement gap to the opportunity gap in U.S. schools. Using nationally representative U.S. data from PISA 2015, this dissertation employs latent class analysis (LCA) with auxiliary variables to examine the relationship between intersectional student background profiles, student sense of belonging, and student learning opportunities in science for 15-year-olds. A structural equation model (SEM) is used to extend these findings by examining potential mediators of intersectional student background and science achievement – opportunity to learn (OTL), sense of belonging, and student perceptions of academic climate – to account for inequitable learning environments in schools. Multilevel structural equation modeling (SEM) is then used to analyze science learning opportunities and academic press as mediators of intersectional student background and scientific literacy outcomes, as well as the school norms and structures that contribute to these experiences and outcomes. The findings from these studies revealed systemic inequality highlighted by a wealth gap between intersectional background groups of similar affluence based on parent occupational status and education. Further, gender disparities in OTL, sense of belonging to school, perceptions of academic climate, and scientific

literacy outcomes consistently emerged across studies. Academic press was identified as an important mediator of student background and science achievement, and was a negative predictor of scientific literacy outcomes. Finally, while academic tracking predicted school mean academic press and OTL, school-level academic climate predicted school mean science achievement. However, there were significant differences in school-level academic climate between school contexts, pointing to a potential focal area to improve equity in schools. By identifying malleable school structures, norms, and instructional practices that shape students' educational experiences and subsequent outcomes, this study provides potential policy levers for addressing concerns about equity in science education, including gaps in science opportunity to learn, engagement, achievement, and postsecondary outcomes.

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EXECUTIVE SUMMARY

Statement of Scholarly Contribution

The purpose of this dissertation is to merge the literature on cultural reproduction (e.g. Bourdieu, 1977) and opportunity to learn (e.g. Schmidt et al. 2015) to explain systematic inequality in access to science learning opportunities, shifting the focus from the achievement gap to the opportunity gap in U.S. schools (Chambers, 2009; Darling-Hammond, 2013). This dissertation utilizes intersectionality (Crenshaw, 1989; Collins, 2015), a framework that has been more widely used in qualitative work but is emerging in quantitative studies (Schudde, 2018), to provide a more accurate account of how students experience compounded inequality through stratification in schools based on privileged group membership and forms of capital. Latent class analysis is used as an innovative approach to incorporating an intersectionality framework in quantitative research (Landale et al., 2017), and both structural equation modeling and multilevel structural equation modeling are used with nationally representative PISA 2015 data to help explain how U.S. schools structure inequality in science learning opportunities. By identifying malleable school structures, norms, and instructional practices that shape students' educational experiences and subsequent outcomes, this dissertation provides potential policy levers for addressing concerns about equity in science education, including gaps in science opportunity to learn, engagement, achievement, and postsecondary outcomes.

Literature Review

For decades, U.S. education policy has focused on the persistent achievement gap based on race and class in public schools (Boykin & Noguera, 2011; Reardon, 2011; Weiss, 2014). Some scholars have sought to explain disparate achievement outcomes by examining the effects of student background on educational attainment. Sociologists have drawn on cultural reproduction

theory (Bourdieu, 1977, 1984; Bourdieu and Passeron, 1990) to examine the effects of cultural capital on student outcomes, including test performance (Jæger, 2011), grades (DiMaggio, 1982; Gaddis, 2013), and educational attainment (Aschaffenburg & Maas, 1997; DiMaggio & Mohr, 1985; Kalmijn & Kraaykamp, 1996; Teachman, 1987), with some studies examining differential effects by race (Roscigno & Ainsworth-Darnell, 1999) and gender (Dumais, 2002). However, the mediating role of schools in the relationship between student background and educational outcomes has largely been overlooked in this body of literature (Wilson & Urick, in press). Because cultural reproduction theory highlights the complicity of schools in social and cultural reproduction (Bourdieu, 1977), the lack of critical examination of how schools structure inequality based on student background is a salient gap in the literature. In the U.S. in particular, it is important to understand the role of schools in perpetuating systemic inequality to combat the deficit narratives about students and families that have historically been employed to explain the "achievement gap" (Chambers, 2009; Nieto, 1998; Yosso, 2005). Understanding disparities in school structures and processes is central to acknowledging and addressing what Chambers (2009) has aptly referred to as the "receivement gap."

The problem of within-school inequality in the U.S. has been documented by Schmidt and colleagues, who have focused on the content exposure dimension of opportunity to learn (OTL) (Schmidt et al., 2015). While OTL has been defined and operationalized in different ways across scholarship and policies, it broadly refers to the learning conditions necessary for students to be successful in meeting expectations for academic performance (Dougherty, 1996; McDonnell, 1995). Not only is math content OTL related to math achievement (Schmidt et al., 2011a; Schmidt et al., 2013; Schmidt et al., 2001), but it also mediates the relationship between socioeconomic status and math achievement (Schmidt et al., 2015). While content coverage is foundational to

student OTL (see Schmidt et al., 2011a; Schmidt et al., 2011b; Schmidt & Maier, 2009), exposure to content alone does not account for other important factors that contribute to student learning (see Starratt, 2003). In particular, teachers play a key role in student OTL by utilizing pedagogical practices and subject area content knowledge that is responsive to student learning needs (Bryk et al., 2010; NRC, 2011; Porter, 2002). Therefore, the instructional dimension of OTL warrants more attention, particularly given students' differential experiences in classrooms and schools that correspond with their background characteristics.

Despite the importance of quality science education to the U.S. economy, public policy, and global competitiveness (NRC, 2012), math and reading instruction has been prioritized over science within the U.S. test-based accountability context, resulting in a narrower science curriculum and fewer opportunities for challenging and engaging instruction starting at a young age (Anderson, 2012; Berliner, 2011; Milner et al., 2012). Moreover, gender and other background disparities persist in access to rigorous elementary and secondary science learning opportunities (Hayes & Trexler, 2016; NRC, 2012; Penfield & Lee, 2010), science interest and aspirations (Riegle-Crumb et al., 2010), science achievement (Morgan et al., 2016), and participation in science higher education and career fields (Else-Quest et al., 2013; Wang & Degol, 2017). While U.S. within-school inequalities in math opportunity to learn have been well-established (Schmidt et al., 2015), inequitable opportunities for higher-level science instruction have not been adequately explored. Access to quality science instruction is complex given the content and pedagogical expertise required of teachers, including the integration of literacy (Pearson et al., 2010; Fang & Wei, 2010; Lee & Buxton, 2013) and math skills (Wang & Degol, 2017), underscoring the importance of understanding patterns of inequity across and within schools. More equitable access to inquiry-based science instruction in particular could help address gaps in

student achievement (Wilson et al., 2010; Thadani et al., 2010), engagement (McConney et al., 2014), and participation in science education and careers (Kanter & Konstantopoulos, 2010).

Analysis of OTL requires attention to the school structures, practices, and norms that contribute to differential learning experiences. Academic tracking is a key stratification mechanism in schools that has continued to shape U.S. students' inequitable access to rigorous and engaging instruction through the disproportionate enrollment of Black, Latinx, and low-SES students in lower tracks (Donaldson et al., 2017; Mickelson & Everett, 2008; Oakes, 1985, 2005; Watanabe, 2008; Werblow et al., 2013). Given that perceptions of students' academic abilities and expectations for performance are differentiated by track, Werblow et al. (2013) suggested that school academic climate reflects underlying beliefs that can help us better understand the relationship between tracking and student outcomes. Academic climate is a measure of a school's emphasis on high academic achievement, and the learning environment and morale created through supportive relationships and norms (Bryk et al., 2010; Sebastian & Allensworth, 2012; Urick & Bowers, 2011, 2014; Werblow et al., 2013). Student and principal perceptions of academic climate have been found to predict student achievement (Urick & Bowers, 2014), and it is through learning climate that principal leadership indirectly influences instructional quality and student achievement (Sebastian & Allensworth, 2012). The salience of school climate measures for analyzing the achievement gap is also reinforced by Berkowitz et al.'s (2017) synthesis of studies that pointed to school climate as mitigating the effects of student background on academic outcomes. Moreover, Reynolds et al. (2017) found that the psychological construct of school identification, or a students' connection to the school, mediated the relationship between a broad measure of school climate and student achievement, calling attention to students' affective outcomes within the learning environment (Trujillo & Tanner, 2014). Thus, school belonging

might be yet another important avenue for understanding students' differential school experiences and outcomes (Booker, 2006), and the complex relationship between student background and social inclusion in schools (Lareau & Horvat, 1999). Collectively, these findings illustrate the need to account for students' instructional experiences and affective responses – and how these are situated within school structures, policies, and practices – to better understand the relationship between student background and achievement.

Theoretical and Conceptual Framework

This dissertation employs a critical quantitative lens (Dixon-Román, 2017; Stage, 2007; Stage & Wells, 2014) to challenge the dominant analyses and interpretations of cultural reproduction theory that have reinforced the perceived value of narrow forms of student capital (Yosso, 2005) while overlooking the role of schools in structuring differential opportunities for students. According to Bourdieu's theory of cultural reproduction (1977), schools play an instrumental role in reproducing power relations in society by privileging forms of symbolic capital associated with the dominant culture. It is through inequitable school structures and practices that social hierarchies are converted into academic hierarchies under the guise of a merit-based system (Bourdieu, 1977).

Accordingly, this dissertation posits that students' differential access to opportunities for more rigorous and engaging science instruction are influenced by school structures (e.g. tracking) and norms (e.g. academic climate) that can help explain opportunity and outcome gaps. Moreover, this dissertation incorporates an intersectionality framework to more closely examine differential learning opportunities and sense of belonging associated with student background, recognizing that "intersecting systems of power catalyze social formations of complex social inequalities that are organized via unequal material realities and distinctive social experiences for people who live

within them" (Collins, 2015, p. 14). In contrast to studies that treat student background variables as discrete categories, an intersectionality framework acknowledges the compounded inequities that can occur at the intersections of marginalized group membership (Crenshaw, 1989; Collins, 2015).

Research Question

The three articles for this dissertation were framed around an overarching research question: *How is opportunity to learn (OTL) inquiry-based science distributed within schools, and what school features influence these patterns?*

Method

Data Sources

The analyses for this dissertation utilize the 2015 Program for International Student Assessment (PISA), an international assessment coordinated by OECD and conducted by NCES in the U.S. PISA 2015 was selected because of the focus on science, detailed questionnaires that capture multiple perspectives of the school and learning environment, nested data structure, and background measures central to analyzing OTL inequalities using the proposed theoretical framework. PISA's focus on real-world application is consistent with calls for STEM education initiatives focused on increasing STEM literacy for all students (NRC, 2011). Finally, the sampling approach and survey weighting yield data that is nationally representative of 15-year-olds attending U.S. schools (OECD, 2017). The sample for this dissertation included U.S. students (n=5,712), teachers (n=3,680), and schools (n=177).

Analytic Technique

The first article of this dissertation utilized latent class analysis (LCA) with auxiliary variables. LCA is a person-oriented (Bergman & Magnusson, 1997) type of finite mixture model

in which individual responses on a set of continuous or categorical indicator variables (Muthén & Muthén, 1998-2017) are grouped based on similarity into latent classes such that there is high homogeneity within each class and a high degree of separation between classes (Masyn, 2013). In addition to the identification and interpretation of latent classes, a structural equation modeling (SEM) framework allows for the inclusion of covariates to predict latent class membership, as well as distal outcome variables that are predicted by class membership (Asparouhov & Muthén, 2014; Nylund-Gibson et al., 2014).

LCA was used to identify intersectional student background groups based on indicators of race and ethnicity, social class, immigration background, language spoken at home, and measures of cultural capital associated with cultural reproduction theory. A regression auxiliary model combined with latent class regression was then used to determine if intersectional group membership moderated the relationship between a covariate, gender, and two distal outcomes: sense of belonging to school and opportunity to learn (OTL) inquiry-based science. Differences between intersectional background groups on the two distal outcomes were also examined.

In the second article, structural equation modeling (SEM) was utilized to extend the findings from the LCA study. Structural equation modeling (SEM) allows for the study of direct and indirect relationships between latent or observed variables of interest (Bollen, 1989; Bowen & Guo, 2012; Hox et al., 2018; Kaplan, 2009; Kline, 2011). In other words, a variable can serve as both a predictor and outcome in the same model. Incorporating latent variables through factor analysis enables the researcher to evaluate validity -- whether the indicators adequately measure the intended construct -- while helping to reduce bias due to measurement error (Schumacker & Lomax, 2016). This study used SEM with the intersectional student background groups identified in the previous study to examine how U.S. students' educational experiences in schools –

opportunity to learn (OTL) inquiry-based science, sense of belonging, and perceptions of academic climate – mediate the relationship between student background and science achievement.

The third article extended findings from the first two studies by utilizing multilevel structural equation modeling (SEM). Multilevel SEM accounts for the hierarchical nature of the data with students nested within schools (Asparouhov & Muthen, 2005) and allows for the study of direct and indirect relationships between latent or observed variables of interest (Hox et al., 2018). This study utilized multilevel SEM to examine the extent to which student-level access to inquiry-based science learning opportunities and academic press mediates the relationship between intersectional student background and scientific literacy outcomes, as well as the influence of school-level context, tracking, and academic climate variables on student learning opportunities, perceptions of academic press, and science outcomes.

Findings

The findings from the first article reinforced the use of LCA as a promising method for incorporating intersectionality frameworks in quantitative research designs. Six distinct intersectional background classes were identified and findings revealed evidence of a wealth gap between classes of similar affluency based on parent occupational status and education. In addition to this evidence of systemic inequality, significant gender disparities within classes were found for OTL and sense of belonging.

The direct and indirect findings from the second article provided important insight about school mediators that can help account for the gap in science outcomes in the U.S. In particular, student perceptions of an academic climate indicator, teacher interest in all students' learning, emerged as a mediator of gender and science achievement. Moreover, while OTL inquiry-based science, academic press, and order were significant mediators of both gender and intersectional

student background and scientific literacy outcomes, some of the findings operated in the opposite direction than anticipated, which warrants further examination. Finally, although intersectional student background and gender were both significant predictors of sense of belonging, sense of belonging was not significantly related to science achievement, a finding that can inform future studies on this important affective outcome.

Finally, findings from the third article identified potential policy levers for addressing educational inequities. After accounting for variance explained at the school level, OTL was not a significant mediator of the relationship between student intersectional background or gender and scientific literacy outcomes. However, academic press was a significant mediator at the student level, and was a significant negative predictor of science achievement. At the school level, while tracking was not a significant predictor of mean school science achievement, tracking was a predictor of mean school academic press and OTL inquiry-based science. There were significant differences in school academic climate based on school context, and school-level perceptions of academic climate were significant predictors of science achievement, findings that can inform education policy and practice.

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ARTICLE 1

"An Intersectional Examination of the Opportunity Gap in Science:

A Critical Quantitative Approach to Latent Class Analysis"

Co-authored with Angela Urick, The University of Oklahoma

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Abstract

This study employs a critical quantitative lens to challenge the dominant analyses and interpretations of cultural reproduction theory that have overlooked the role of schools in structuring differential opportunities for students. Using the U.S. sample from nationally representative PISA 2015 data, Latent Class Analysis was used to identify intersectional student background groups based on indicators of race and ethnicity, social class, immigration background, language spoken at home, and measures of cultural capital associated with cultural reproduction theory. A regression auxiliary model combined with latent class regression was then used to determine if intersectional group membership moderated the relationship between a covariate, gender, and two distal outcomes: sense of belonging to school and opportunity to learn (OTL) inquiry-based science. Differences between intersectional background groups on the two distal outcomes were also examined. The findings from this study reinforced the use of LCA as a promising method for incorporating intersectionality frameworks in quantitative research designs. Six distinct intersectional background classes were identified and findings revealed evidence of a wealth gap between classes of similar affluency based on parent occupational status and education. In addition to this evidence of systemic inequality, significant gender disparities within classes were found for OTL and sense of belonging.

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Introduction

Since the publication of *A Nation at Risk* in the 1980s, concerns about student achievement have prompted numerous policy efforts to raise standards and improve test scores through accountability. No Child Left Behind (NCLB), Race to the Top, and adoption of Common Core Standards across many states have reflected a belief that rigorous academic standards and aligned curriculum, coupled with strict accountability measures around high-stakes testing and teacher evaluation, will provide schools with the tools and incentives to raise student performance (Au, 2013; Mathis & Trujillo, 2016). Within this high-stakes testing context, scholars and policymakers have sought to address the persistent achievement gap between White students and Students of Color, as well as class-based disparities in achievement (Boykin & Noguera, 2011; Irizarry, 2011; Ladson-Billings, 2006; Reardon, 2011; Weiss, 2014).

Rather than promote equitable learning opportunities, as laws such as NCLB purport, in practice the policies intended to standardize curriculum can actually constrain teachers' ability to utilize their knowledge and skills in the classroom to engage in effective pedagogy that meets students' learning needs (Irizarry, 2011; Stritikus & English, 2009). Further, these policies can exacerbate the effects of academic tracking by focusing on students' standardized test performance, contributing to a narrowing of the curriculum, use of test prep materials, and emphasis on basic skills (Darling-Hammond et al., 2016; Hursh, 2007; Lipman, 2004). While the 2015 Every Student Succeeds Act (ESSA) has attempted to provide a more flexible and holistic approach to accountability to reverse some of these trends (Darling-Hammond et al., 2016), Mathis & Trujillo (2016) have noted that "at its core, ESSA is still a primarily test-based educational regime" (p. 6).

The assumption of a level playing field is a particularly problematic aspect of standardization as a reform strategy (Milner, 2013). Consequently, many scholars have argued that the focus on the achievement gap is misplaced, and that there is a need to shift attention from the achievement gap to the opportunity gap (Chambers, 2009) that explains why historically underserved students have not reached the levels of achievement of their privileged peers. Ladson-Billings' (2006) "education debt" analogy is a particularly powerful illustration of how the current problem of disparate academic outcomes reflects the cumulative effects of inequitable policies and practices. This calls attention to the long history of systematic inequality in U.S. education (see Anderson, 1988; Chambers, 2009; Cordasco, 1973; Kantor & Lowe, 2013; Ladson-Billings, 2006; Spring, 2001), and how these practices have been embedded in broader discriminatory policies and structural inequality (see Darling-Hammond, 2013; García & Weiss, 2017; Orfield & Lee, 2006; Rothstein, 2015; Rothstein & Wilder, 2005; Royce, 2019). In particular, resegregation of schools and income inequality are closely intertwined contributors to both in-school and out-of-school opportunity gaps (García & Weiss, 2017; Rothstein, 2015; Barnett & Lamy, 2013; Berliner et al., 2014; Darling-Hammond, 2013; Putnam, 2015; Royce, 2019; Weiss, 2014).

In schools, academic tracking remains a key mechanism for sorting students and providing curricular and instructional differentiation. Though students are ostensibly tracked into sequences of coursework on the basis of ability (Bottia et al., 2016; Lucas & Beresford, 2010), the disproportionate representation of low-SES students and Students of Color in lower tracks (Mickelson & Everett, 2008; Oakes, 1982; Watanabe, 2008; Werblow et al., 2013) contradicts this illusion of meritocracy (Darling-Hammond, 2004a). Students in lower tracks are exposed to less challenging curriculum and instruction geared towards test preparation (Auerbach, 2002; Irizarry, 2011; Oakes, 2005; Watanabe, 2008), illustrating that they bear the brunt of high-stakes testing

policies (Darling-Hammond, 2004a). Teachers are also tracked, such that less experienced teachers tend to be assigned to lower tracks (Kelly, 2004; Rubin & Noguera, 2004). Further, tracking is a means through which lower expectations are implicitly and explicitly communicated to students, which can translate to self-fulfilling prophecies (Brophy & Good, 1970) and student "push out" (Burciaga et al., 2009). In addition to inequitable access to rigorous learning opportunities as a result of tracking, the curriculum and pedagogical practices in schools tend to privilege White, affluent students' knowledge and experience. Thus, "the inability of educators to comprehend the social realities, cultural resources, and understandings of Black, Latino, Native American, and other nondominant groups is one of the main drivers of the opportunity gap in American education" (Carter, 2013, p. 147; see also Yosso, 2005). English language policies and programs have also constrained the learning opportunities of English learners (ELs) through a prioritization of English language acquisition over academic content, assignment to lower tracks (Callahan, 2005), and a shift from bilingual instruction to an exclusive focus on English language proficiency (Gándara & Rumberger, 2009).

Given these patterns of inequity in schools, the purpose of this study is to merge the literature on cultural reproduction (Bourdieu, 1977a, 1984; Bourdieu & Passeron, 1990) and opportunity to learn (OTL) (Schmidt et al., 2011a; Schmidt et al., 2013; Schmidt et al., 2001; Schmidt et al., 2015) to help explain disparate educational outcomes. According to Bourdieu (1977a), schools play an instrumental role in reproducing power relations in society by privileging forms of symbolic capital associated with the dominant culture. A critical quantitative lens (Dixon-Román, 2017; Stage, 2007; Stage & Wells, 2014) is employed to challenge models based on cultural reproduction theory that have overlooked the role of schools in structuring differential opportunities for students (Wilson & Urick, in press). This study utilizes intersectionality

(Crenshaw, 1989, 1991; Collins, 2015), a framework that has been more widely used in qualitative work but is emerging in quantitative studies (Schudde, 2018), to provide a more accurate account of how students experience compounded inequality in complex ways in the learning environment based on privileged group membership and forms of capital. Latent Class Analysis (LCA) is used as an innovative approach to incorporate an intersectionality framework in quantitative research (Landale et al., 2017) and more closely examine gaps in science learning opportunity and sense of belonging in U.S. schools (Chambers, 2009; Schmidt et al., 2015) using nationally representative PISA 2015 data.

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Literature Review

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Cultural Reproduction Theory

Bourdieu has used the analogy of a game to explain how schools reinforce and reproduce mechanisms of social stratification (Grenfell & James, 1998). The field of education is governed by both explicit and implicit rules and principles, which are played out in terms of symbolic capital (Bourdieu, 1977b; Grenfell & James, 1998). This symbolic capital, which socializes students to the rules and strategies of the game, is transmitted through a family's conversion of economic, social, and cultural capital (Bourdieu, 1977a,b; Grenfell and James 1998). Thus, students who possess forms of capital aligned with the dominant cultural and valued by society are awarded in schools, while students who do not are marginalized (Bourdieu, 1977a). This occurs through a curriculum comprised of "hierarchically arranged bodies of school knowledge" (Giroux, 1983) that requires familiarity with the dominant culture but fails to transmit the "instruments of appropriation" necessary for all students to be successful (Bourdieu, 1977a, p. 494). In this way, schools covertly help maintain power relations and social hierarchies by both privileging and withholding access to the dominant culture through stratification mechanisms and differential

opportunities (Bourdieu, 1977a). It is through these school structures and practices that social hierarchies are converted into academic hierarchies under the guise of a merit-based system (Bourdieu, 1977a).

Yosso's (2005) conceptualization of community cultural wealth has provided an important challenge to researchers who seek to use cultural reproduction theory to examine the relationship between student background and academic outcomes. While cultural reproduction theory has emphasized privileged forms of capital to explain the mechanisms behind social and cultural reproduction, research should be careful to acknowledge the valuable forms of capital possessed by diverse communities that go unacknowledged by schools and other social institutions (Yosso, 2005). Yosso's (2005) argument underscores that transforming inequitable school structures, norms, practices, and curricula involves challenging deeply rooted assumptions that place the onus on students to meet narrow institutional expectations rather than on schools to adopt a more inclusive approach to serving students and families. If cultural reproduction theory can provide insight into why persistent inequalities exist and extend into schools, Yosso's (2005) notion of community cultural wealth provides insight into how to acknowledge, resist, and challenge these mechanisms through asset-based approaches (see Ladson-Billings, 1995, 2014; Villegas & Lucas, 2002).

Although cultural reproduction theory clearly acknowledges the role of schools in providing inequitable learning experiences for students based on their background, many of the studies that have operationalized student capital have sought to examine its effects on student achievement without accounting for educational processes (Wilson & Urick, in press). Further, Yosso's critique underscores how interpretations of cultural reproduction theory can lead to marginalization in schools for students who do not conform to the dominant culture, pointing to

affective outcomes that deserve attention. The literature on opportunity to learn and student sense of belonging can help address these gaps and contribute to a more robust explanation of the school-mediated relationship between student background and academic outcomes.

Opportunity to Learn

A construct that has been used in research since the 1960s to help examine differences in students' educational experiences is opportunity to learn (OTL). Dating back to its use in the First International Mathematics Study (FIMS) in 1964 (Floden, 2002; McDonnell, 1995), OTL has been conceptualized in different ways in its evolution across research and policy (McDonnell, 1995). Around the same time that it was employed in FIMS to ensure that students had been exposed to the content covered in the assessment (Floden, 2002; McDonnell, 1995), Carroll (1963) conceptualized OTL as the time needed to learn relative to the time spent engaged in learning. These construct dimensions continued to be influential in subsequent iterations of International Association for the Evaluation of Educational Achievement (IEA) studies (McDonnell, 1995; McKnight, Crosswhite, Dossey, Kifer, Swafford, Travers, & Cooney, 1987; Robitaille & Garden, 1989; Schmidt, Cogan, Houang, & McKnight, 2011a; Schmidt & Maier, 2009; Schmidt & McKnight, 2012).

Perhaps due to the easily quantifiable nature of both time and content coverage, OTL has been used more extensively in quantitative studies. In particular, Schmidt and colleagues have generated a prolific body of quantitative work on OTL (Cogan, Schmidt, & Wiley, 2001; Houang & Schmidt, 2008; Schmidt, Burroughs, Zoido, & Houang, 2015; Schmidt, et al., 2011a; Schmidt, Cogan, & McKnight, 2011b; Schmidt, Houang, Cogan, Blomeke, Tatto, Hsieh, Santillan, Bankov, Han, Cedillo, Schwille, & Paine, 2008; Schmidt, Zoido, & Cogan, 2013), reflecting its origins as a content-covered variable for comparative purposes. In addition to arguing for the fundamental

importance of content in the measurement of OTL (Schmidt et al. 2011a), Schmidt and colleagues have demonstrated that OTL math content is not only related to math achievement (Schmidt et al., 2011a; Schmidt et al., 2013; Schmidt et al., 2001), but it also mediates the effects of SES on math achievement (Schmidt et al., 2015). Moreover, Schmidt et al. (2015) found that the U.S. exhibited high levels of within-school inequalities in math OTL compared to other countries.

While Schmidt and colleagues have been consistent in their operationalization of OTL as content coverage, other scholars have used a variety of additional OTL indicators, demonstrating a lack of agreement across the literature in what constitutes OTL. These expanded indicators have included, for example, variables related to classroom instruction (Kurz, Elliott, Lemons, Zigmond, Kloo, & Kettler, 2014; Smithson, Porter, & Blank, 1995), teacher characteristics (Aguirre-Muñoz & Boscardin, 2008; Goertz, 1994), and resources for learning (Boykin & Noguera, 2011; Elliot, 1998; Herman & Klein, 1996; Kimura-Walsh, Yamamura, Griffin, & Allen, 2009; Oakes, 1990). Findings across studies have supported the relationship between OTL and student achievement (Arehart, 1979; Boscardin, Aguirre-Muñoz, Chinen, Leon, & Shin, 2004; Boscardin, Aguirre-Munoz, Stoker, Kim, Kim, & Lee, 2005; Schmidt et al., 2011a; Schmidt et al., 2013; Schmidt et al., 2001; Wang, 1998; see Elliott & Bartlett, 2016), and the salient issue of differential access to OTL corresponding with student background (Abedi, Courtney, Leon, Kao, & Azzam, 2006; Abedi & Herman, 2010; Darity, Castellino, Tyson, Cobb, & McMillen, 2001; Heafner, 2015; Kim & Hocevar, 1998; Minor, 2015; Schmidt et al., 2015; Wang, 2010; Wang & Goldschmidt, 1999).

The issue of access to rigorous science instruction is particularly important in the U.S. given the achievement gap in science (Morgan et al., 2016), the high levels of within-school inequality in math OTL compared to other countries demonstrated in past research (Schmidt et al., 2015), and the country's unique history of systemic inequality and institutionalized racism

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(Darling-Hammond, 2013; Ladson-Billings, 2006; Rothstein, 2015; Rothstein & Wilder, 2005; Royce, 2019). Despite the importance of quality science education to the U.S. economy, public policy, and global competitiveness (NRC, 2012), math and reading instruction have been prioritized over science within the U.S. test-based accountability context, resulting in a narrower science curriculum and fewer opportunities for challenging and engaging instruction starting at a young age (Anderson, 2012; Berliner, 2011; Milner et al., 2012). Moreover, gender and other background disparities persist in access to rigorous elementary and secondary science learning opportunities (Hayes & Trexler, 2016; NRC, 2012; Penfield & Lee, 2010), science interest and aspirations (Riegle-Crumb et al., 2011), science achievement (Morgan et al., 2016), and participation in science higher education and career fields (Else-Quest et al., 2013; Wang & Degol, 2017). While U.S. within-school inequalities in math opportunity to learn have been well-established (Schmidt et al., 2015), inequitable opportunities for higher-level science instruction have not been adequately explored.

Access to quality science instruction is complex given the content and pedagogical expertise required of teachers, including the integration of literacy (Pearson et al., 2010; Fang & Wei, 2010; Lee & Buxton, 2013) and math skills (Wang & Degol, 2017), underscoring the importance of understanding patterns of inequity across and within schools. Disparities in access to higher-level science opportunities might reflect a trajectory of differential access to math and reading instruction (Morgan et al., 2016) that would be foundational to rigorous science instruction, illustrating the consequences of tracking for students' postsecondary outcomes (Giersch, 2016). Thus, more equitable access to inquiry-based science instruction could help address gaps in student achievement (Wilson et al., 2010; Thadani et al., 2010), engagement (McConney et al., 2014), and participation in science education and careers (Kanter &

Konstantopoulos, 2010). Further, students' differential experiences in classrooms and schools that correspond with their background characteristics would suggest that the instructional dimension of science OTL (Wang, 1998) warrants attention.

Students' Sense of Belonging

Given the social stratification within schools, and the marginalization of racially and culturally diverse students, it is important to examine the opportunity gap in schools as well as students' affective outcomes, such as sense of belonging (Trujillo & Tanner, 2014), that are related to student achievement (Reynolds et al., 2017; Walton & Cohen, 2007). Sense of belonging, or identification with school, differs by race and gender, and is often connected to prior achievement and a level of classroom participation (Voelkl, 1997). The racial and ethnic composition of a school helps to explain how students see themselves as belonging and performing. Minoritized students feel disengaged from the school when there is a large power differential (Goodenow, 1993), discrimination, and a lack of relationships with teachers (Faircloth & Hamm, 2005). Students emotionally and physically withdraw from school when they do not identify themselves as belonging or valuing its outcomes (Voelkl, 1997). Overall, if students, particularly Students of Color, see themselves as dissimilar to peers and teachers at the school, they will likely have low sense of belonging (Booker, 2007; Goodenow, 1993; Hemmings, 1996; Ogbu & Simons, 1998; Phelan, Davidson & Cao, 1991). "However, a school that is psychologically welcoming and supportive of all students, regardless of the ethnic composition of the student body and faculty, is likely to produce students who demonstrate higher levels of achievement" (Booker, 2007, p. 304).

With race as a factor, a sense of belonging promotes the link between motivation and success for students (Faircloth & Hamm, 2005). A pedagogy of belonging is important to combat the "us" versus "them" created by tracking and other differentials of power and experience (Beck

& Malley, 2003). Teachers who create a cooperative learning environment place value on student engagement and connect students to a larger community and purpose (Beck & Malley, 2003). A purposeful approach to engagement and inclusion encourages students to build stable social networks and interpersonal relationships which define their sense of belonging (Chiu, Chow, McBride & Mol, 2016; Willms, 2003). Just as sense of belonging improves overall well-being and academic outcomes, a welcoming, successful learning environment increases sense of belonging, a bi-directional relationship (Willms, 2003). Thus, students' feelings of belonging to a school, connections with peers, and an absence of awkwardness or loneliness, or overall disconnection, are indications of a surrounding academic program which engages and includes students.

Theoretical and Conceptual Framework

Critical Frameworks for Analyzing the Opportunity Gap

The omission of key school factors in the extant research on cultural capital and student achievement, along with Yosso's (2005) critique of the treatment of cultural capital in this literature, suggest that a critical quantitative lens (Dixon-Román, 2017; Stage, 2007; Stage & Wells, 2014) should be employed to address these shortcomings. Critical quantitative approaches challenge the positivist research paradigm that has traditionally been associated with quantitative research (Dixon-Román, 2017; Stage, 2007). For example, rather than attempting to appear objective, quantitative criticalists acknowledge that there is a relationship between the researcher, what is being studied, and how it is approached, and make explicit the theoretical lenses that have informed the design and execution of the analysis, as well as its interpretation (Dixon-Román, 2017). According to Stage (2007), the critical quantitative researcher has two tasks: 1) "use data to represent educational processes and outcomes on a large scale to reveal inequities and to identify social or institutional perpetuation of systematic inequities in such processes and outcomes," and

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2) "question the models, measures, and analytic practices of quantitative research in order to offer competing models, measures, and analytic practices that better describe experiences of those who have not been adequately represented" (p. 10). In developing the paradigm further, Stage & Wells (2014) added a third task: "to conduct culturally relevant research by studying institutions and people in context" (p. 3). This approach places emphasis on the development of research questions that seek to address issues of privilege, power, and injustice in society and its institutions (Stage, 2007), including the perpetuation of systematic inequities (Stage & Wells, 2014).

Intersectionality

Giroux (1983) has argued that Bourdieu's work "provides no theoretical opportunity to unravel how cultural domination and resistance are mediated through the complex interface of race, gender, and class" (p. 272). Given the systematic inequality experienced by students on the basis of race and ethnicity, social class, immigration background, and language (Berliner et al., 2014; Darling-Hammond, 2013; Flores, 2007; Orfield & Lee, 2006; Darling-Hammond, 2004a; Darling-Hammond, 2004b; Oakes, 1990; Gutiérrez, 2004; Stritikus & English, 2009; Barnett & Lamy, 2013; Berliner et al., 2014; Putnam, 2015; Royce, 2019; Weiss, 2014; García & Weiss, 2017; Rothstein, 2015; Mickelson & Everett, 2008; Oakes, 1982; Watanabe, 2008; Werblow et al., 2013; Blanchett, 2006; Carter, 2013), an examination of the opportunity gap should extend beyond cultural capital alone. While analysis of these individual categories of identity could provide insight into the opportunity gap, the field of intersectionality studies that has developed since the 1980s (Cho, Crenshaw, & McCall, 2013) has demonstrated "the need to account for multiple grounds of identity when considering how the social world is constructed" (Crenshaw, 1991, p. 1245).

The development of intersectionality as a field of study has been heavily influenced by the seminal work of Crenshaw (1989, 1991). In her critique of the single-axis framework underlying antidiscrimination law, feminist theory, and antiracist politics, Crenshaw (1989) "sets forth a problematic consequence of the tendency to treat race and gender as mutually exclusive categories of experience and analysis" (p. 139). The result is that "sex and race discrimination have come to be defined in terms of the experiences of those who are privileged but for their racial or sexual characteristics" (Crenshaw, 1989, p. 139), which sometimes places Black women's interests at odds with more privileged members of their race or sex. Crenshaw's (1989, 1991) analysis demonstrates how feminist and antiracist discourse has marginalized Black women by failing to account for their experiences at the intersection of race and gender. The field of intersectionality studies has expanded to include other axes, or systems, of power to examine social problems (Collins, 2015) without adherence to a "full-fledged grand theory or a standardized methodology" (Cho et al., 2013, p. 789). Despite ongoing debates and different approaches to applying intersectionality in research and praxis, Collins (2015) has identified a key point of agreement underlying this work: "the term intersectionality references the critical insight that race, class, gender, sexuality, ethnicity, nation, ability, and age operate not as unitary, mutually exclusive entities, but as reciprocally constructing phenomena that in turn shape complex social inequalities" (p. 2). Understanding how race and racism intersect with other forms of subordination has also been addressed as a tenet of Critical Race Theory (CRT) to analyze experiences of racial injustice in the U.S. (Yosso, 2005).

Intersectionality has been most widely applied and developed in qualitative work (Schudde, 2018), although there have been calls across disciplines to develop this line of inquiry in quantitative research (see Bauer, 2014; Bowleg & Bauer, 2016; Else-Quest & Hyde, 2016).

Schudde (2018) has demonstrated parallels to intersectionality in quantitative research that have sought to examine heterogeneous effects through the use of propensity score strata or interactions in regression models, noting that there are challenges and limitations to these approaches. Despite these challenges, incorporating intersectionality frameworks in quantitative research reflects a growing approach to studying issues of power, discrimination, and structural inequality in education (see Covarrubias, 2011; López et al., 2018) and society (Landale, Oropesa, & Noah, 2017).

Models that examine how schools structure access to opportunity to learn based on intersectional student backgrounds better represent the critique of society and social reproduction mechanisms reflected in cultural reproduction theory. The current body of research that omits the role of schools in cultural and social reproduction places the emphasis on privileged forms of cultural capital and therefore has the potential to reinforce their value and contribute to the same reproduction function it seeks to examine. Acknowledging the role of schools and identifying the school structures, norms, and practices that determine student access to OTL is an explicit effort to challenge this cycle of reproduction. Moreover, incorporating an intersectionality framework can provide a more careful examination of opportunity gaps that reflect systematic inequities in schools, as well as the affective outcomes of these experiences.

Thus, this study uses complex measures of student background (e.g. intersectional student background profiles) to examine OTL science inequities and differential sense of belonging, shifting the focus from the achievement gap to the opportunity gap and an important affective indicator relevant to student success. It also focuses on the instructional domain of OTL, which has received less attention in OTL research despite its salience in the tracking literature (Ansalone, 2009; Donaldson, 2017; Oakes, 2005; Watanabe, 2008). Because intersectionality frameworks

have been more widely used in qualitative studies, there is no clear consensus on the best approach to integrating intersectionality into quantitative research, although many scholars have favored regression approaches with interactions or propensity score strata to examine effect heterogeneity (Schudde, 2018). Building on the work of Landale et al. (2017), who used Latent Class Analysis (LCA) to examine the relationship between intersecting social statuses and perceived discrimination, this study proposes LCA as a more parsimonious way to identify complex, intersectional groups represented in the data and examine their differential experiences in schools.

Research Questions

1) What latent intersectional student background classes can be identified based on indicators of race/ethnicity, immigration background, language spoken at home, social class, and cultural capital?

2) To what extent does gender influence intersectional student background class membership?

3) To what extent does intersectional student background class membership moderate the relationship between gender and OTL inquiry-based science?

4) To what extent does intersectional student background class membership moderate the relationship between gender and sense of belonging to school?

5) Are there significant differences between intersectional student background classes on OTL inquiry-based science and sense of belonging to school?

Method

Data Sources

The current study is a secondary analysis of the 2015 Program for International Student Assessment (PISA), an international assessment coordinated by OECD and conducted by NCES in the U.S. (NCES, n.d.). PISA is administered every three years with assessments in all three core

subject areas, a rotating major domain of study, and optional cross-curricular competencies (OECD, 2017; NCES, n.d.). PISA focuses on 15-year-olds' reading, mathematics, and science literacy with an emphasis on real-life application (OECD, 2017; NCES, n.d.). In addition to the assessments, student and school questionnaires are administered in all participating countries, and some countries also implement optional parent and teacher questionnaires (OECD, 2017). PISA 2015 utilized a stratified systematic sample design with a two-stage sampling process (NCES, n.d.). Schools were sampled in the first stage, followed by students within sampled schools in the second stage (NCES, n.d.; OECD, 2017). To ensure representativeness of the sample, base weights were calculated for schools based on enrollment size and selection probability, and for students based on selection probability, and adjustments were made for school and student nonresponse (NCES, n.d.; OECD, 2017).

Although often used to study predictors of achievement and differences in performance across countries (e.g. Andersen & Jæger, 2015; Schmidt et al., 2013; Schmidt et al., 2015; Tsai, Smith, & Hauser, 2017), PISA surveys capture student background and school contextual information useful for examining disparities within countries (e.g. Marteleto & Andrade, 2013). For the current study, PISA 2015 was selected because of its focus on science as the major domain of study, detailed questionnaires that capture student perceptions of the school and learning environment, and background measures central to analyzing OTL inequalities using the proposed theoretical framework. PISA's focus on real-world application is also consistent with calls for STEM education initiatives focused on increasing STEM literacy for all students, which involves application in a wide variety of settings beyond STEM education and careers (NRC, 2011). Finally, the sampling approach and survey weighting yield data that is nationally representative of 15-year-

olds attending U.S. schools (OECD, 2017). The sample for this study includes U.S. students (n=5,712).

Measures and Instrumentation

      Latent class analysis indicators. Aligned with cultural reproduction theory and intersectionality frameworks, the LCA indicators selected to identify intersectional student background classes reflect characteristics that afford individuals differential power, privilege, and status in U.S. society (Bourdieu, 1977; Collins, 2015; Grenfell & James, 1998; Ladson-Billings, 2006). These include race/ethnicity, immigration background, language spoken at home, and indicators of cultural capital and social class. PISA derived item response theory (IRT) scales were standardized (OECD, 2017), so raw item responses were used to create composites that align with each PISA index that used IRT modeling (see Appendix A). Because the default LCA model is not scale free, using standardized indicator variables would lead to inaccurate results due to analyzing a correlation matrix rather than a covariance matrix (Muthén, 2007).

      Immigration background [IMMIG] is a PISA index calculated from students' responses about their country of birth and their parents' country of birth, with OECD categories indicating whether students are native, second-generation, or first-generation (OECD, 2017). To ensure an adequate sample size for each group, the PISA variable was recoded to *native* (0) and *first- or second-generation* (1).

      Language spoken at home [LANGN] is a PISA derived variable with OECD categories indicating whether students speak Spanish, English, or another language most of the time at home (OECD, 2017). To ensure a large enough sample size for each group, the PISA variable was recoded to *English* (0) and *language other than English* (1).

Three indicators of social class are included in the latent class model: parent education, parent occupational status, and family wealth. The PISA index of highest educational level of parents [HISCED], which was constructed by classifying students' responses about their parents' K-12 level of completion and post-secondary educational qualifications according to ISCED 1997 levels (OECD, 2017), was recoded as a dichotomous variable with *academic higher education* (0) and *vocational higher education or less* (1). Highest occupational status of parents [HISEI] is a PISA index created from students' open-ended responses to questions about their parents' job and job duties that were coded and aligned to the international socio-economic index of occupational status (ISEI). The raw items from PISA's family wealth index [WEALTH)], which was derived from IRT modeling (OECD, 2017), were recoded to reflect whether students had a *room of their own* and *link to the internet* (0 – no, 1 – yes), as well as how many *televisions*, *cars*, *bathrooms*, *computers*, *tablets*, and *ebooks* students had at home (0 – none, 1 – one, 2 – two, 3 – three or more), and then summed to create a composite wealth variable. These indicators of social class are aligned with past operationalizations (Chin & Phillips, 2004), with family wealth serving as a proxy for income (Marteleto & Andrade, 2013).

Four indicators of cultural capital are included in the model: parent emotional support, cultural possessions, home educational resources, and number of books in the home. The raw items used to measure parent emotional support [EMOSUPS], a PISA derived IRT scale based on students' perceptions of their parents' interest, support, and encouragement relevant to school endeavors, were averaged to create a composite variable. Because there was not enough variance in the mean composite, it was recoded as a dichotomous variable reflecting agreement with the items, or *perceived sense of parent emotional support* (0), and disagreement with the items, or *perceived lack of parent emotional support* (1). Raw items used to measure cultural possessions

[CULTPOSS], a PISA derived IRT scale based on students' responses to questions about a subset of home possessions, were recoded to reflect whether students had *classic literature*, *books of poetry*, *works of art*, and *books on art, music, or design* in the home (0 – no, 1 – yes), as well as how many musical instruments were in the home (0 – none, 1 – one, 2 – two, 3 – three or more). These recoded items were then summed to create a cultural possessions composite variable. The raw item responses used to create home educational resources [HEDRES], another derived IRT scale based on a subset of home possessions related to educational support, were recoded to indicate whether students had *a desk to study at*, *a quiet place to study*, *a computer to use for school work*, *educational software*, *books to help with school work*, *technical reference books*, and *a dictionary* (0 – no, 1 – yes), and these recoded items were summed to create a composite. The variable used to measure the number of books students reported to have in their home [ST013Q01TA] was recoded as 0-10 books (0), 11-25 books (1), 26-100 books (2), 101-200 books (3), 201-500 books (4), more than 500 books (5). Several of these indicators of cultural capital are consistent with past operationalizations (see Andersen & Jæger, 2015), including dominant "highbrow" interpretations (see Lareau & Weininger, 2003), such as exposure to literature (DiMaggio & Mohr, 1985) and music (DiMaggio, 1982), as well as reading habits (Gaddis, 2013; Ganzeboom, DeGraaf, & Robert, 1990; Jæger & Mollegaard, 2017; Jæger & Holm, 2007) and educational resources (Roscigno & Ainsworth-Darnell, 1999). However, consistent with Lareau and Weininger's (2003) argument in favor of a broader alternative conceptualization of cultural capital, [EMOSUPS] is also included as a proxy for parents' assertive engagement in schooling that conforms to institutionalized standards.

Distal outcomes. Sense of belonging to school [BELONG] is a derived IRT scale based on students' responses to several questions, such as whether they feel lonely or make friends easily

at school (OECD, 2017). The indicator of OTL – inquiry-based science teaching and learning practices [IBTEACH] – is also a derived IRT scale based on students' responses to how often they engage in higher-level learning activities in science lessons, such as conducting or designing experiments, or explaining or debating ideas (OECD, 2017). The selection of inquiry-based science teaching and learning practices as an indicator of OTL is consistent with literature that has incorporated the higher-level instructional domain (Urick et al., 2018), and is an appropriate predictor of scientific literacy outcomes because of its emphasis on active engagement (Minner et al., 2010). Construct validation was conducted by OECD (OECD, 2017) and reliability for both scales in the U.S. was high (BELONG, α = .86; IBTEACH, α = .89).

Table 1. Descriptives

Variables	N	Minimum	Maximum	Mean	SD
Gender	5712	0	1	0.50	-
White, not Hispanic	5643	0	1	0.45	-
Black or African American	5643	0	1	0.13	-
Hispanic or Latino	5643	0	1	0.30	-
Immigration background	5471	0	1	0.23	-
Home language	5653	0	1	0.19	-
Social Class					
Wealth	5085	0	20	12.99	3.18
Parent education	5601	0	1	.54	-
Parent occupational status	5232	12	89	54.13	21.62
Cultural Capital					
Parent emotional support	5533	0	1	.10	-
Cultural possessions	5378	0	7	3.34	2.09
Home educational resources	5310	0	7	5.48	1.61
Books in home	5625	0	5	1.81	1.42
Distal Outcomes					
Sense of belonging	5559	-3.13	2.61	-0.09	1.02
OTL inquiry-based science	5097	-3.34	3.18	0.34	1.04

Covariate. OECD categories for student gender [ST004D01T] were recoded to *male* (0) and *female* (1). Gender is included as a covariate in the LCA model because including it as a latent class indicator might lead to model identification problems (see Landale et al., 2017).

The final student weight [W_FSTUWT] was applied in each analysis for representativeness. See Appendix A for a full list of variables and questionnaire items. See Table 1 for descriptives.

Analytic Technique

Latent class analysis (LCA), a person-oriented approach to data analysis (Bergman & Magnusson, 1997), is a type of finite mixture model in which individual responses on a set of indicator variables (Muthén & Muthén, 1998-2017) are grouped based on similarity into latent classes such that there is high homogeneity within each class and a high degree of separation between classes (Masyn, 2013). It is based on the assumption that within a heterogeneous population, there are homogeneous groups (e.g. classes) that explain the relationship between observed categorical indicators (Masyn, 2013). LCA is similar to factor analysis, with the key difference being that the latent variable in LCA is categorical, consisting of latent classes (Collins & Lanza, 2010). Further, while factor analysis produces groups of similar items, latent class analysis assigns groups to similar respondents. Traditional LCA uses only categorical indicators to identify latent classes and Latent Profile Analysis (LPA) can be used with continuous indicators (Masyn, 2013). However, Mplus can accommodate both continuous and categorical indicators in one model (Muthén & Muthén, 1998-2017). In addition to the identification and interpretation of latent classes, a structural equation modeling (SEM) framework allows for the inclusion of covariates to predict latent class membership, as well as distal outcome variables that are predicted by class membership (Asparouhov & Muthén, 2014a; Masyn, 2013; Nylund-Gibson et al., 2014).
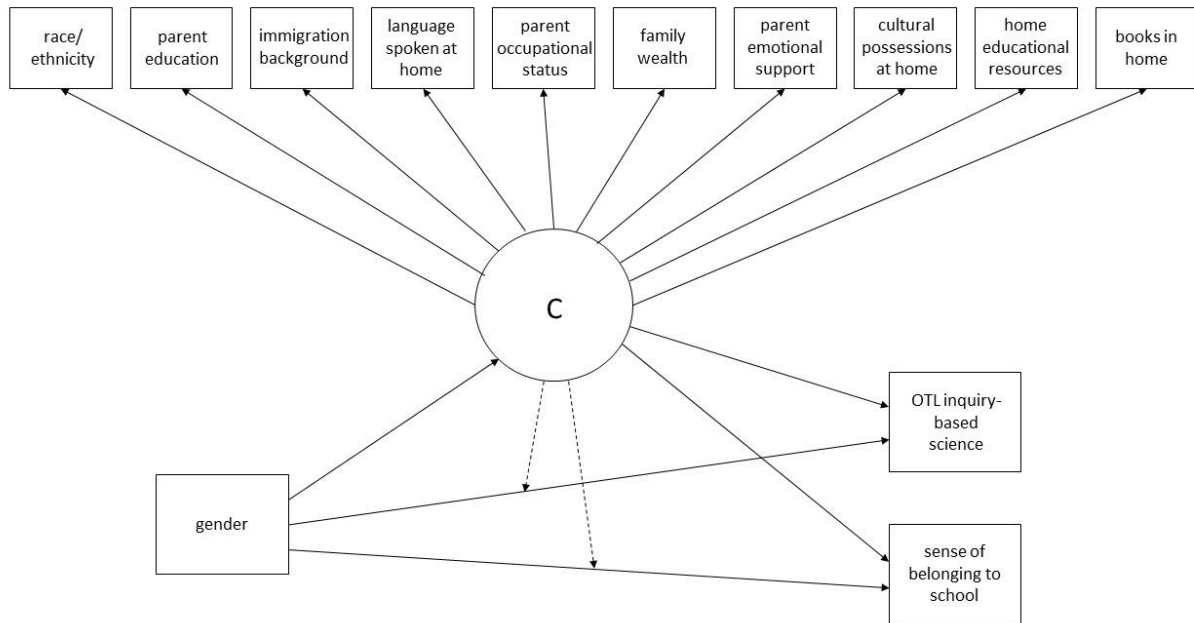
Figure 1. Regression Auxiliary Model with Latent Class Regression

For the current study, the BCH method was employed using Mplus7 to estimate a regression auxiliary model combined with latent class regression (Asparouhov & Muthén, 2014b) in which the covariate influences latent class membership, latent class membership influences the distal outcomes, and latent class membership moderates the relationship between the covariate and distal outcomes (see Figure 1). To reduce bias and avoid changes in the latent class measurement parameters from the use of auxiliary variables (e.g. covariates or distal outcomes), a three-step approach has been recommended, which consists of identifying the best-fitting LCA model using only latent class indicators (the unconditional model), creating a most likely class variable to assign individuals to classes, and then estimating a model with auxiliary variables that has fixed measurement parameters based on the unconditional model to account for measurement error associated with class assignment (Asparouhov & Muthén, 2014a; Lanza et al., 2013; Nylund-

Gibson et al., 2014). Like the three-step method, the BCH method accounts for measurement error through the use of weights, but it is been found to outperform the three-step approach for continuous distal outcomes and prevents the shift in classes that the three-step method does not entirely resolve (Asparouhov & Muthén, 2014b).

Table 2. Findings from Class Enumeration Process.

Model Specification	K[a]	LL[b]	AIC	BIC	aBIC	Adj. LMR-LRT p-value
Class-invariant, diagonal[d]	1	-89260.113	178554.227	178667.157	178613.136	-
	2	-85008.213	170076.426	170275.714	170180.383	0.0000
	3	-83216.705	166519.409	166805.056	166668.415	0.0000
	4	-82258.221	164628.441	165000.446	164822.495	0.0000
	5	-81557.175	163252.349	163710.713	163491.451	**0.0000**
	6	-81177.104	162518.208	163062.930	162802.358	0.7009
	7	-80828.093	161846.186	162477.266	162175.385	0.3997
	8	-80522.300	161260.599	161978.037	161634.845	0.4266
Class-varying, diagonal[e]	1	-89260.113	178554.227	178667.157	178613.136	-
	2	-84492.629	169055.258	169287.761	169176.542	0.0000
	3	-82346.582	164799.163	165151.239	164982.821	0.0000
Class-invariant, unrestricted[f]	1[c]	-86647.637	173349.274	173528.634	173442.836	-
	2	-83007.530	166095.060	166360.778	166233.670	0.0000
	3	-81645.661	163397.321	163749.397	163580.979	0.0000
	4	-81034.007	162200.014	162638.448	162428.720	0.0000
	5	-80495.042	161148.083	161672.876	161421.837	0.0000
	6	**-80091.054**	**160366.108**	**160977.259**	**160684.911**	**0.0000**
	7	-79853.214	159916.427	160613.936	160280.278	0.0000
Class-varying, unrestricted[g]	1	-86647.637	173349.274	173528.634	173442.836	-
	2	-82911.240	165932.481	166297.842	166123.069	0.0000
	3	-81389.718	162945.437	163496.801	163233.052	0.0000

Notes: [a]# of classes, [b]Maximum log likelihood function value, [c]Minimum goodness-of-fit benchmark model, [d]indicator covariances fixed at zero within class and equal variances across classes, [e]indicator covariances fixed at zero within class and variances allowed to differ across classes; [f]indicators free to covary within class; equal variances/covariances across classes; [g]indicators free to covary within class; different variances/covariances across classes

Prior to performing the BCH procedure, the unconditional model was first identified through a process of class enumeration and model fit comparison (Masyn, 2013). For each of four model specifications (see Table 2), models were run with K+1 classes until the models were no longer well-identified (see Masyn, 2013). Based on fit statistics and considerations of parsimony

and interpretability (Masyn, 2013), a model was selected from each of the four specifications for comparison (see boxes in Table 2). The 6-class model with a class-invariant, unrestricted specification was selected as the final model based on indicators of relative fit, including the approximate Bayes Factor and a lower BIC, as well as class interpretability (Masyn, 2013; see bold box in Table 2).

In the first step of the BCH procedure, group-specific BCH weights were computed during 6-class, class-invariant, unrestricted model estimation (Asparouhov & Muthén, 2014b). In the second step, the latent class variable was treated as an observed variable through the most likely class assignment for each observation, and the previously estimated BCH weights were applied to the full regression model that included auxiliary variables (Asparouhov & Muthén, 2014b). In this model, gender was included as a covariate to predict intersectional background class membership using multinomial logistic regression, OTL inquiry-based science and sense of belonging were included as distal outcomes to determine if the means of these outcome variables vary significantly across classes (Asparouhov & Muthén, 2014a; Masyn, 2013; Nylund-Gibson et al., 2014), and latent class membership was tested as a moderator of the linear regression of the distal outcomes on gender (Asparouhov & Muthén, 2013). (See Figure 1) To test whether there was a significant overall association between gender and student intersectional class membership, two models were fitted: Model 0, with class regressed on gender and the multinomial regression coefficient for gender fixed at 0, and Model 1, with class regressed on gender and multinomial regression coefficients freely estimated (see Masyn, 2013). A chi-square difference test was then conducted (Masyn, 2013) using the loglikelihood values. To test for significant differences in class intercepts for the distal outcomes (sense of belonging and OTL inquiry-based instruction), Wald statistics

were calculated for each class comparison controlling for the covariate (gender) (see Muthen, 2017).

<div align="center">

Results

</div>

Class Interpretation of the Unconditional LCA Model

One pattern that is clear across the classes is the high homogeneity in each class on race/ethnicity indicators (see Table 3, Figure 2). Based on these findings, two Hispanic or Latino classes emerged (Classes 1 and 4), two Black or African American classes emerged (Classes 2 and 3), and two White, not Hispanic classes emerged (Classes 5 and 6). However, there are important differences between classes of similar race/ethnicity that not only inform an intersectional interpretation of classes, but also point to important systemic inequalities. While Class 1 and Class 4 are estimated to be predominately Hispanic or Latino, Class 1 had a much lower proportion of parents with academic postsecondary education. Class 1 also had the lowest class-specific mean on parent occupational status compared to Class 4, which had a class mean higher than the overall sample mean on this indicator. As seen in Table 3, Class 1 was more homogeneous in terms of immigration background, with a higher estimated proportion of first- or second-generation immigrants, and Class 4 had a higher estimated proportion of students who indicated English as their language spoken at home.

There were also clear differences between Class 2 and Class 3, which both had an estimated majority of students who identified as Black or African American. While these two classes were very similar in terms of immigration background and home language, there was a high degree of separation between the classes on parent occupational status, with Class 2 having the second-lowest class-specific mean and Class 3 having the second-highest class-specific mean on this indicator. Class 2 was also much more homogeneous with regard to highest parent education, with

an estimated majority of parents with vocational higher education or less. Around 26% of students

in Class 2 were estimated to have a parent with academic postsecondary education compared to an

estimated 59% of students in Class 3 (see Table 3).

Table 3. Model-Estimated, Class-Specific Item Response Probabilities for Binary Indicators

Item	Item Response Probabilities					
	Class 1 (18.8%)- Less affluent Hispanic or Latinx	Class 2 (5.5%)- Less affluent Black or African American	Class 3 (7.7%)- More affluent Black or African American	Class 4 (18.5%)- More affluent Hispanic or Latinx	Class 5 (14.2%)- Less affluent White	Class 6 (35.2%)- More affluent White
White, not Hispanic	**0.02**	**0.00**	**0.00**	**0.02**	**0.85**	**0.92**
Black or African American	**0.00**	**1.00**	**1.00**	**0.00**	**0.00**	**0.00**
Hispanic or Latino	**0.90**	**0.00**	**0.00**	**0.74**	**0.00**	**0.00**
Immigration background (first or second generation)[a]	**0.72**	**0.13**	**0.13**	0.40	**0.03**	**0.02**
Home language (language other than English)[b]	0.65	**0.05**	**0.04**	**0.29**	**0.01**	**0.01**
Parent education (vocational higher education or less)[c]	**0.88**	**0.74**	0.41	0.52	**0.79**	**0.27**
Parent emotional support (disagree – no support)[d]	**0.13**	**0.09**	**0.08**	**0.11**	**0.14**	**0.07**

Notes: Bold items indicate a high degree of class homogeneity (item response probabilities >0.7 or <0.3)
Reference groups: [a]native, [b]English, [c]academic higher education, [d]agree - perceived sense of parent emotional support

Class 5 and Class 6, which both had an estimated majority of White students, were similar

in terms of immigration background and language spoken at home, with both groups estimated to

have predominately native-born students who spoke English at home. However, there was a high

degree of separation between these two groups on parent education, with a high estimated

proportion of students in Class 5 who had a parent with vocational higher education or less, and a

high proportion of students in Class 6 with a parent who had academic higher education. The two

classes were also well-separated on parent occupational status, with Class 6 exhibiting the highest

class-specific mean, and the mean for Class 5 falling below the overall sample mean.

These findings suggest that the classes can be interpreted as a more affluent group of Hispanic or Latinx students (Class 4) and a less affluent group of Hispanic or Latinx students (Class 1), a more affluent group of Black or African American students (Class 3) and a less affluent group of Black or African American students (Class 2), and a more affluent group of White students (Class 6) and less affluent group of White students (Class 5). This intersectional interpretation by race and class is reinforced by the separation between more and less affluent classes on key social class indicators. For example, the less affluent classes (Classes 1, 2, and 5) are consistently well-separated from the more affluent classes (Classes 3, 4, and 6) on highest parent occupational status. Each less affluent class is also well-separated from at least one more affluent class on the highest parent education indicator. Moreover, Classes 1 and 4 provide additional intersectional dimensions related to immigration background and language spoken at home that are distinct from the remaining classes.

Finally, the lack of separation between some classes provides important evidence of systemic inequality between race/ethnicity groups of similar social class backgrounds. While each of the less affluent classes share similar highest parent occupational status means (see Table 5, Figure 3), only Class 1 and Class 2 are well-separated from Class 6 on both wealth and number of books in the home. This means that despite similar occupational statuses, the distinction in wealth between the more affluent White group, with the highest class-specific mean for wealth and books in the home, and the less affluent White group is much lower than the difference in wealth between the affluent White group and less affluent Hispanic or Latinx and Black or African American groups. Moreover, despite the higher occupational status of the more affluent Hispanic or Latinx group (Class 4), which falls above the overall sample mean, the class-specific wealth mean falls slightly below the overall sample wealth mean. This demonstrates that higher occupational status

does not uniformly correspond with wealth advantages across race/ethnicity groups. Further, while all of the less affluent classes had class-specific means below the overall sample mean for each continuous LCA indicator (parent occupational status, wealth, cultural possessions, home educational resources, and books in the home), the more affluent White group was the only more affluent class to consistently exhibit class-specific means above the overall sample mean on all continuous indicators. The more affluent White class was also the only more affluent class that was homogeneous in parent academic higher education. Collectively, these findings highlight an important wealth disparity, as well as differences in parent educational attainment, between race/ethnicity groups of similar social class backgrounds. Thus, while results from the class interpretation process inform future analyses of the relationships between latent class membership and auxiliary variables (Masyn, 2013), they also provide important insight into the potential of LCA as a quantitative approach to incorporating intersectionality. A closer examination of class homogeneity and separation provides more detailed information about similarities within and differences between the groups that facilitated this interpretation.

Homogeneity

Examination of the response probabilities for the binary LCA indicators provides important evidence of class homogeneity (see Table 3 and Figure 2; Masyn, 2013). Class 1 (less affluent Hispanic or Latinx), to which approximately 18.8% of the students in the sample belonged, was characterized by high homogeneity with respect to race/ethnicity, immigration background, parent education, and parent emotional support. In this class, an estimated 90% of students would endorse the *Hispanic or Latino* race/ethnicity category, 72% would endorse the *first- or second-generation* immigration background category, and 88% of students in this category would endorse the *vocational higher education or less* category for highest parent education. Students in this class

had a low probability of endorsement of the *no parent emotional support* category (.13); in other words, the majority of respondents in this group (87%) would endorse agreement with receiving parent emotional support.

Class 2 (less affluent Black or African American) was the smallest class with an estimated proportion of 5.5%. Class 2 was characterized by high homogeneity with respect to all of the binary background indicators. In this class, an estimated 100% of students would endorse the *Black or African American* race/ethnicity category and 74% would endorse the *vocational higher education or less* highest parent education category. Students in this class had low probability of endorsement of the *first- or second-generation immigration background* category (.13), *language other than English* home language category (.05), and the *no parent emotional support* category (.09). This means that an estimated 87% of students in this category would endorse the *native* immigration background category, 95% would endorse the *English* home language category, and 91% would endorse agreement with receiving parent emotional support.

Class 3 (more affluent Black or African American) was also a relatively small class, with approximately 7.7% of students belonging to that group. Students in Class 3 exhibited high homogeneity with respect to race/ethnicity, immigration background, language spoken at home, and parent emotional support. An estimated 100% of students would endorse the *Black or African American* race/ethnicity category. Students in Class 3 had a low probability of endorsement of the *first- or second-generation immigration background* category (.13), *language other than English* home language category (.04), and the *no parent emotional support* category (.08). Similar to Class 2, this means that an estimated majority of students in Class 3 would endorse the *native* immigration background category (87%), the *English* home language category (96%), and would endorse agreement with receiving parent emotional support (92%).
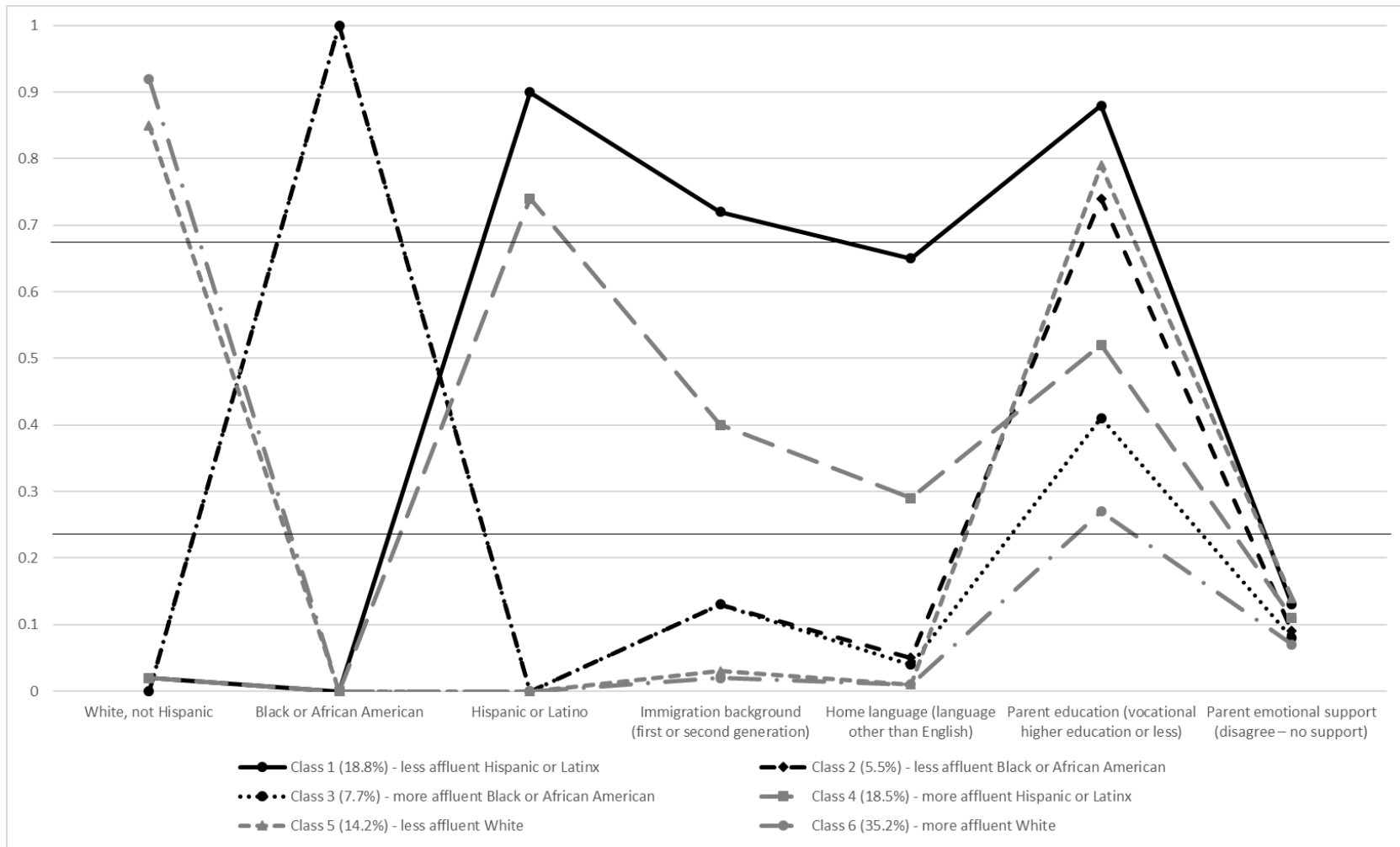
Figure 2. Model-Estimated, Class-Specific Item Response Probability Plot for Binary Indicators

Class 4 (more affluent Hispanic or Latinx) had an estimated proportion of 18.5%. Class 4 demonstrated high homogeneity on race/ethnicity, home language, and parent emotional support indicators. An estimated 74% of students in this class would endorse the *Hispanic or Latino* race/ethnicity category. Students in this class had a low probability of endorsement of the *language other than English spoken at home* category (.29), as well as the *no parent emotional support* category (.11). In other words, an estimated 71% of students in Class 4 would endorse the *English* home language category and an estimated 89% would endorse agreement with receiving parent emotional support.

Approximately 14.2% of students belonged to Class 5 (less affluent White). Students in Class 5 exhibited high homogeneity with respect to all student background binary indicators. In this class, an estimated 85% of students would endorse the *White, not Hispanic* race/ethnicity category and 79% would endorse the *vocational higher education or less* parent education category. This class also reflected a low probability of endorsement of the *first- or second-generation* immigration background category (.03), *language other than English* home language category (.01), and the *no parent emotional support* category (.14). This means that an estimated majority of students in Class 5 would endorse the *native* immigration background category (97%), the *English* home language category (99%), and would endorse agreement with receiving parent emotional support (86%).

Finally, Class 6 (more affluent White) was the largest class with an estimated proportion of 35.2%. Class 6 was also characterized by high homogeneity with respect to all student background binary indicators. In this class, an estimated 92% of students would endorse the *White, not Hispanic* race/ethnicity category. Students in this class exhibited a low probability of endorsement of the *first- or second-generation* immigration background category (.02), *language*

other than English home language category (.01), vocational higher education or less parent education category (.27), and the *no parent emotional support* category (.07). In other words, an estimated 98% of students in this class would endorse the *native* immigration background category, 99% would endorse the *English* home language category, 73% would endorse the *academic higher education* parent education category, and 93% would endorse agreement with receiving parent emotional support.

While the specification of the best-fitting unconditional model, which involved allowing continuous indicators to covary within class but constraining variances and covariances to be equal across classes (see Table 2; Masyn, 2013), did not allow for meaningful evaluations of class homogeneity for continuous indicators, the class-specific means provide descriptive information that can aid in class interpretation. For Class 1, Class 2, and Class 5, the class-specific means fell below the overall sample mean for all of the continuous student background indicators: highest parent occupational status, family wealth, cultural possessions, home educational resources, and number of books in the home (see Table 1 and Table 5). Compared to the overall sample mean, Class 3 (more affluent Black or African American) had a higher class-specific mean on indicators of parent occupational status, wealth, and home educational resources, but a lower class-specific mean on cultural possessions and number of books in the home. In comparison to the overall sample mean, Class 4 (more affluent Hispanic or Latinx) had a higher class-specific mean on indicators of parent occupational status, cultural possessions, and home educational resources, but a lower class-specific mean on wealth and number of books in the home. Finally, Class 6 (more affluent White) had a higher class-specific mean on all continuous indicators compared to the overall sample mean.

Separation

While homogeneity provides an initial understanding of the similarity within each class to help generate a description of their profiles, separation helps us to gain insight about each class through a comparison of characteristics across groups. In addition to the visual representation of class separation that can be seen in Figure 2, the model-estimated item endorsement odds ratios for binary indicators in Table 4 provide further evidence of class separation (Masyn, 2013). Notably, none of the classes were well-separated on the parent emotional support indicator, suggesting similar agreement in perceived parent emotional support across all classes. However, these classes did have separation based on immigration background, home language, and parent education.

Based on odds ratios, Class 1 (less affluent Hispanic or Latinx) would be considered well-separated from Class 2, Class 3, Class 5, and Class 6 on both immigration background and home language binary indicators. This result means that the less affluent Hispanic or Latinx class is only similar to the more affluent Hispanic or Latinx group on immigration background and home language. Class 1 was also well-separated from Class 3, Class 4, and Class 6 on highest parent education, each of the more affluent classes.

Class 2 (less affluent Black or African American) was well-separated from Class 5 and Class 6 (more and less affluent White) on immigration background, and would also be considered well-separated from Class 4, Class 5, and Class 6 (more affluent Hispanic or Latinx, and less and more affluent White) on home language based on the model-estimated item endorsement odds ratios. In addition, Class 2 was well-separated from Class 6 (more affluent White) on parent education. These separation results demonstrate a difference between the less affluent Black or African American group and both White classes, regardless of affluency, on immigration

background and home language. Further, the less affluent Black or African American class compared to the more affluent White class had a greater number of parents with vocational or less education versus academic postsecondary education.

Table 4. Model-Estimated Item Endorsement Odds Ratios for Binary Indicators

	Odds Ratios			
	Immigration background (first or second generation)[a]	Home language (language other than English)[b]	Parent education (vocational higher education or less)[c]	Parent emotional support (disagree – no support)[d]
Class 1 (less affluent Hispanic or Latinx) vs. Class 2 (less affluent Black or African American)	**17.03**	**36.51**	2.54	1.56
Class 1 (less affluent Hispanic or Latinx) vs. Class 3 (more affluent Black or African American)	**17.66**	**42.21**	**10.17**	1.82
Class 1 (less affluent Hispanic or Latinx) vs. Class 4 (more affluent Hispanic or Latinx)	3.82	4.64	**6.57**	1.19
Class 1 (less affluent Hispanic or Latinx) vs. Class 5 (less affluent White)	**95.09**	**189.82**	1.85	0.94
Class 1 (less affluent Hispanic or Latinx) vs. Class 6 (more affluent White)	**148.86**	**308.93**	**19.06**	2.02
Class 2 (less affluent Black or African American) vs. Class 3 (more affluent Black or African American)	1.04	1.16	4.01	1.16
Class 2 (less affluent Black or African American) vs. Class 4 (more affluent Hispanic or Latinx)	0.22	**0.13**	2.59	0.76
Class 2 (less affluent Black or African American) vs. Class 5 (less affluent White)	**5.59**	**5.20**	0.73	0.60
Class 2 (less affluent Black or African American) vs. Class 6 (more affluent White)	**8.74**	**8.46**	**7.51**	1.29
Class 3 (more affluent Black or African American) vs. Class 4 (more affluent Hispanic or Latinx)	0.22	**0.11**	0.65	0.65
Class 3 (more affluent Black or African American) vs. Class 5 (less affluent White)	**5.39**	4.50	**0.18**	0.52
Class 3 (more affluent Black or African American) vs. Class 6 (more affluent White)	**8.43**	**7.32**	1.87	1.11
Class 4 (more affluent Hispanic or Latinx) vs. Class 5 (less affluent White)	**24.91**	**40.91**	0.28	0.79
Class 4 (more affluent Hispanic or Latinx) vs. Class 6 (more affluent White)	**38.99**	**66.58**	2.90	1.70
Class 5 (less affluent White) vs. Class 6 (more affluent White)	1.57	1.63	**10.29**	2.15

Notes: Bold items indicate a high degree of separation between classes (odds ratio >5 or <0.2)
Reference groups: [a]native, [b]English, [c]academic higher education, [d]agree - perceived sense of parent emotional support

Some gaps between both White classes, regardless of affluency, repeated when compared with the more affluent Black group. Based on the odds ratios, Class 3 (more affluent Black or African American) was well-separated from Class 5 and Class 6 (more and less affluent White) on immigration background. Class 3 would also be considered well-separated from Class 4 (more affluent Hispanic or Latinx) and Class 6 (more affluent White) on home language. The more affluent Hispanic or Latinx class was more likely to endorse speaking a language other than English, and the more affluent White class was less likely to endorse speaking another language at home, compared to this more affluent Black group. However, there was a high degree of separation between Class 3 and Class 5 (less affluent White) on highest parent education. The more affluent Black or African American group had a higher number of parents with academic postsecondary education compared to the less affluent White class.

Table 5. Model-Estimated, Class-Specific Means for Continuous Indicators

	Mean				
	Parent occupational status	Wealth	Cultural possessions	Home educational resources	Books in home
Class 1 (18.8%) (less affluent Hispanic or Latinx)	26.34	11.27	2.58	4.82	0.94
Class 2 (5.5%) (less affluent Black or African American)	29.36	11.33	2.35	5.02	1.18
Class 3 (7.7%) (more affluent Black or African American)	67.32	13.08	3.00	5.79	1.47
Class 4 (18.5%) (more affluent Hispanic or Latinx)	66.92	12.95	3.54	5.65	1.68
Class 5 (14.2%) (less affluent White)	33.39	12.41	2.93	5.08	1.73
Class 6 (35.2%) (more affluent White)	69.94	14.27	3.99	5.89	2.55

Class 4 (more affluent Hispanic or Latinx) would be considered well-separated from Class 5 and Class 6 (less and more affluent White) on both immigration background and home language indicators. The odds ratios also indicated a high degree of separation between Class 5 and Class 6

on parent education. The more affluent Hispanic or Latinx class had a greater number of parents with academic postsecondary education compared to the less affluent White group; however, a greater number of parents in the more affluent White group had academic postsecondary education compared to the more affluent Hispanic or Latinx class.

For continuous LCA indicators, class separation is depicted visually in Figure 3 and can also be assessed through the estimated standardized differences in class-specific means found in Table 6. As can be seen in Figure 3, there was a low degree of separation between the classes on indicators of cultural possessions and home educational resources. Conversely, among the continuous indicators, the highest degree of separation between classes was on the parent occupational status indicator. Class 1 (less affluent Hispanic or Latinx) was well-separated from Class 3, Class 4, and Class 6 (more affluent Black or African American, Hispanic or Latinx, and White) on highest parent occupational status. There was a high degree of separation between Class 2 (less affluent Black or African American) and Class 3, Class 4, and Class 6 (more affluent Black or African American, Hispanic or Latinx, and White) on parent occupational status. Class 3, Class 4, and Class 6 (each more affluent group) were each well-separated from Class 5 (less affluent White) on the parent occupational status indicator.

Overall, separation between classes on parent occupational status demonstrated consistent gaps between the more and less affluent groups. Further, based on the standardized mean differences, there was also a moderate degree of separation between some classes on continuous indicators of wealth and number of books in the home (see Table 6). Class 1 (less affluent Hispanic or Latinx) and Class 2 (less affluent Black or African American) were both moderately well-separated from Class 6 (more affluent White) on wealth and number of books in the home. This finding is interesting since there was not significant separation across less and more affluent
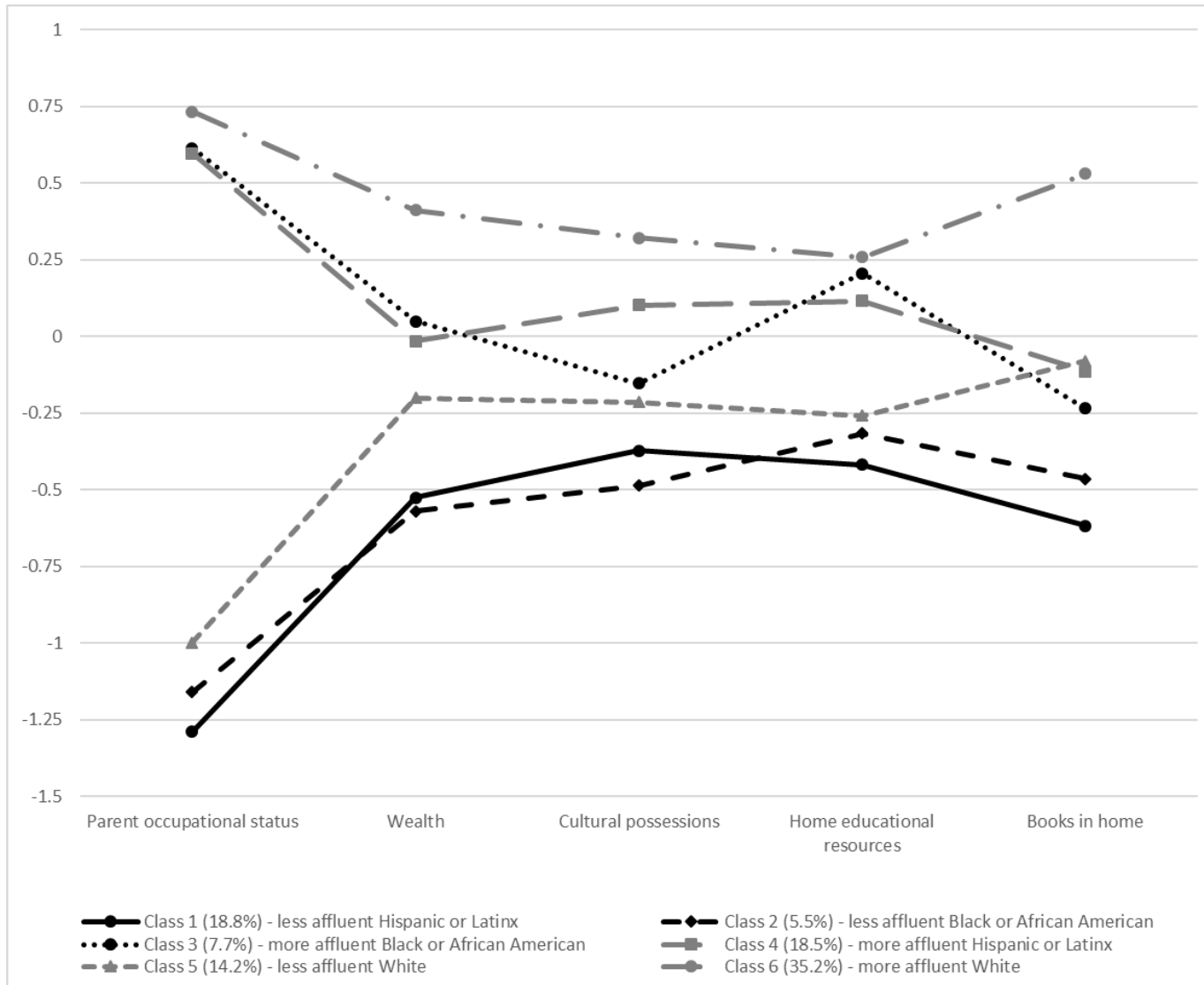
Figure 3. Standardized Class Means Plot for Continuous Indicators

Table 6. Estimated Standardized Differences in Class-Specific Means for Continuous Indicators

	Standardized Mean Differences				
	Parent occupational status	Wealth	Cultural possessions	Home educational resources	Books in home
Class 1 (less affluent Hispanic or Latinx) vs. Class 2 (less affluent Black or African American)	-0.30	-0.02	0.12	-0.13	-0.19
Class 1 (less affluent Hispanic or Latinx) vs. Class 3 (more affluent Black or African American)	**-4.05**	-0.61	-0.21	-0.63	-0.41
Class 1 (less affluent Hispanic or Latinx) vs. Class 4 (more affluent Hispanic or Latinx)	**-4.01**	-0.57	-0.48	-0.53	-0.58
Class 1 (less affluent Hispanic or Latinx) vs. Class 5 (less affluent White)	-0.70	-0.38	-0.18	-0.17	-0.61
Class 1 (less affluent Hispanic or Latinx) vs. Class 6 (more affluent White)	**-4.31**	*-1.01*	-0.71	-0.69	*-1.25*
Class 2 (less affluent Black or African American) vs. Class 3 (more affluent Black or African American)	**-3.75**	-0.59	-0.33	-0.50	-0.23
Class 2 (less affluent Black or African American) vs. Class 4 (more affluent Hispanic or Latinx)	**-3.71**	-0.55	-0.60	-0.41	-0.39
Class 2 (less affluent Black or African American) vs. Class 5 (less affluent White)	-0.40	-0.36	-0.29	-0.04	-0.43
Class 2 (less affluent Black or African American) vs. Class 6 (more affluent White)	**-4.01**	*-0.99*	-0.82	-0.56	*-1.07*
Class 3 (more affluent Black or African American) vs. Class 4 (more affluent Hispanic or Latinx)	0.04	0.04	-0.27	0.09	-0.16
Class 3 (more affluent Black or African American) vs. Class 5 (less affluent White)	**3.35**	0.23	0.04	0.46	-0.20
Class 3 (more affluent Black or African American) vs. Class 6 (more affluent White)	-0.26	-0.40	-0.50	-0.06	-0.84
Class 4 (more affluent Hispanic or Latinx) vs. Class 5 (less affluent White)	**3.32**	0.18	0.31	0.37	-0.04
Class 4 (more affluent Hispanic or Latinx) vs. Class 6 (more affluent White)	-0.30	-0.44	-0.23	-0.15	-0.68
Class 5 (less affluent White) vs. Class 6 (more affluent White)	**-3.61**	-0.63	-0.53	-0.52	-0.64

Note: Bold values indicate a high degree of separation > |2|; italicized values indicate a moderate degree of separation > |.85| and < |2| (see Masyn, 2013)

classes of the same race and ethnicity (Hispanic or Latinx and Black or African American) in wealth and number of books in home; instead, the gap existed between the more affluent White class and less affluent Hispanic or Latinx and Black or African American classes.

Regression Auxiliary Model with Latent Class Regression

The class-specific regression of the two distal outcomes, sense of belonging and OTL inquiry-based science, on gender can be seen in Table 7. It is important to note that in a preliminary test, there was not a significant overall association between student gender and intersectional background class membership (Model 0 vs. Model 1: $X^2_{diff} = 6.69$, $df = 5$, $p > .05$). However, when testing the relationship between gender and distal outcomes, with class membership as a moderator, gender emerged as a significant predictor of both sense of belonging and OTL inquiry-based science for several classes. Females reported significantly less agreement with sense of belonging to school items compared to males in the less affluent Hispanic or Latinx class (β = -0.129, $p \leq .05$), less affluent Black or African American class (β = -0.345, $p \leq .05$), more affluent Black or African American class (β = -0.328, $p \leq .01$), less affluent White class (β = -0.271, $p \leq .001$), and more affluent White class (β = -0.164, $p \leq .01$). Compared to males, females also reported significantly less frequent exposure to opportunities for inquiry-based science teaching and learning practices in the less affluent Hispanic or Latinx class (β = -0.206, $p \leq .01$), more affluent Hispanic or Latinx class (β = -0.223, $p \leq .01$), less affluent White class (β = -0.231, $p \leq .01$), and more affluent White class (β = -0.124, $p \leq .01$). These moderating effects of student background class membership on the relationships between gender and sense of belonging, as well as gender and OTL inquiry-based science, provide another intersectional dimension for examining students' experiences in schools.

Table 7. Results of Distal Outcomes (Sense of Belonging, OTL Inquiry-Based Science) Regressed on Gender[1] for Each Class

	β	S.E.	t	
BELONG on GENDER				
Class 1 (less affluent Hispanic or Latinx)	-0.129	0.063	-2.042	*
Class 2 (less affluent Black or African American)	-0.345	0.137	-2.519	*
Class 3 (more affluent Black or African American)	-0.328	0.115	-2.862	**
Class 4 (more affluent Hispanic or Latinx)	-0.096	0.070	-1.386	
Class 5 (less affluent White)	-0.271	0.077	-3.533	***
Class 6 (more affluent White)	-0.164	0.053	-3.064	**
OTL on GENDER				
Class 1 (less affluent Hispanic or Latinx)	-0.206	0.075	-2.731	**
Class 2 (less affluent Black or African American)	-0.036	0.156	-0.229	
Class 3 (more affluent Black or African American)	-0.165	0.137	-1.197	
Class 4 (more affluent Hispanic or Latinx)	-0.223	0.074	-3.010	**
Class 5 (less affluent White)	-0.231	0.083	-2.774	**
Class 6 (more affluent White)	-0.124	0.047	-2.621	**

Notes: ~ p ≤ .10, * p ≤ .05, ** p ≤ .01, *** p ≤ .001

[1]Female = 1, Male =

Finally, the differences between classes on each of the distal outcomes, sense of belonging to school and OTL inquiry-based science, controlling for gender, are displayed in Table 9 (see Table 8 for class-specific intercepts). There were significant differences between Class 1 and Class 2 ($W = 6.541$, $df = 1$, $p \leq .05$), Class 1 and Class 3 ($W = 17.783$, $df = 1$, $p \leq .001$), and Class 1 and Class 6 ($W = 14.043$, $df = 1$, $p \leq .001$) on sense of belonging, with the less affluent Black or African American class, more affluent Black or African American class, and more affluent White class each reporting more agreement with sense of belonging to school than the less affluent Hispanic or Latinx class. The more affluent Hispanic or Latinx class ($W = 4.666$, $df = 1$, $p \leq .05$) and less affluent White class ($W = 4.357$, $df = 1$, $p \leq .05$) also reported significantly less agreement with sense of belonging to school than the less affluent Black or African American class. Class 3, the more affluent Black or African American class, which reported the highest level of agreement with sense of belonging, had significantly higher sense of belonging than the more affluent Hispanic or Latinx class ($W = 13.690$, $df = 1$, $p \leq .001$), the less affluent White class ($W = 12.628$, $df = 1$, $p \leq .001$), and the more affluent White class ($W = 4.429$, $df = 1$, $p \leq .05$). The more affluent Hispanic or Latinx class ($W = 7.632$, $df = 1$, $p \leq .01$) and less affluent White class ($W = 6.008$, $df = 1$, $p \leq .05$) reported significantly lower sense of belonging than the more affluent White class.

Table 8. Class-Specific Intercepts for Distal Outcomes Controlling for Gender

	Intercept	
	Sense of Belonging	OTL Inquiry-Based Science
Class 1 (less affluent Hispanic or Latinx)	-0.146	0.497
Class 2 (less affluent Black or African American)	0.190	0.530
Class 3 (more affluent Black or African American)	0.298	0.504
Class 4 (more affluent Hispanic or Latinx)	-0.095	0.521
Class 5 (less affluent White)	-0.092	0.413
Class 6 (more affluent White)	0.086	0.312

Table 9. Results for Test of Differences Between Classes on Distal Outcomes Controlling for Gender

	Sense of Belonging		OTL Inquiry-Based Science	
	Wald statistic	p-value	Wald statistic	p-value
Class 1 (less affluent Hispanic or Latinx) vs. Class 2 (less affluent Black or African American)	6.541	*	0.054	
Class 1 (less affluent Hispanic or Latinx) vs. Class 3 (more affluent Black or African American)	17.783	***	0.003	
Class 1 (less affluent Hispanic or Latinx) vs. Class 4 (more affluent Hispanic or Latinx)	0.465		0.074	
Class 1 (less affluent Hispanic or Latinx) vs. Class 5 (less affluent White)	0.486		0.935	
Class 1 (less affluent Hispanic or Latinx) vs. Class 6 (more affluent White)	14.043	***	7.247	**
Class 2 (less affluent Black or African American) vs. Class 3 (more affluent Black or African American)	0.442		0.025	
Class 2 (less affluent Black or African American) vs. Class 4 (more affluent Hispanic or Latinx)	4.666	*	0.004	
Class 2 (less affluent Black or African American) vs. Class 5 (less affluent White)	4.357	*	0.656	
Class 2 (less affluent Black or African American) vs. Class 6 (more affluent White)	0.665		2.607	
Class 3 (more affluent Black or African American) vs. Class 4 (more affluent Hispanic or Latinx)	13.690	***	0.025	
Class 3 (more affluent Black or African American) vs. Class 5 (less affluent White)	12.628	***	0.633	
Class 3 (more affluent Black or African American) vs. Class 6 (more affluent White)	4.429	*	3.567	~
Class 4 (more affluent Hispanic or Latinx) vs. Class 5 (less affluent White)	0.002		1.507	
Class 4 (more affluent Hispanic or Latinx) vs. Class 6 (more affluent White)	7.632	**	8.376	**
Class 5 (less affluent White) vs. Class 6 (more affluent White)	6.008	*	1.738	

After controlling for the covariate gender, both the less affluent ($W = 7.247$, $df = 1$, $p \leq .01$) and more affluent ($W = 8.376$, $df = 1$, $p \leq .01$) Hispanic or Latinx class reported significantly more frequent exposure to OTL inquiry-based science than the more affluent White class. There were no other significant differences between classes on this distal outcome.

In conclusion of these results, we found six distinct classes defined primarily by an intersection of race and affluency. The classes were consistently separated by parent occupational status into less and more affluent groups for each race/ethnicity (Black or African American,

Hispanic or Latinx, White), with differences in parent education by affluence among several groups of similar race and ethnicity. There was also notable separation between the less affluent Black or African American and Hispanic or Latinx groups and the more affluent White group on the indicator of wealth (measured by non-essential, ease-of-life possessions) and the number of books in home. Interestingly, parent emotional support, cultural possessions, and home educational resources did not define the separation of groups across these race and affluency profiles.

Gender was associated with two distal outcomes, sense of belonging and OTL inquiry-based science, with class membership as a moderator. Females consistently reported less sense of belonging to school and less exposure to opportunities for inquiry-based science across most of the classes. There were some differences in these distal outcomes by classes when controlling for gender. Most notably, the more affluent Black or African American class reported the highest sense of belonging, followed by the less affluent Black or African American class, then the more affluent White class. Both Hispanic or Latinx classes, more and less affluent, reported the lowest sense of belonging among the classes but more exposure to inquiry-based science compared to the more affluent White class. These findings demonstrate the extent that students within each class view their access to particular opportunities and affective experiences within school.

<div align="center">**Discussion**</div>

Building on the work of Landale et al. (2017), the findings from this study reinforced the use of LCA as a promising method for incorporating intersectionality frameworks in quantitative research designs. Rather than rely on interaction effects in regression analysis that are researcher-specified and can be difficult to interpret, particularly for interactions of more than two variables, LCA offers an approach to capture and describe complex intersectional group characteristics that emerge from the data. The contribution this approach can make to the field of critical quantitative

work is underscored by the relative affluence of the groups by race and ethnicity. Despite each of the less affluent groups having similar proportions of parent education (students whose parents had higher vocational education or less) and similar levels of parent occupational status, only the less affluent Hispanic or Latinx and less affluent Black or African American groups were well-separated from the more affluent White group in wealth and number of books in the home. This means that there is less of a wealth gap between less affluent and more affluent White families compared to the other less affluent groups. Moreover, it suggests that occupational status and structural opportunities, such as higher education – which have been used as proxies of social class in past research – are less of a determinant of wealth for White families. This is further reinforced by the finding that the more affluent Hispanic or Latinx group, which had high occupational status and close to 50% of students with parents who had academic higher education, had a class wealth mean that fell slightly below the overall sample wealth mean. A study using researcher-specified thresholds for assigning students to more or less affluent groups based on wealth would likely choose uniform criteria for each group that might overlook the systemic inequality highlighted by the wealth gap (see Darity, Hamilton, Paul, Aja, Price, Moore, & Chiopris, 2018) that could help explain differences in students' school experiences and subsequent outcomes.

These findings also have implications for the measures of social class that are used in future studies. While parent occupational status clearly distinguished between more and less affluent groups, parent education did not exhibit the same consistent separation patterns. Books in the home, which has been conceptualized by Carnoy and Rothstein (2013) as family academic resources and argued to be a more useful predictor of student achievement than general measures of household possessions, had similar patterns of separation that revealed the absence of a gap between less affluent White students and each of the more affluent groups on these measures. This

approach captured important intersectional differences in traditional social class measures that can inform future selection of measures and development of models that capture this complexity.

Further, the lack of separation between classes on indicators of cultural possessions and home educational resources – traditional indicators of cultural capital – warrants further examination. Given the critiques of how cultural capital has been operationalized in past research (Lareau and Weininger 2003), particularly the focus on highbrow cultural activities, these findings suggest that more robust measures of student capital are needed to understand students' differential experiences in schools (see Wilson & Urick, in press). The measures used in this study were selected to align with past research on cultural reproduction theory in order to challenge the omission of school structures, policies, and practices in explaining differential student outcomes based on cultural capital. At the same time, the study was limited to those measures that were available in the PISA 2015 dataset. It is important to note that the items for the cultural possessions at home scale reflect White, affluent, Eurocentric conceptions of culture that have been historically reflected in U.S. curriculum. The omission of culturally diverse forms of capital in the international study of students' school experiences and outcomes parallels a similar omission of culturally and racially diverse representation in U.S. course content and materials (Irizarry, 2011), as well as a lack of adequate teacher preparation for culturally responsive pedagogy (Sleeter, 2017; Warren, 2018). Future research could meaningfully extend the findings from this study by operationalizing student capital measures, such as community cultural wealth (Yosso, 2005; see Sablan, 2019), that acknowledge and value the assets possessed by diverse students and communities that have historically been undervalued by schools and other dominant culture institutions. This work is important to challenging curricular content and pedagogical practices that have oppressed and marginalized Students of Color and students from less affluent backgrounds by affirming students'

knowledge, experiences, and perspectives while also seeking to understand gaps that stem from differential school experiences. While the current study is a promising start in identifying patterns of privilege and inequity in schools associated with narrow measures of student capital, it is clear that more work needs to be done to avoid reinforcing them as normative or exclusive indicators of student, family, or community capital. This calls for cultural competence in the development of survey items to more effectively measure capital.

Another important finding related to cultural capital is the lack of separation between all classes with regard to parents' emotional support. This finding demonstrates that across intersections of race and ethnicity, social class, language, and immigration background, the majority of students agree that that their parents express support for their educational efforts, activities, achievement, difficulties, and confidence. These similar proportions of students across groups who agree that they receive parent emotional support provide important pushback to deficit perspectives that have sought to blame students and their families for lack of success in schools (see Irizarry, 2011). Deficit narratives have attributed blame to parents for not valuing education as an alternative to critical examination of students' educational experiences in schools (see Irizarry, 2011) – educational practices or policies that have marginalized and failed to engage students in meaningful, humanizing (Camangian, 2015), and culturally relevant work. The use of student perception measures is especially valuable, as it captures the messages from parents that students have internalized regardless of the means through which parents communicate the importance of schools, which could be interpreted differently by outside observers. The findings suggest that schools and school leaders need to develop better understandings of the different ways that parents from diverse backgrounds manifest their support for their children's education, and use this understanding to inform asset-based approaches to working with students and families.

In addition to systemic wealth inequality, the use of LCA also provided important intersectional evidence of gender inequality for both sense of belonging to school and OTL inquiry-based science. While the inability to include gender as an LCA indicator highlights the limitation of this methodological approach, modeling intersectional student background group membership as a moderator of the relationship between gender and the distal outcomes allowed for meaningful intersectional analysis that incorporated gender. For sense of belonging to school, girls in all but one class (the more affluent Hispanic or Latinx class) reported significantly less agreement with belonging to school items compared to boys. However, despite consistency in the direction of the relationship, there were differences in effect size across the groups. In both the less affluent and more affluent Black or African American groups, girls reported sense of belonging that was approximately a third of a standard deviation lower than boys. Girls in the less affluent White group reported sense of belonging that was approximately a fourth of a standard deviation lower than boys. This suggests that while Black or African American girls across social class groups report similarly lower levels of agreement than boys for sense of belonging, there are differences by social class for White girls. For OTL-inquiry based science, girls in the less affluent Hispanic or Latinx, more affluent Hispanic or Latinx, less affluent White, and more affluent White groups reported significantly less frequent exposure to inquiry-based science teaching and learning practices than boys, with just under a quarter of a standard deviation difference between girls and boys for both Hispanic or Latinx groups and the less affluent White group. Again this points to similar levels reported across social class groups for Hispanic or Latinx girls, but differences in levels of exposure across social class groups for White girls. These differences across intersectional groups reinforce the potential of LCA for identifying more nuanced patterns of inequity at the intersections of race, ethnicity, class, and gender that bear further investigation.

Ultimately, these findings seem to reinforce earlier reports indicating that boys tend to receive more attention and encouragement from teachers, and classroom activities are often geared towards boys' interests and strengths (*The AAUW report*, 1992). Interactions with teachers also differ by race, as African American girls were found to have fewer interactions than White girls despite more frequent attempts to initiate interactions with teachers (*The AAUW report*, 1992). Moreover, gender stereotypes and lack of representation in the curriculum for girls and girls of color have constrained educational opportunities across subject areas (*The AAUW report*, 1992), which might also help explain lower sense of belonging in school, as well as the persistence of gaps in science outcomes by gender (Else-Quest et al., 2013; Riegle-Crumb et al., 2011; Wang & Degol, 2017). Given the long trajectory of findings on differential school experiences associated with gender, this study underscores the need to understand how educators can more effectively disrupt specific patterns of intersectional privilege in schools, and identify the leadership and school supports necessary to enact more equitable orientations and practices.

The findings from the test of class differences on distal outcomes after controlling for gender warrant further inquiry. A similar pattern emerged across the intersectional groups of similar race and ethnicity, with more affluent students within each race and ethnicity group reporting greater agreement with sense of belonging to school than less affluent students. However, despite this relative pattern, there were significant differences between race and ethnicity groups regardless of affluence. Less affluent and more affluent Hispanic or Latinx students reported the lowest agreement with sense of belonging to school, while less affluent and more affluent Black or African American students reported the highest agreement with sense of belonging to school. Accordingly, significant differences on sense of belonging to school were found between the more and less affluent Black or African American groups and the more and less affluent Hispanic or

Latinx groups, as well as the less affluent White group. The more affluent Black or African American group also had significantly higher agreement than the more affluent White group. The high level of sense of belonging to school reported by both Black or African American groups raises important questions about how historically underserved students have made sense of their educational experiences within a systemically unjust social and educational context, and how this construct relates to academic outcomes. One possibility is that because structural features, such as tracking, disproportionately separate Students of Color and lower-SES students into lower tracks, students are able to forge a sense of identity and belonging with peers who have had similarly inequitable school experiences (see Chambers, 2009). However, as the tracking literature has demonstrated, this sense of belonging reflected in a connection with peers might come at the cost of a negative orientation towards school, coursework, relationships with teachers, or their own academic abilities as a result of lower expectations, less rigorous and engaging instruction, and a less supportive (e.g. culturally responsive and humanizing, see Camangian, 2015) academic environment (Ansalone, 2009; Chambers, 2009; Donaldson et al., 2017; Gamoran, 1992; Harris, 2011; Karlson, 2015; Oakes, 1982; Oakes, 2005; Watanabe, 2008). Another possibility is that Black or African American students are confronting counterfeit social capital (Ream, 2003), or the appearance of caring exchanges between teachers and students that are not accompanied by high academic expectations and meaningful learning opportunities. Further work is needed to examine these possibilities and provide more insight into the findings.

Finally, there were significant differences between the more and less affluent Hispanic or Latinx groups and the more affluent White group on OTL inquiry-based science, with the more and less affluent Hispanic or Latinx groups reporting more frequent opportunities for inquiry-based science. This finding contrasts the particularly low levels of agreement for sense of

belonging to school reported by both Hispanic or Latinx groups. Given the trajectory of assimilationist, subtractive education policies in the U.S. (Boykin & Noguera, 2011; Gutiérrez, 2004), particularly the prioritization of English proficiency over dual language development (Gándara & Rumberger, 2009), and the vitriolic political discourse around bilingualism and immigration in the U.S. (MacDonald & Carrillo, 2008; Stritikus & English, 2009), it is perhaps unsurprising that the two groups comprised of more individuals at the intersections of Hispanic or Latinx race and ethnicity, first or second generation immigrant status, and speaking a language other than English at home would report less sense of belonging to school. Given the higher reported frequency of OTL inquiry-based science for both groups of Hispanic or Latinx students, a key area for future research is the relationship between sense of belonging to school and OTL, as well as the implications for a range of academic outcomes, from an intersectional perspective. In addition to the insight that could be gathered through a complementary qualitative approach, examining these relationships in a mediating paths model could promote understanding of how students' differential affective experiences, such as belonging, and access to OTL contribute to disparate outcomes.

Appendix A. Variables list.

	Construct	PISA Index/Variable	Question/Item
student level	student background	ST004D01T	Are you female or male?
		RACETHC	NAT/Collapsed derived student race/ethnicity
		Immigration status (IMMIG)	In what country were you and your parents born?
		Language spoken at home (LANGN)	What language do you speak at home most of the time?
	student background: social class	Highest educational level of parents (HISCED)	What is the highest level of schooling (not including college) completed by your mother/father? Does your mother/father have any of the following degrees, certificates, or diplomas?
		Highest occupational status of parents (HISEI)	What is your mother's main job? What does your mother do in her main job? What is your father's main job? What does your father do in his main job?
		Family wealth (WEALTH)[1]	Which of the following are in your home? - A room of your own - A link to the internet How many of these are at your home? - Televisions - Cars - Rooms with a bath or shower - Computers - Tablet computers - E-book readers
	student background: cultural capital	Parents emotional support (EMOSUPS)[1]	Thinking about this school year: to what extent do you agree or disagree with the following statements? - My parents are interested in my school activities - My parents support my educational efforts and achievements - My parents support me when I am facing difficulties at school - My parents encourage me to be confident
		Cultural possessions at home (CULTPOSS)[1]	Which of the following are in your home? - Classical literature - Books of poetry - Works of art - Books on art, music, or design How many of these are there at your home? - A musical instrument
		Home educational resources (HEDRES)[1]	Which of the following are in your home? - A desk to study at - A quiet place to study - A computer you can use for your school work - Educational software - Books to help with your school work - Technical reference books or manuals - A dictionary
		ST013Q01TA	How many books are there in your home?
	student belonging	Sense of Belonging to School (BELONG)	Thinking about your school: to what extent do you agree with the following statements? - I feel like an outsider (or left out of things) at school. - I make friends easily at school.

			• I feel like I belong at school. • I feel awkward and out of place in my school. • Other students seem to like me. • I feel lonely at school.
	opportunity to learn	Inquiry-based science teaching and learning practices (IBTEACH)	When learning science topics at school, how often do the following activities occur? • Students are given opportunities to explain their ideas • Students spend time in the laboratory doing practical experiments • Students are required to argue about science questions • Students are asked to draw conclusions from an experiment they have conducted • The teacher explains how a science idea can be applied to a number of different phenomena (e.g. the movement of objects, substances with similar properties) • Students are allowed to design their own experiments • There is a class debate about investigations • The teacher clearly explains the relevance of science concepts to our lives

Notes: [1]Raw item responses used to create composites that align with PISA index

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ARTICLE 2

"Applying an Intersectional Framework to the Study of Opportunity to Learn Science, Sense of Belonging, and Academic Climate in U.S. Schools: A Mediation Model"

Abstract

The purpose of the current study is to address gaps in the literature on cultural reproduction theory by employing a critical quantitative lens that examines how U.S. schools contribute to differential science outcomes based on intersectional student backgrounds. Using nationally representative PISA 2015 data, this study uses structural equation modeling (SEM) with intersectional student background groups identified in a previous study to examine how U.S. students' educational experiences in schools – opportunity to learn (OTL) inquiry-based science, sense of belonging, and perceptions of academic climate – mediate the relationship between student background and science achievement. The direct and indirect findings from this study provide important insight about school mediators that can help account for the gap in science outcomes in the U.S. In particular, student perceptions of an academic climate indicator, teacher interest in all students' learning, emerged as a mediator of gender and science achievement. Moreover, while OTL inquiry-based science, academic press, and order were significant mediators of both gender and intersectional student background and scientific literacy outcomes, some of the findings operated in the opposite direction than anticipated, which warrants further examination. Finally, although intersectional student background and gender were both significant predictors of sense of belonging, sense of belonging was not significantly related to science achievement, a finding that can inform future studies on this important affective outcome.

Introduction

Persistent disparities in educational outcomes in the U.S. have been a concern of scholars, policymakers, and educators for decades. While considerations of equity have ostensibly played a role in the political discourse and efforts aimed at closing the "achievement gap" (see Chambers, 2009), global competitiveness has also been a primary concern of neoliberal education policies such as No Child Left Behind (NCLB) (Hursh, 2007). In this context, individual choice and competition, coupled with high-stakes testing and accountability, have been utilized as key levers in education reform efforts (Hursh, 2007).

Although gaps have persisted on a range of education outcomes, such as graduation rates, enrollment in advanced coursework, and college attainment (Ladson-Billings, 2006), research and policy have generally focused on the achievement gap as measured by standardized testing results, such as state-mandated achievement exams, the SAT, or National Assessment of Educational Progress (NAEP). Lee (2002) found that while the racial and ethnic gap narrowed for basic skills between the 1970s and early 1980s, the gap for higher-level skills grew beginning in the late 1980s. Moreover, the White-Hispanic gap and White-Black achievement gap has remained stable between the early 1990s and 2015 across many grades and subject areas (Musu-Gillette, de Bray, McFarland, Hussar, Sonnenberg, & Wilkinson-Flicker, 2017). The most recent NAEP results for 2017 indicated that the average math and reading scores for White students in grades 4 and 8 were significantly higher than those for Black and Hispanic students (NCES, 2018). Males scored significantly higher in math for grades 4 and 8, whereas females scored significantly higher in reading in both grades (NCES, 2018). However, the gender score gap was considerably smaller than the race/ethnicity score gap.

Even with the recent education policy transition from NCLB to the Every Student Succeeds Act (ESSA), standardized testing remains a salient accountability tool (Mathis & Trujillo, 2016). The irony is that while standardized testing has been used in policy as a tool for identifying achievement gaps and attempting to address them through the threat of sanctions for schools who do not show adequate progress, these testing systems also have "racist and classist legacies" (Au, 2013) stemming from their early connection to eugenics and the adaptation of IQ testing in the U.S. Moreover, policy reliance on standardized testing has played a role in masking, creating, and sustaining opportunity gaps. The use of IQ tests in the U.S. in the early twentieth century laid the groundwork for hierarchical sorting of students, and standardized testing began to be used in schools in conjunction with the social efficiency movement as an "objective" and efficient means of tracking students within an industrial factory model of schools based on their future roles in society (Au, 2013; Grodsky, Warren, & Felts, 2008). According to Au (2013), "the assumptive objectivity of standardized testing was thus used to 'scientifically' declare the poor, immigrants, women, and non-whites in the U.S. as mentally inferior, and to justify educational systems that mainly reproduced extant socio-economic inequalities" (p. 10).

This assumption of objectivity underlies a key contradiction in the function of standardized testing. While proponents of standardized testing posit that it serves a social redistribution function by opening doors for less privileged students to, for example, higher education opportunities, critics have argued that it serves a social reproduction purpose as a rationale for sorting students based on ability and a gatekeeping mechanism that reinforces social stratification (Au, 2013; Grodsky et al., 2008; Mehan, 2008). Further, the assumption that testing can promote social redistribution is rooted in an ideology of meritocracy that attributes blame to students for underachievement while masking the structural inequalities that contribute to these outcomes (Au,

2013; Chambers, 2009). This underscores the salience of consequential validity in the use of standardized testing to make high-stakes decisions, such as retention or college admission, as underserved students are punished for scores that reflect their inadequate learning opportunities rather than their effort or ability (Grodsky et al., 2008).

Critics of the high-stakes accountability context have also demonstrated how power and privilege have been employed in achievement policy and discourse. Milner (2013) has noted that "as with knowledge, certain areas of achievement are privileged and valued over others, and there appears to be a socially constructed hierarchy of which and what achievements and knowledge matter more in comparison to others" (p. 5), such that the knowledge and skills possessed by affluent White students are acknowledged and rewarded in the education system to the exclusion of those possessed by Students of Color, low-SES students, and English language learners (see also Bourdieu, 1977a). Lipman (2004) has also criticized the racialized nature of education policy, arguing that

> Accountability is also a highly racialized discourse of deficits. The separation of 'good' and 'bad' schools, of 'failing' and 'successful' students, that is accomplished through the testing, sorting, and ordering processes of standardized tests, distribution of stanine scores, retention of students, and determination of probation lists constructs categories of functionality and dysfunctionality, normalcy and deviance. In this sense, the test is, in Foucault's language, 'a ritual of power.' It embodies the power of the state to sort and define students and schools, creating and reinforcing oppressive power relations (Carlson, 1997) of race and class. 'Failing' schools and 'failing' students (and by implication, 'failing' communities), most African American and Latino/a, are measured against the 'success' of schools that are generally more white, more middle-class. (p. 177-178)

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This underscores how a system and its policies on the surface can suggest a commitment to students who have historically been underserved while implementing such policies and practices according to the same standards and structures that created inequitable opportunities and disparate outcomes in the first place. By failing to address the deficit perspectives inherent in the system (Chambers, 2009; Nieto, 1998; Yosso, 2005), and the broader structural inequalities in society (Milner, 2013), accountability policies can serve to reinforce the attitudes and practices that underlie persistent achievement gaps.

Understanding the contradictions and inequities underlying education policy are important for evaluating research approaches to examining the educational outcome gap in the U.S. Without adequately accounting for the educational experiences that mediate student background and academic outcomes, educational research has the potential to reinforce the practice of mandating outputs without attention to school inputs and processes, shifting blame to students and families for differential success. The purpose of the current study is to address gaps in the literature on cultural reproduction theory by employing a critical quantitative lens that examines how schools contribute to differential science outcomes based on intersectional student backgrounds.

Literature Review

Scholars have sought to explain the "achievement gap" using a number of competing theories (see Nieto, 2005, for an overview). These have ranged from deficit theories that have attributed blame to students and families without accounting for issues of systemic inequality to theories that have been more attune to the ways educators and schools challenge or reproduce inequality through their orientation to students, families, and communities (Nieto, 2005; see Giroux, 1983; Ladson-Billings, 1995, 2014; Noddings, 2015; Ogbu & Simons, 1998; Stanton-Salazar, 1997; Stephens & Townsend, 2015). Among these perspectives, economic (see Bowles

& Gintis, 1976) and social reproduction (see Bourdieu, 1977a, 1984; Bourdieu & Passeron, 1990) theories call attention to the role of structural inequality, poverty, and racism in student achievement disparities (Nieto, 2005). According to these theories, schools both reflect and contribute to structural inequalities based on race, class, and gender by privileging the interests of the dominant classes and sorting students in ways that reflect the stratification of society (Nieto, 2005; see Bourdieu, 1977a; Grenfell & James, 1998).

Many of the theories addressing the outcome gap have faced criticism (Nieto, 2005), and none offer a comprehensive picture of how best to understand and address educational inequity and disparate outcomes. Collectively, however, these theories, and respective criticisms, underscore the important role that schools play within a stratified U.S. society, and their potential to remediate or exacerbate opportunity and learning gaps that stem from structural inequality. An important consideration is how these theories translate to research and inform practice and policy. The research that has utilized cultural reproduction theory (Bourdieu, 1977a, 1984; Bourdieu & Passeron, 1990) as a framework for examining the relationship between student background and achievement represents one line of scholarship that has fallen short of its potential to illuminate issues of inequity in schools. Despite the theoretical underpinnings, this body of research has yet to critically examine the role of the education system in perpetuating achievement gaps through school-based opportunity gaps (see Chambers, 2009; Ladson-Billings, 2006; Schmidt et al., 2015).

Cultural Reproduction Theory in Educational Research

Cultural reproduction theory (Bourdieu, 1977a, 1984; Bourdieu & Passeron, 1990) has informed studies that examine the effects of student capital on a range of educational outcomes, with a particular focus on cultural capital. Across the literature, a debate has emerged over how to operationalize cultural capital. Indicators of status related to "highbrow" culture have been a

primary way that cultural capital has been measured (Lareau and Weininger, 2003). This can be seen in numerous studies that define it as familiarity with or participation in "high culture" or cultural activities (Aschaffenburg & Maas, 1997; DiMaggio, 1982; DiMaggio & Mohr, 1985; Dumais, 2002; Jæger, 2011; Jæger & Mollegaard, 2017; Kalmijn & Kraaykamp, 1996; Roscigno & Ainsworth-Darnell, 1999). Common indicators have included reading habits (Andersen & Jæger, 2015; Gaddis, 2013; Ganzeboom, DeGraaf, & Robert, 1990; Jæger & Mollegaard, 2017; Jæger & Holm, 2007), museum visits (Gaddis, 2013; Roscigno & Ainsworth-Darnell, 1999), and attendance or participation in artistic, theatrical, or musical performances (Aschaffenburg & Maas, 1997; DiMaggio, 1982; DiMaggio & Mohr, 1985; Kalmijn & Kraaykamp, 1996). However, Lareau and Weininger (2003) have argued that the conceptualization of cultural capital should be extended to include skills and resources for navigating the educational system, as well as the attitudes and strategies employed by parents to intervene in their children's education, that conform to the standards of evaluation established by the school system (Lareau & Weininger, 2003). Among the studies that Lareau & Weininger (2003) have cited as illustrative of this expanded conceptualization of cultural capital, indicators have included English language fluency and literacy (Blackledge, 2001), material resources (Smrekar, 1996), and interaction styles with teachers (Carter, 2003). Regardless of operationalization, however, the fundamental argument of cultural reproduction theory is that schools are designed to privilege students with resources, attitudes, and dispositions aligned with the dominant culture (Bourdieu, 1977a,b; Grenfell & James, 1998).

Research conducted outside of the U.S. has generally provided support for the positive relationship between cultural capital and student outcomes (see Jæger, 2011 for an overview), with some studies extending analysis to how this relationship varies between low- and high-SES

students (Andersen & Jæger, 2015; Jæger & Mollegaard, 2017). These findings are largely consistent with results from U.S. studies (see Jæger, 2011). However, given the differences in education systems (see Andersen & Jæger, 2015) and distribution of economic inequality (see Jæger & Holm, 2007) that exist between countries, a closer examination of U.S. studies is warranted.

Across several decades of research, U.S. studies have identified the positive effects of cultural capital on student outcomes, including test performance (Jæger, 2011), grades (DiMaggio, 1982; Gaddis, 2013), and educational attainment (Aschaffenburg & Maas, 1997; DiMaggio & Mohr, 1985; Kalmijn & Kraaykamp, 1996; Teachman, 1987), with some studies examining differential effects by race (Roscigno & Ainsworth-Darnell, 1999) and gender (Dumais, 2002). Potter and Roksa (2013) found that class-based cumulative family experiences explained part of the baseline math and reading score gap and accounted for a substantial portion of the skill gap throughout students' school trajectory. Many of these studies have accounted for additional variables related to student and family background, such as family structure and indicators of SES (DiMaggio, 1982; Gaddis, 2013; Jæger, 2011; Potter & Roksa, 2013; Roscigno & Ainsworth-Darnell, 1999; Teachman, 1987), and some have addressed the role of habitus (Dumais, 2002; Gaddis, 2013). However, the mediating role of schools in the relationship between student background and educational outcomes has largely been overlooked in the body of literature. Roscigno & Ainsworth-Darnell (1999) have provided an exception to this trend by incorporating indicators of teacher evaluations and track placement as proxies for the micropolitical process mediating the relationship between cultural capital and student outcomes (see also Farkas, Grobe, Sheehan, & Shuan, 1990), although they acknowledged the need for further examination of teacher-student interactions and school practices such as tracking. Potter & Roksa (2013) have

also acknowledged the need to better understand students' schooling experiences and provided preliminary schooling measures, but these were more reflective of the general school context rather than the structures and processes related to teaching and learning.

Because cultural reproduction theory highlights the complicity of schools in social and cultural reproduction (Bourdieu, 1977a), the lack of critical examination of how schools structure inequality based on student background is a salient gap in the literature. In the U.S. in particular, it is important to understand the role of schools in perpetuating systemic inequality to combat the deficit narratives about students and families that have historically been employed to explain the "achievement gap" (Chambers, 2009; Nieto, 1998; Yosso, 2005). Understanding disparities in school structures and processes is central to acknowledging and addressing what Chambers (2009) has aptly referred to as the "receivement gap."

Opportunity to Learn

Opportunity to learn is one construct that can be used to assess the "receivement gap" (Chambers, 2009) in U.S. schools. Opportunity to learn (OTL) has evolved as a research construct and policy mechanism that calls attention to students' differential exposure to content, instruction, and educational resources in schools as a predictor of performance (McDonnell, 1995). Exposure to curricular content has been a primary way that OTL has been operationalized since the 1960s, when it was included in the International Association for the Evaluation of Educational Achievement's (IEA) First International Mathematics Study (FIMS) to ensure valid comparisons in student achievement between countries (Floden, 2002; McDonnell, 1995). It has also been conceptualized and operationalized to include indicators such as providing adequate time needed for learning (Carroll, 1963), classroom instruction (Kurz, Elliott, Lemons, Zigmond, Kloo, & Kettler, 2014; Smithson, Porter, & Blank, 1995), teacher characteristics (Aguirre-Muñoz &

Boscardin, 2008; Goertz, 1994), and resources for learning (Boykin & Noguera, 2011; Elliot, 1998; Herman & Klein, 1996; Kimura-Walsh, Yamamura, Griffin, & Allen, 2009; Oakes, 1990).

Findings across studies have identified a relationship between OTL and student achievement (Arehart, 1979; Boscardin, Aguirre-Muñoz, Chinen, Leon, & Shin, 2004; Boscardin, Aguirre-Munoz, Stoker, Kim, Kim, & Lee, 2005; Schmidt et al., 2011a; Schmidt et al., 2013; Schmidt et al., 2001; Wang, 1998; see Elliott & Bartlett, 2016), and disparities in access to OTL corresponding with student background (Abedi, Courtney, Leon, Kao, & Azzam, 2006; Abedi & Herman, 2010; Darity, Castellino, Tyson, Cobb, & McMillen, 2001; Heafner, 2015; Kim & Hocevar, 1998; Minor, 2015; Schmidt et al., 2015; Wang, 2010; Wang & Goldschmidt, 1999). In particular, Schmidt and colleagues have found that OTL math content mediates the relationship between SES and math achievement and that in the U.S., within-school inequalities in math OTL exceed the levels found in many other countries (Schmidt et al., 2015).

A preliminary review of the OTL literature has also suggested that educational outcomes have driven conceptualizations of OTL. This is highlighted by the IEA's early interest in identifying the overlap between student exposure to curricular content and the content of the items of the assessment. Indeed, student achievement as indicated by performance on assessments has been a recurring outcome of interest in studies on OTL (see Robitaille & Garden, 1989; Wright & Li, 2008; Schmidt et al., 2015; Wang, 1998), which in turn has influenced the variables or dimensions selected to represent the opportunities necessary for students to be successful on the respective assessment. This is an important trend that deserves attention. Although NCLB was ostensibly intended to help close the achievement gap for historically underserved populations, an unintended consequence has been a narrowing of the curriculum and instructional strategies to test preparation and basic skills for many students (Olson, 2007).This suggests that another important

consideration in addressing OTL is the level of rigor, or cognitive demand, reflected in the content of instruction (Porter, 2002; see Urick, Wilson, Ford, Frick, & Wronowski, 2018) and expectations for student performance.

Collectively, this body of work suggests that OTL is a concept of importance to policymakers concerned with the achievement gap and matters of equity within schools. Schmidt et al. (2011) have justified their narrow focus on content as an aspect of schools that could be addressed through policy reform. Given the potential usefulness of OTL for identifying and addressing inequities, however, a narrow focus on content precludes acknowledgement of other important factors that work in tandem to create an effective learning environment for students with different learning needs (see Starratt, 2003). One such factor is the role of teachers in utilizing subject area content knowledge and pedagogical practices that are responsive to a range of student learning needs to effectively support student learning of planned content (Bryk et al., 2010; NRC, 2011; Porter, 2002).

Academic Climate and Sense of Belonging to School

In addition to OTL, other facets of the school learning environment related to student achievement could be helpful for identifying inequities based on student background that contribute to outcome gaps. Accounting for academic climate and sense of belonging to school reflects the importance of norms and relationships that support high academic expectations within an inclusive learning community.

Across the literature on school improvement and school effectiveness, various labels have been used for academic climate, including learning climate (Sebastian & Allensworth, 2012) and student-centered learning climate (Bryk et al, 2010). Despite these minor differences in terminology, the construct has been operationalized in similar ways. Academic climate generally

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refers to the norms, practices, and relationships centered on high expectations for student learning (Bryk et al., 2010; Sebastian & Allensworth, 2012; Urick & Bowers, 2011, 2014; Werblow et al., 2013). Dimensions include safety and order that facilitates a focus on teaching and learning (Sebastian & Allensworth, 2012); academic press, or the common push for achievement shared by educators and students (Bryk et al., 2010; Cannata, Smith, & Haynes, 2017); and the supportive relationships that foster strong morale among teachers and students (Urick & Bowers, 2011, 2014). Academic climate has been found to explain difference in students' academic growth (Heck, 2006) and achievement (Urick & Bowers, 2014). Coupled with other supportive school properties, facets of academic climate have been shown to mediate the relationship between student SES and achievement (Hoy, Tarter, & Hoy, 2006). However, Bryk et al. (2010) indicated that given the weaker effects of academic press on achievement than expected, further attention to this construct was warranted, including its potential as an indicator of "social-psychological phenomena" (p. 202). This points to the ways that students' affective outcomes are potentially intertwined with their experiences in the learning environment, including the norms that influence their relationships with peers and educators.

Reynolds et al. (2017) found that the psychological construct of school identification, or a students' connection to the school, mediated the relationship between a broad measure of school climate and student achievement, calling attention to students' affective outcomes within the learning environment (Trujillo & Tanner, 2014). Thus, school belonging might be yet another important avenue for understanding students' differential school experiences and outcomes (Booker, 2006), and the complex relationship between student/family background and social inclusion in schools (Lareau & Horvat, 1999). Walton & Cohen's (2007) findings have suggested

that a sense of social belonging might be particularly salient for the motivation and achievement of students who have been historically marginalized in academic settings.

Theoretical and Conceptual Framework

This study employs a critical quantitative lens (Dixon-Román, 2017; Stage, 2007; Stage & Wells, 2014) to extend the literature on cultural reproduction while accounting for important critiques of the theory itself and related studies. Critical quantitative research challenges a positivist approach that does not adequately account for the subjectivity of the researcher's theoretical lens, questions, and approach to studying phenomena (Dixon-Román, 2017; Stage, 2007). Importantly, critical quantitative research foregrounds issues of systemic inequities and how they are perpetuated, provides alternative quantitative models or approaches that better capture the experiences of those who have been inadequately represented, and seeks to contextualize these experiences in a culturally relevant way (Stage, 2007; Stage & Wells, 2014). Accordingly, this study provides an alternative model that addresses the need to account for students' instructional experiences and affective responses in school to better understand the relationship between student background and achievement. In particular, accounting for school-based opportunities addresses a key shortcoming in the research on cultural reproduction theory that has emphasized class-based differences in student and family dispositions and resources without acknowledging the fundamental role of schools in teaching and learning.

Bourdieu posited that within the "game" of education, which is governed by implicit and explicit rules, students are differentially advantaged or disadvantaged by schools due to their socialization (or lack thereof) to the rules from exposure to the dominant culture (Bourdieu, 1977b; Grenfell & James, 1998). Thus, students wield differential symbolic capital that is privileged in schools, and schools are covertly designed to exclude those who lack dominant forms of capital

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from acquiring it while appearing to operate from a principle of merit (Bourdieu, 1977a,b; Grenfell & James, 1998). Cultural capital, social capital, and economic capital can thus be converted and leveraged by affluent students and families to "confirm their monopoly of the instruments of appropriation of the dominant culture and thus their monopoly of that culture" (Bourdieu, 1977a, p. 494)".

Yosso (2005) has described community cultural wealth as a concept that challenges traditional interpretations of Bourdieu's cultural reproduction theory and the assumptions associated with the notion of cultural capital. The concept of community cultural wealth is grounded in critical race theory (CRT), which has built on interdisciplinary critical scholarship to analyze racial injustice, including the racialized experiences of People of Color and the intersections of racism with other forms of subordination (Yosso, 2005). Yosso (2005) has defined CRT in education as "a theoretical and analytical framework that challenges the ways race and racism impact educational structures, practices, and discourses" (p. 74). She has noted that "CRT is conceived as a social justice project that works toward the liberatory potential of schooling," which "acknowledges the contradictory nature of education, wherein schools most often oppress and marginalize while they maintain the power to emancipate and empower" (Yosso, 2005, p. 74). Yosso (2005) has critiqued interpretations of Bourdieu's cultural reproduction theory that have led schools to work from an assumption that Students of Color are culturally deficient, and that this helps explain outcome gaps between Whites and People of Color. In line with such deficit thinking, "educators most often assume that schools work and that students, parents and community need to change to conform to this already effective and equitable system" (Yosso, 2005, p. 75; see also Nieto, 1998). This shifts the conversation on student achievement, as outcome gaps can be understood as a failure of the education system to understand, value, and leverage students' assets,

rather than a lack of student or family capital. It is through this shift in understanding that schools could begin to realize their potential in promoting equality of opportunity and social mobility.

As noted by Yosso (2005), intersectionality is central to one of the tenets underlying CRT. The field of intersectionality has evolved since Crenshaw's (1989, 1991) early critique of the single-axis framework that contributed to hierarchies of privilege within mutually exclusive categories of race and gender. In contrast to studies that treat student background variables as discrete categories, an intersectionality framework acknowledges the compounded inequities that can occur at the intersections of marginalized group membership (Crenshaw, 1989; Collins, 2015). A model that approaches race, ethnicity, immigration background, language, and social class from an intersectional perspective could provide important insight about how students at the intersections of systems of power might experience compounded discrimination in schools. Therefore, an intersectionality framework would be a useful extension of Bourdieu's cultural reproduction theory to provide a closer examination of the opportunity gaps associated with student background that contribute to disparate academic outcomes.

Bourdieu's cultural reproduction theory has also been criticized for being too mechanistic and not accounting for human agency and resistance (Giroux, 1983; see also Grenfell & James; Mehan, 2008; Nieto, 2005). However, no theory comprehensively addresses the achievement gap. In her overview of theories that have been generated around the achievement gap, Nieto (2005) has concluded that "school achievement, always difficult to explain, must be approached by taking into account multiple, competing, and dynamic conditions: the school's tendency to replicate society and its inequities; cultural and language incompatibilities; the unfair and bureaucratic structures of schools; the nature of the relationships among students, teachers, and the communities they serve; and the political relationship of particular groups to society and the schools" (p. 52).
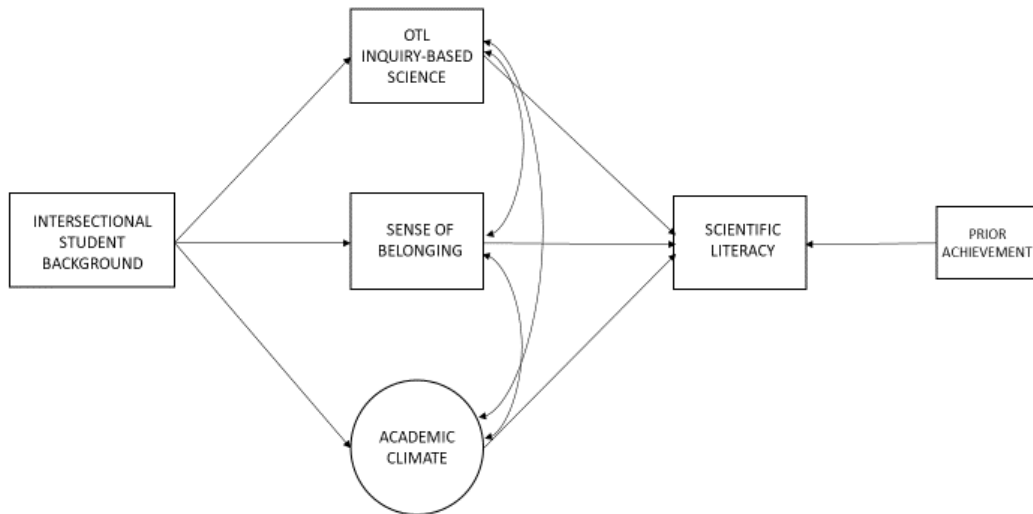
Figure 1. Conceptual and theoretical framework

With this complexity in mind, this study seeks to integrate the literature on cultural reproduction theory, intersectionality, and opportunity to learn to address the ways that schools reflect and perpetuate systemic inequality. This study examines how differential school experiences, including access to opportunity to learn, sense of belonging, and academic climate, mediate the relationship between an intersectional understanding of student background and science achievement to better explain the outcome gap (see Figure 1). Science was selected as the outcome of interest because it has been less extensively studied in the OTL literature despite gender and other background disparities in access and outcomes (Else-Quest et al., 2013; Hayes & Trexler, 2016; Morgan et al., 2016; NRC, 2012; Penfield & Lee, 2010; Riegle-Crumb et al., 2011; Wang & Degol, 2017). Moreover, despite the integration of literacy and math skills required for science instruction (Pearson et al., 2010; Fang & Wei, 2010; Lee & Buxton, 2013; Wang & Degol, 2017), science has been prioritized behind math and reading instruction in the U.S.

accountability context (Anderson, 2012; Berliner, 2011; Milner et al., 2012). Thus, disparities in science outcomes might reflect differences in science opportunities as well as a compounding of inequality in other subject areas required for success in science (Morgan et al., 2016).

Research Questions

1) Does OTL inquiry-based science mediate the relationship between intersectional student background profiles and scientific literacy outcomes?

2) Does student sense of belonging to school mediate the relationship between intersectional student background profiles and scientific literacy outcomes?

3) Does student perception of academic climate mediate the relationship between intersectional student background profiles and scientific literacy outcomes?

Method

Data Sources

This study is a secondary data analysis of the 2015 Program for International Student Assessment (PISA). PISA is an international assessment coordinated by the Organization for Economic Cooperation and Development (OECD) and conducted by the National Center for Education Statistics (NCES) in the United States (NCES, n.d.). First conducted in 2000 and administered every three years, participation in PISA has grown steadily since the first administration, from 32 countries and economies in 2000 to 72 countries and economies in 2015 (OECD, 2017). PISA emphasizes real-life application, assessing 15-year-olds' reading, mathematics, and science literacy (OECD, 2017; NCES, n.d.). While all three core subject areas are assessed with each administration, PISA utilizes a rotating major domain of study with more in-depth assessment items (OECD, 2017; NCES, n.d.). Science was the focus domain for PISA 2015 (OECD, 2017).

In addition to the assessments, student and school questionnaires are administered in all participating countries, and countries can opt to include parent and teacher questionnaires (OECD, 2017). These questionnaires provide important student background and school context information to inform analyses of student achievement results and facilitate comparisons within and between countries. Because the focal subject area domain rotates with each PISA administration, the content of the questionnaires differs accordingly. For example, while many of the student background items – such as questions about parents' education or possessions at home – remain consistent across PISA surveys, other items are specific to the domain of interest, such as students' interest in science topics or perceptions of teacher support in science classes in PISA 2015 (OECD, 2017).

PISA is comparable in many ways to other sources designed to provide nationally representative student achievement data, such as the National Assessment of Educational Progress (NAEP, i.e. the "Nation's Report Card"), the Progress in International Reading Literacy Study (PIRLS), and the Trends for International Mathematics and Science Study (TIMSS). Each of these assessments is conducted regularly, though the administration timelines vary, and each study provides valid and reliable measures of U.S. students' aggregate performance, as well as performance measures for various demographic groups (NCES, 2007; NCES, 2010; Stephens & Coleman, 2007). However, in contrast to the grade-based samples used by the other assessments, PISA uses an age-based sample to account for differences in education systems between countries and account for what students have learned both inside and outside of school as they near the end of compulsory schooling (AIR, 2016; NCES, n.d.; NCES, 2007; NCES, 2010; Stephens & Coleman, 2007). Further, while each of the other assessments is tied closely to either nationally or internationally established curriculum frameworks, PISA utilizes broad literacy measures that

underscore an emphasis on application to real-life situations (AIR, 2016; NCES, n.d.; NCES, 2007; NCES, 2010; Stephens & Coleman, 2007). Finally, the PISA questionnaires provide more detailed information about student and family background, attitudes towards school and learning, school context, and learning opportunities. Thus, PISA is a particularly useful dataset for inquiry focused on the relationship between these factors and student achievement.

PISA 2015 utilized a stratified systematic sample design with a two-stage sampling process, with schools sampled in the first stage and students sampled from these schools in the second stage (NCES, n.d.; OECD, 2017). The U.S. school sampling frame included schools with at least one of grades 7 through 12 that were stratified into 11 groups based on region, school type (e.g. public, private), and whether the school included 10th grade (NCES, n.d.). The schools were sorted within each stratum based on 5 variables related to location and student composition (NCES, n.d.). The original U.S. school sample included 240 schools, which were selected with probability proportionate to the estimated enrollment of eligible students at the school, or systematic probability proportional to size (PPS) sampling (NCES, n.d.; OECD, 2017). Sampling software was used to draw the student sample based on lists of eligible students provided by participating schools (NCES, n.d.). Students had to be 15 years and 3 months to 16 years and 2 months at the beginning of the testing period to participate (NCES, n.d.; OECD, 2017).Within each school, eligible students had an equal probability of being selected and 42 were randomly sampled; in schools with fewer than 42 eligible students, all students that fell within the age range were selected (NCES, n.d.).

In total, 177 U.S. schools, which included 142 original and 35 replacement schools, and 5,712 U.S. students participated in PISA 2015 (NCES, n.d.). Weights were calculated at the school and student level to adjust for probability of selection, nonresponse, and other estimation errors

related to school size and enrollment number of eligible students (NCES, 2014; OECD, 2017). In addition to these sampling weights, a resampling method (i.e. Fay's method of balanced repeated replicates, or BRR) can be used to avoid biased estimates of standard errors due to the sampling design (NCES, 2014). These resampling procedures account for the stratified sampling design, rather than assuming a simple random sample, so that nationally representative estimates can be obtained (NCES, 2014).

The analysis for this study focused on the student level, utilizing items from the student questionnaire and assessment. The sample for this study included U.S. students (n=5,712). See Table 1 for descriptives.

Measures and Instrumentation

Exogeneous Variables

Intersectional Student Background. Intersectional student background groups were identified and interpreted in a previous study (see Wilson & Urick, 2019) through the use of latent class analysis (LCA) with indicators of student race/ethnicity, immigration background, language spoken at home, social class, and cultural capital (see Appendix A for a full list of student background variables). LCA was used to identify homogeneous groups that were distinct from one another based on similar responses to indicator items (Masyn, 2013). Based on a class enumeration process that involved model fit comparisons, followed by interpretation of item response patterns (Masyn, 2013), six intersectional student background groups were identified: a *less affluent Hispanic or Latinx group*, a *less affluent Black or African American* group, a *more affluent Black or African American* group, a *more affluent Hispanic or Latinx* group, a *less affluent White* group, and a *more affluent White* group. Rather than controlling for individual student background characteristics separately, these groups reflect the potential of LCA to facilitate analysis of

inequitable schooling experiences at the intersections of race/ethnicity, language, immigration background, and social class (Crenshaw 1989, 1991; Collins, 2015; see Landale et al., 2017), with extended measures that account for the ways that narrow forms of cultural capital are privileged in schools (Bourdieu, 1977a; Yosso, 2005). This approach to intersectional analysis in critical quantitative research (Dixon-Román, 2017; Stage, 2007; Stage & Wells, 2014) can provide further insight into the ways that systems of power are maintained (Collins, 2015) and social hierarchies are reproduced (Bourdieu, 1977a), as well as the complicity of schools in these processes. In the current study, each of the six groups were dummy coded, with *more affluent White* as the reference group.

Gender. While gender would ideally serve as an additional LCA indicator in forming intersectional student background groups given its prominence in the intersectionality field of study (Crenshaw 1989, 1991), concerns about model identification problems (see Landale et al., 2017; Wilson & Urick, 2019) resulted in gender being included as a separate covariate in both the previous and current study. The PISA variable student gender [ST004D01T], as categorized by OECD, was recoded to *male* (0) and *female* (1).

Prior Achievement. Student grade level [ST001D01T] was included as a control for prior achievement (Marteleto & Andrade, 2013). This PISA variable was dummy coded into *below grade 10* and *above grade 10*, with *grade 10* (the modal grade, see OECD, 2017) as the reference group.

Table 1. Descriptives

Variables	N	Minimum	Maximum	Mean	SD
Reference Groups					
More affluent White	5662	0	1	0.36	-
Male	5712	0	1	0.50	-
Grade 10	5712	0	1	0.72	-

Student Background

Less affluent Hispanic or Latinx	5662	0	1	0.19	-
Less affluent Black or African American	5662	0	1	0.05	-
More affluent Black or African American	5662	0	1	0.08	-
More affluent Hispanic or Latinx	5662	0	1	0.18	-
Less affluent White	5662	0	1	0.14	-
Female	5712	0	1	0.50	-
Below grade 10	5712	0	1	0.10	-
Above grade 10	5712	0	1	0.17	-

Endogenous Variables

OTL inquiry-based science	5097	-3.34	3.18	0.34	1.04
Sense of belonging	5559	-3.13	2.61	-0.09	1.02
Teacher interest in student learning	5127	1.00	4.00	3.27	0.86
Order (latent variable)					
Students don't listen	5152	1.00	4.00	2.95	0.86
Noise and disorder	5137	1.00	4.00	2.94	0.87
Teacher waits for quiet	5129	1.00	4.00	3.11	0.86
Students cannot work well	5112	1.00	4.00	3.28	0.81
Students don't start working	5125	1.00	4.00	3.20	0.84
Academic Press (latent variable)					
Performing in course	5076	1.00	4.00	2.37	0.93
Feedback on strengths	5067	1.00	4.00	2.26	0.98
Areas to improve	5064	1.00	4.00	2.30	0.99
Improve performance	5056	1.00	4.00	2.35	0.99
Learning goals	5044	1.00	4.00	2.35	1.01
Science Achievement					
Plausible value 1	5712	203.66	856.62	496.19	98.18
Plausible value 2	5712	181.97	862.68	495.75	98.17
Plausible value 3	5712	191.09	881.78	497.16	99.68
Plausible value 4	5712	164.12	806.81	496.79	99.07
Plausible value 5	5712	170.25	820.67	496.28	97.89
Plausible value 6	5712	191.36	834.00	496.38	98.27
Plausible value 7	5712	145.19	837.91	496.27	99.34
Plausible value 8	5712	182.14	829.40	496.54	98.94
Plausible value 9	5712	141.97	800.89	495.67	97.99
Plausible value 10	5712	153.75	802.08	495.41	98.76

Endogenous Variables

Opportunity to Learn. The indicator of OTL for this study, inquiry-based science teaching and learning practices [IBTEACH], was a derived IRT scale based on students' responses to how often they engage in higher-level learning activities in science lessons, such as conducting or designing experiments, explaining or debating ideas, and applying science concepts (OECD, 2017; see Appendix A). Construct validation conducted by OECD (OECD, 2017) indicated high reliability for this scale in the U.S. sample (IBTEACH, $\alpha = .89$). This OTL indicator represents the instructional domain of OTL (Kurz, Elliott, Lemons, Zigmond, Kloo, & Kettler, 2014; Smithson, Porter, & Blank, 1995). It was selected to fill a gap in the literature that has primarily focused on content coverage, and to emphasize the importance of rigor in equitable distributions of OTL (Urick et al., 2018). Considering access to more rigorous instruction is important as assessing students' mastery of minimum basic skills and knowledge does not adequately address gaps in student preparation for postsecondary success (Giersch, 2016), particularly in higher education. Moreover, students' ability to apply science concepts in contexts outside of the classroom is aligned with an additional outcome of interest – scientific literacy – and goals for broader student success in STEM beyond those students interested in STEM education or careers (NRC, 2011).

Sense of Belonging. Sense of belonging to school [BELONG] was also a derived IRT scale based on students' extent of agreement with statements such as feeling awkward, lonely, or left out at school (OECD, 2017; see Appendix A for the full list of items). Construct validation by OECD (2017) indicated that reliability for this scale in the U.S. was high (BELONG, $\alpha = .86$).

Academic Climate. Consistent with past literature, measures of academic climate were selected to capture students' perceptions of the school's emphasis on high academic achievement, and the learning environment and morale created through supportive relationships and norms

(Bryk et al., 2010; Sebastian & Allensworth, 2012; Urick & Bowers, 2011, 2014; Werblow et al., 2013). Teacher interest [ST100Q01TA] was measured by a Likert-style student questionnaire item in which students responded *how often the teacher shows an interest in every students' learning in science classes*. Responses were reverse coded, *never or hardly ever* (1) to *every lesson* (4), so that higher values corresponded with increased frequency indicative of more positive academic climate. Descriptives were evaluated for skewness and kurtosis, and the variable was treated as continuous (Norman, 2010).

Order and academic press were both latent variables, each measured by five continuous factor indicators. Descriptives for all ten Likert-style questionnaire items were evaluated for skewness and kurtosis prior to performing confirmatory factor analysis (CFA) (Muthen, 2015; Norman, 2010) using Mplus v.7.4. CFA was used to assess measurement model fit before including latent variables in the full structural model. Preliminary CFA results indicated standardized factor loadings that ranged from 0.79-0.83 for order and 0.78-0.94 for academic press (see Figure 2). Each factor explained more than 50% of the variance in their respective indicators, with R^2 values ranging from 0.60-0.88 (Kline, 2011). Model fit was very good (RMSEA = 0.07; CFI = 0.97; TLI = 0.96; SRMR = 0.02) (see Kline, 2005; Hooper et al., 2008).

For the order items [ST097Q01TA-ST097Q05TA], students responded to how often disruptive things happen in science classes, such as students not listening to the teacher or the teacher waiting a long time for students to quiet down (see Figure 2 & Appendix A for the full list of items). Item responses were ordered so that higher values corresponded with a more orderly climate, *every lesson* (1) to *never or hardly ever* (4).

For the academic press items [ST104Q01NA-ST104Q05NA], students responded to how often they received feedback from teachers on their learning progress and goals in science class,

such as feedback on strengths in the science subject and areas for improvement, as well as ways to reach the student's learning goals (see Figure 2 & Appendix A for the full list of items). Item responses were ordered so that higher values reflected more frequent feedback related to student performance, *never or almost never* (1) to *every lesson or almost every lesson* (4).
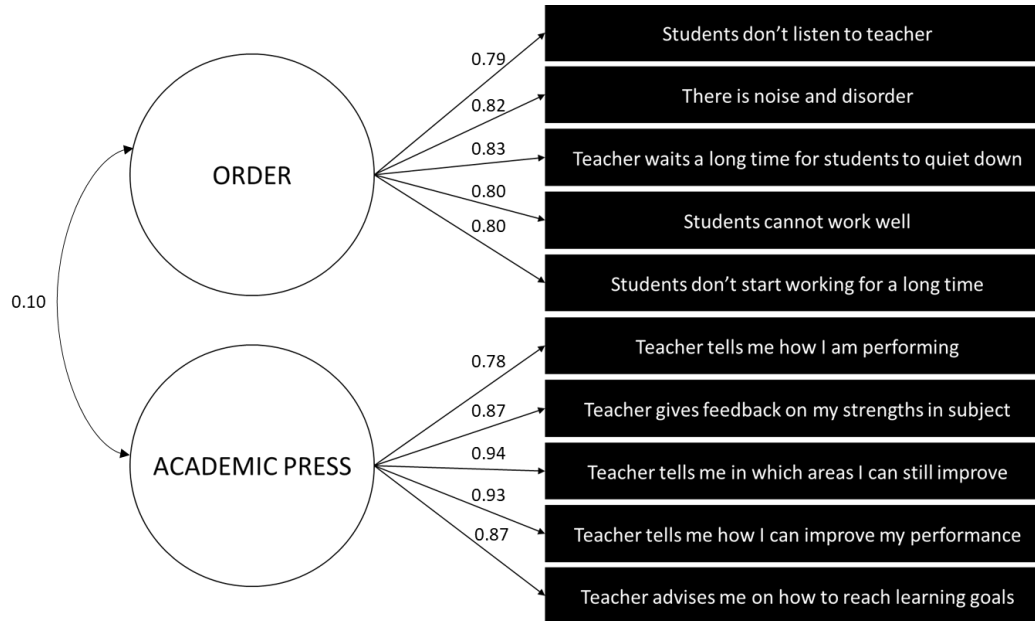
Figure 2. Measurement model with CFA standardized solution

Science Achievement. The measure of student achievement used for this study – scientific literacy – is reflective of PISA's emphasis on real-world application rather than alignment with curriculum frameworks (AIR, 2016; NCES, n.d.; NCES, 2007; NCES, 2010; Stephens & Coleman, 2007). Scientific literacy was measured by Plausible Values 1-10 in Science [PV1SCIE-PV10SCIE]. These values reflect multiple imputations based on IRT scaling and student questionnaire information because each student answered only a subset of assessment items (OECD, 2017). Because it is necessary to include all plausible values to avoid underestimation of standard errors (Laukaityte & Wiberg, 2017), a separate data file was created for each of the ten

plausible values and TYPE=IMPUTATION in Mplus was used to average estimates over the ten datasets and obtain correct standard errors (Muthen, 2013).

Analytic Technique

The purpose of this analysis was to identify how students' experiences in school – including access to OTL, sense of belonging, and academic climate – mediate the relationship between intersectional student background and science achievement. These mediating paths are important for identifying how schools structure inequalities that contribute to disparate outcomes, which has been overlooked in many studies focused on "achievement gaps" and student background. Moreover, the inclusion of intersectional student background groups in the analysis adds complexity to our understanding of inequity in schools by acknowledging the layers of privilege that translate to differential experiences and outcomes. This provides a critical examination of schools as both a reflection and perpetuator of systemic inequality. The full structural model that was tested (see Figure 3) was developed from the conceptual and theoretical framework in Figure 1.

Because the proposed model included both latent (see Figure 2) and mediating variables, a structural equation modeling (SEM) approach was used. Structural equation modeling (SEM) allows for the study of direct and indirect relationships between latent or observed variables of interest (Bollen, 1989; Bowen & Guo, 2012; Hox et al., 2018; Kaplan, 2009; Kline, 2011). In other words, a variable can serve as both a predictor and outcome in the same model. In SEM, the predictive relationships between variables are specified through the structural model, and the relationships between indicators and latent variables are specified through the measurement model (Hox et al., 2018) (see Figures 2 & 3). Incorporating latent variables through factor analysis enables the researcher to evaluate validity -- whether the indicators adequately measure the

intended construct -- while helping to reduce bias due to measurement error (Schumacker & Lomax, 2016).
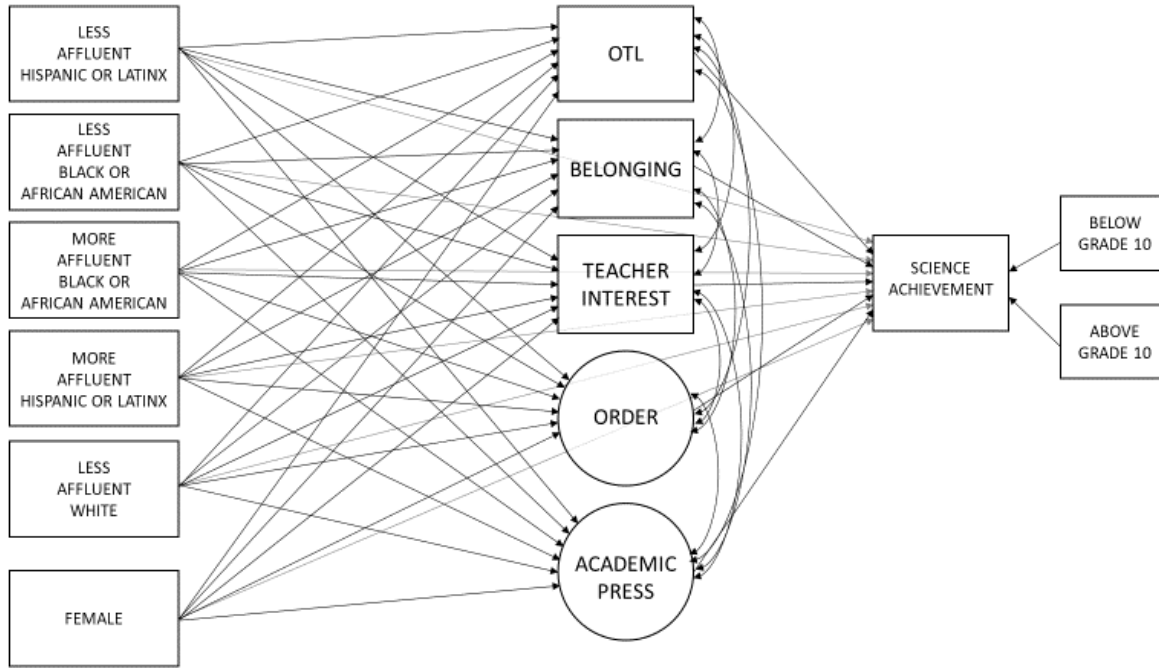
Figure 3. Full structural model

Mplus v.7.4 was used to conduct the SEM analysis. After evaluating preliminary measurement model fit, the full measurement and structural model was tested simultaneously. Because limited fit statistics are provided when replicate weights are used, an initial analysis was conducted using MLR estimation and only the final student weight [W_FSTUWT] was applied to examine fit of the full model. Fit statistics consistently indicated good model fit (RMSEA = 0.04; CFI = 0.97; TLI = 0.95; SRMR = 0.02), although the chi-square test of model fit was not interpreted due to sensitivities to sample size (see Kline, 2005; Hooper et al., 2008).

The final model was then tested using the final student weight [W_FSTUWT] and all 80 BRR replicate weights [W_FSTURWT1-W_FSTURWT80] with Fay's coefficient set to 0.5 for

representativeness (NCES, 2014). The replicate weights were used in conjunction with the TYPE=COMPLEX analysis command to appropriately adjust standard errors to account for nesting of students in schools and the two-stage, stratified sampling design (Muthén & Muthén, 1998-2017). Because replicate weights were included in this analysis, ML was used as the estimator (Muthén & Muthén, 1998-2017). The available fit statistics (RMSEA = 0.04; SRMR = 0.02) again confirmed good model fit.

Results

Direct Effects for Student Background, Prior Achievement, and Science Achievement

The test of direct effects of student background on science achievement demonstrated that each of the intersectional student background groups in the model – less affluent Hispanic or Latinx students, less affluent Black or African American students, more affluent Black or African American students, more affluent Hispanic or Latinx students, and less affluent White students – had significantly lower scientific literacy scores on the PISA assessment than more affluent White students (see Figure 4). Less affluent White students had the smallest gap, with scores around a third of a standard deviation lower than more affluent White students (β = -0.34, $p \le .001$). The gap between more affluent Hispanic or Latinx students and more affluent White students was a little under half of a standard deviation (β = -0.42, $p \le .001$), and for less affluent Hispanic or Latinx students, the gap was close to three quarters of a standard deviation (β = -0.77, $p \le .001$). The gap was highest for both groups of Black or African American students, with more affluent Black or African American students scoring a little over four fifths of a standard deviation lower than more affluent White students (β = -0.84, $p \le .001$) and less affluent Black or African American students scoring around one standard deviation lower than more affluent White students (β = -1.02, $p \le .001$).

Gender was also a significant predictor of science achievement. Females had significantly lower scientific literacy scores than males (β = -0.13, $p \le .001$).

Controls for prior achievement also indicated differences in scientific literacy outcomes based on student grade level (see Figure 4). 15-year-old students who were below grade 10 had a little over half of a standard deviation lower scientific literacy scores compared to students in grade 10 (β = -0.62, $p \le .001$), while students above grade 10 scored almost a quarter of a standard deviation higher than grade 10 students (β = 0.20, $p \le .001$).

Figure 4. Standardized path coefficients for SEM model of direct effects of student background and prior achievement on science achievement. Partial findings are presented for readability. See Figure 3 for the full model tested. Statistically significant paths are in black and nonsignificant paths are in grey. * p $\le$ .05, ** p $\le$ .01, *** p $\le$ .001

Direct and Indirect Effects for OTL

As seen in Figure 5, less affluent Hispanic or Latinx students (β = 0.13, p $\le$ .01), less affluent Black or African American students (β = 0.25, p $\le$ .01), more affluent Black or African

American students (β = 0.17 , p ≤ .05), and more affluent Hispanic or Latinx students (β = 0.14 ,

p ≤ .001) reported more frequent opportunities for inquiry-based science instruction (OTL) than

more affluent White students. Females reported less frequent inquiry-based science practices

(OTL) than males (β = -0.17, p ≤ .001).

OTL had a significant, negative direct relationship with scientific literacy outcomes (β = -

0.07, p ≤ .001) (see Figure 5). In other words, students who reported more frequent exposure to

OTL inquiry-based science had lower scientific literacy scores.

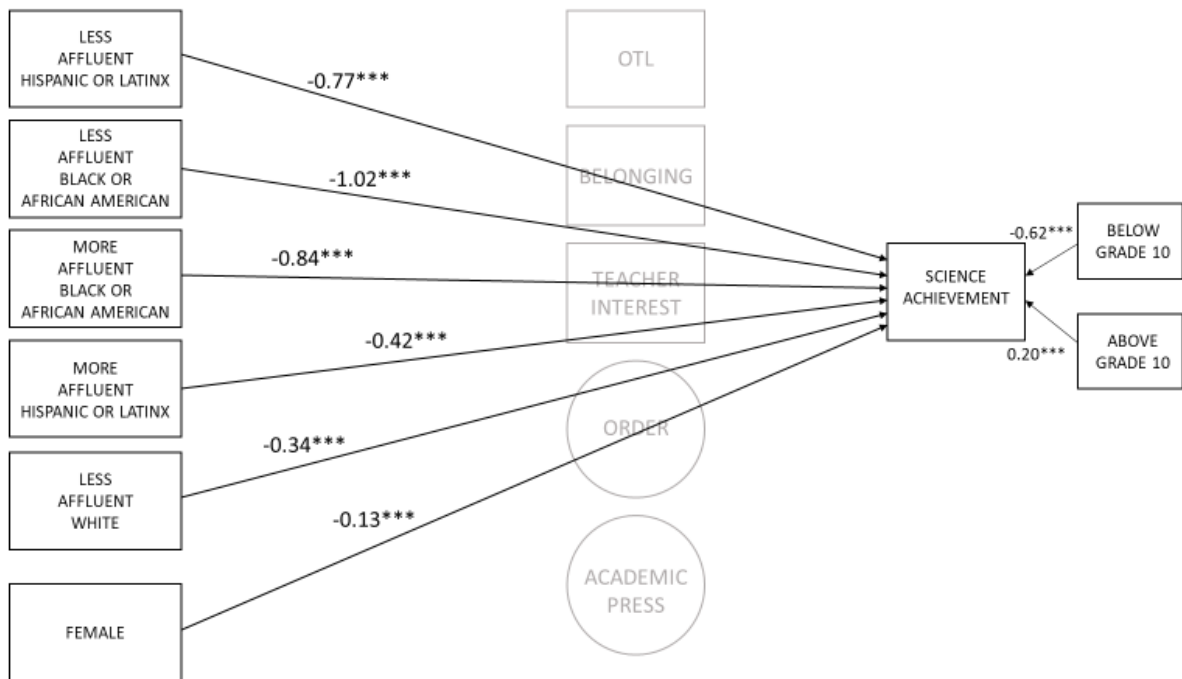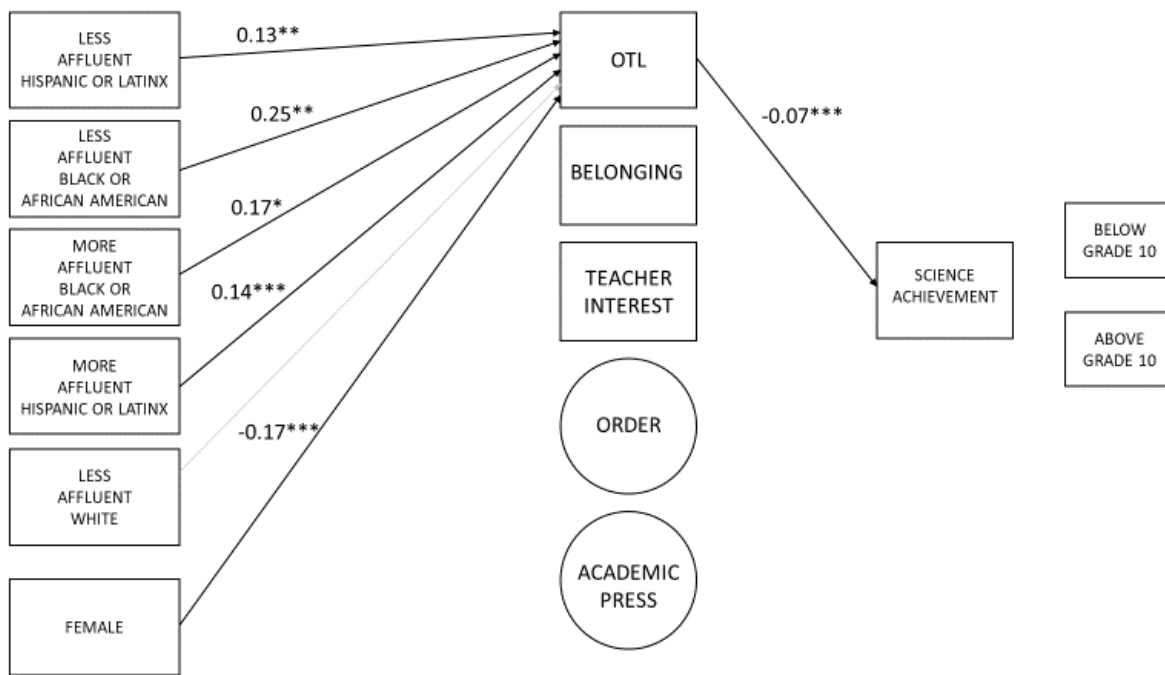**Figure 5.** Standardized path coefficients for SEM model of direct effects of student background on OTL and OTL on science achievement. Partial findings are presented for readability. See Figure 3 for the full model tested. Statistically significant paths are in black and nonsignificant paths are in grey. * p ≤ .05, ** p ≤ .01, *** p ≤ .001

Table 2. Standardized indirect effects for student background to achievement

	Standardized Indirect Effect	
Less Affluent Hispanic or Latinx to Science Achievement		
via OTL	-0.010	*
via Belonging	0.002	
via Teacher Interest	-0.007	
via Order	-0.035	***
via Academic Press	-0.041	***
Sum of indirect effects	-0.091	***
Less Affluent Black or African American to Science Achievement		
via OTL	-0.018	**
via Belonging	0.000	
via Teacher Interest	0.013	
via Order	-0.104	***
via Academic Press	-0.066	***
Sum of indirect effects	-0.175	***
More Affluent Black or African American to Science Achievement		
via OTL	-0.012	*
via Belonging	-0.001	
via Teacher Interest	-0.008	
via Order	-0.052	**
via Academic Press	-0.064	***
Sum of indirect effects	-0.137	***
More Affluent Hispanic or Latinx to Science Achievement		
via OTL	-0.010	*
via Belonging	0.001	
via Teacher Interest	-0.006	
via Order	0.000	
via Academic Press	-0.030	***
Sum of indirect effects	-0.045	***
Less Affluent White to Science Achievement		
via OTL	-0.003	
via Belonging	0.002	
via Teacher Interest	-0.004	
via Order	-0.034	***
via Academic Press	-0.019	
Sum of indirect effects	-0.057	***
Female to Science Achievement		
via OTL	0.012	***
via Belonging	0.002	
via Teacher Interest	-0.010	**
via Order	0.019	**
via Academic Press	0.031	***
Sum of indirect effects	0.054	***

Note: * $p \leq .05$, ** $p \leq .01$, *** $p \leq .001$

Moreover, OTL was a significant partial mediator of intersectional student background and achievement for most of the groups (see Table 2). There was a significant, negative indirect relationship between intersectional student background and scientific literacy outcomes via OTL for less affluent Hispanic or Latinx students ($\beta = -0.010$, $p \leq .05$), less affluent Black or African American students ($\beta = -0.018$, $p \leq .01$), more affluent Black or African American students ($\beta = -0.012$, $p \leq .05$), and more affluent Hispanic or Latinx students ($\beta = -0.010$, $p \leq .05$). This indirect relationship was negative because while each of the groups reported more frequent OTL than more affluent White students, OTL was a negative predictor of scientific literacy scores.

There was a significant, positive indirect relationship between gender and achievement through OTL ($\beta = 0.012$, $p \leq .001$). This indirect relationship was positive because female students reported less frequent OTL than male students and OTL was a negative predictor of science achievement.

Direct and Indirect Effects for Sense of Belonging

As seen in Figure 6, less affluent Hispanic or Latinx students ($\beta = -0.20$, $p \leq .001$), more affluent Hispanic or Latinx students ($\beta = -0.13$, $p \leq .001$), and less affluent White students ($\beta = -0.20$, $p \leq .001$) reported lower sense of belonging to school than more affluent White students. However, more affluent Black or African American students reported greater sense of belonging to school than more affluent White students ($\beta = 0.13$, $p \leq .01$). Females reported less sense of belonging to school than males ($\beta = -0.18$, $p \leq .001$).

Sense of belonging to school was not a significant predictor of science achievement (see Figure 6); therefore, there were no significant indirect relationships between intersectional student background or gender and achievement via sense of belonging to school.
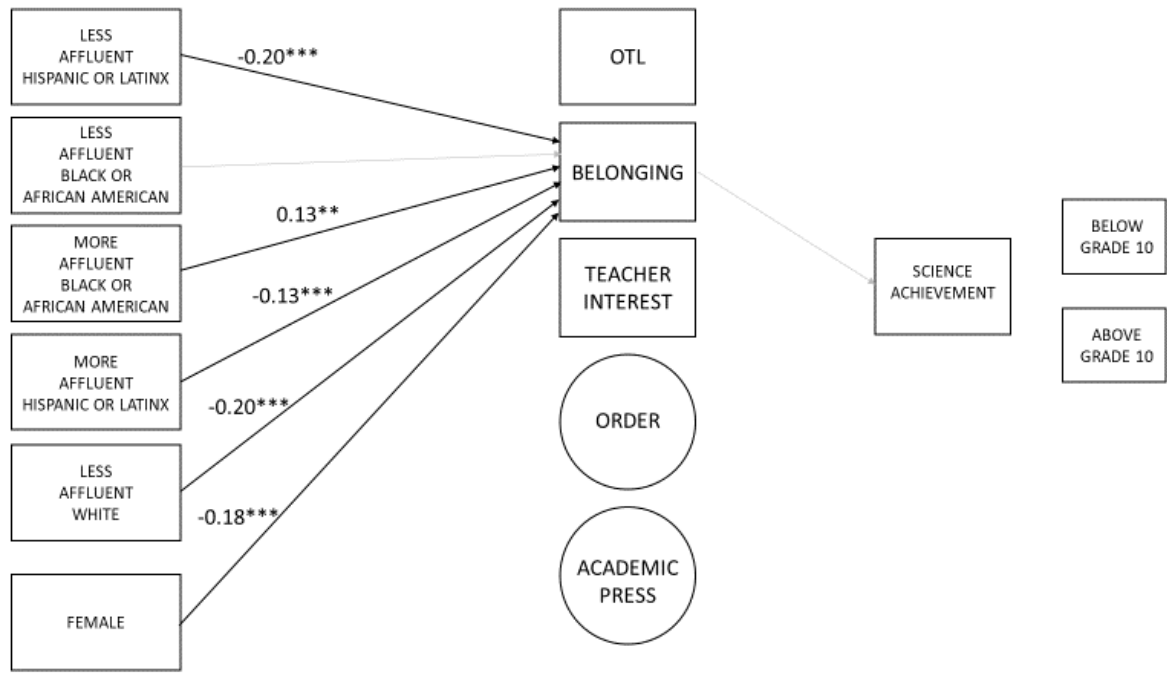
Figure 6. Standardized path coefficients for SEM model of direct effects of student background on sense of belonging and sense of belonging on science achievement. Partial findings are presented for readability. See Figure 3 for the full model tested. Statistically significant paths are in black and nonsignificant paths are in grey. * p ≤ .05, ** p ≤ .01, *** p ≤ .001

Direct and Indirect Effects for Teacher Interest

As seen in Figure 7, of the student background paths tested, only gender was a significant predictor of teacher interest in student learning. Females reported less frequent perceptions of teachers' interest in every student's learning in science class compared to males (β = -0.08; p ≤ .01).

There was a significant, positive direct relationship between teacher interest in every student's learning and scientific literacy outcomes (β = 0.12, p ≤ .001) (see Figure 7). In other words, students who perceived that their teacher showed an interest in every student's learning more frequently had higher scientific literacy scores.

Teacher interest in student learning was also a significant partial mediator of gender and science achievement (see Table 2). There was a significant, negative indirect relationship between gender and scientific literacy outcomes via teacher interest (β = -0.010, p ≤ .01). This indirect relationship was negative because females reported less frequent teacher interest, and teacher interest was a positive predictor of scientific literacy scores.
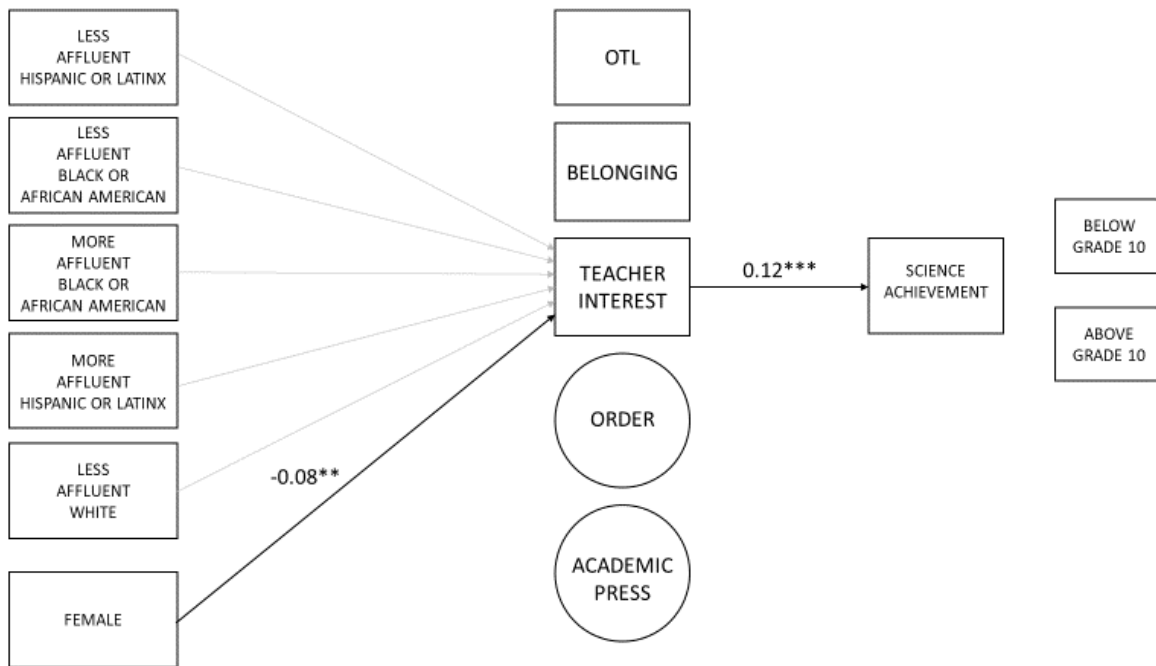
Figure 7. Standardized path coefficients for SEM model of direct effects of student background on teacher interest in student learning and teacher interest on science achievement. Partial findings are presented for readability. See Figure 3 for the full model tested. Statistically significant paths are in black and nonsignificant paths are in grey. * p ≤ .05, ** p ≤ .01, *** p ≤ .001

Direct and Indirect Effects for Order

As seen in Figure 8, less affluent Hispanic or Latinx students (β = -0.17, p ≤ .001), less affluent Black or African American students (β = -0.49, p ≤ .001), more affluent Black or African American students (β = -0.25, p ≤ .01), and less affluent White students (β = -0.16, p ≤ .001) reported a less orderly academic climate in their science classes than more affluent White students.

Less affluent Black or African American students reported that their science classes were around a half of a standard deviation less orderly than more affluent White students' science classes, the highest gap among the groups. Females reported a more orderly academic climate in science classes than males ($\beta = 0.09$, $p \leq .01$).

Order had a significant, positive direct effect on science achievement ($\beta = 0.21$, $p \leq .001$) (see Figure 8). Students who perceived a more orderly academic climate in science classes had higher scientific literacy scores.

Order was also a significant partial mediator of intersectional student background and achievement for most of the groups (see Table 2). There was a significant, negative indirect relationship between intersectional student background and achievement via order for less affluent Hispanic or Latinx students ($\beta = -0.035$, $p \leq .001$), less affluent Black or African American students ($\beta = -0.104$, $p \leq .001$), more affluent Black or African American students ($\beta = -0.052$, $p \leq .01$), and less affluent White students ($\beta = -0.034$, $p \leq .001$). The indirect relationship was negative because these groups reported a less orderly academic climate in science compared to more affluent White students, and order was a positive predictor of scientific literacy.

There was a significant, positive indirect relationship between gender and achievement via order ($\beta = 0.019$, $p \leq .01$). This indirect relationship was positive because females reported a more orderly academic climate in science classes than males, and order was a positive predictor of science achievement.

Figure 8. Standardized path coefficients for SEM model of direct effects of student background on order and order on science achievement. Partial findings are presented for readability. See Figure 3 for the full model tested. See Figure 2 for the measurement model. Statistically significant paths are in black and nonsignificant paths are in grey. * p ≤ .05, ** p ≤ .01, *** p ≤ .001

Direct and Indirect Effects for Academic Press

As seen in Figure 9, less affluent Hispanic or Latinx students (β = 0.24, p ≤ .001), less affluent Black or African American students (β = 0.39, p ≤ .001), more affluent Black or African American students (β = 0.37, p ≤ .001), and more affluent Hispanic or Latinx students (β = 0.18, p ≤ .001) reported more frequent academic press, or feedback from teachers on their learning progress and goals in science class, compared to more affluent White students. For both less and more affluent Black or African American students, this gap was a little more than a third of a standard deviation, the highest among the groups. Females reported less frequent academic press in science class than males (β = -0.18, p ≤ .001).

Academic press had a significant, negative direct effect on science achievement (β = -0.17, p ≤ .001) (see Figure 9). In other words, students who reported more frequent feedback related to their performance in science class had lower scientific literacy scores.
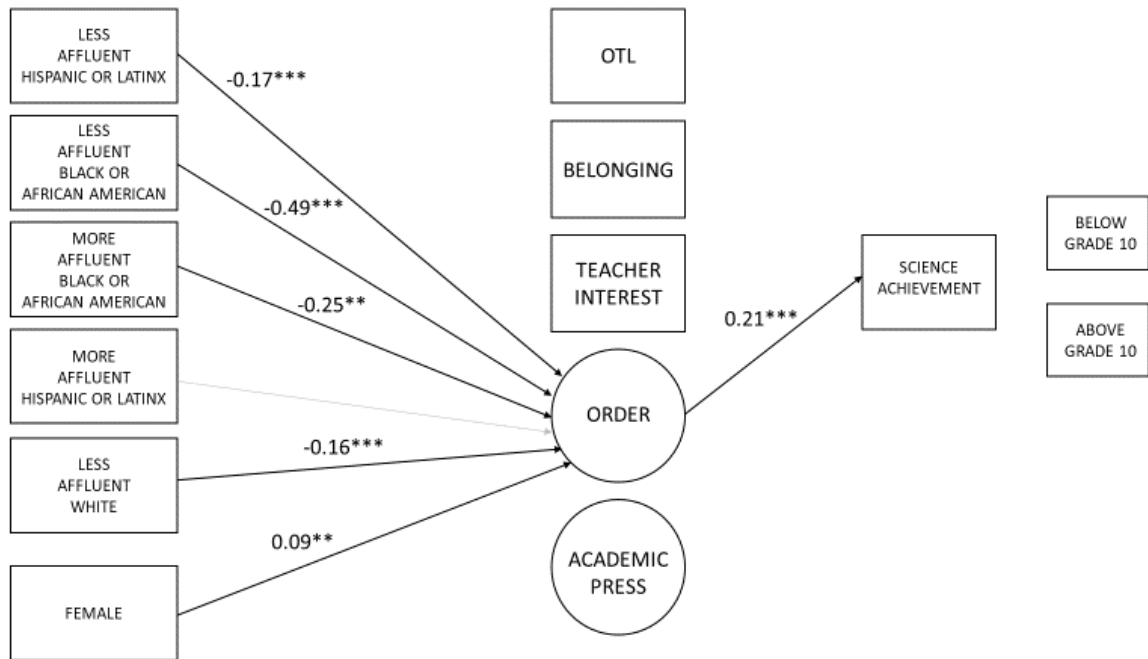

Figure 9. Standardized path coefficients for SEM model of direct effects of student background on academic press and academic press on science achievement. Partial findings are presented for readability. See Figure 3 for the full model tested. See Figure 2 for the measurement model. Statistically significant paths are in black and nonsignificant paths are in grey. * p ≤ .05, ** p ≤ .01, *** p ≤ .001

Academic press was also a significant partial mediator of intersectional student background and science achievement for most of the groups (see Table 2). There was a significant, negative indirect relationship between intersectional student background and scientific literacy outcomes via academic press for less affluent Hispanic or Latinx students (β = -0.041, p ≤ .001), less affluent Black or African American students (β = -0.066, p ≤ .001), more affluent Black or African American students (β = -0.064, p ≤ .001), and more affluent Hispanic or Latinx students (β = -

0.030, p ≤ .001). The indirect relationship was negative because each of these groups reported more frequent academic press compared to more affluent White students, and academic press was a negative predictor of scientific literacy.

There was a significant, positive indirect relationship between gender and science achievement via academic press (β = 0.031, p ≤ .001). This indirect relationship was positive because females reported less frequent academic press in science class than males, and academic press was a negative predictor of scientific literacy.

See Table 3 for correlations between mediating variables in the model.

Table 3. Correlation coefficients for mediating variables in model

	OTL	Belonging	Interest	Order	Press
OTL		0.11***	0.41***	0.03	0.40***
Belonging			0.11***	0.13***	0.14***
Interest				0.21***	0.39***
Order					0.11***
Press					

Note: * p ≤ .05, ** p ≤ .01, *** p ≤ .001

Discussion

The direct and indirect findings from this study have provided important insight about school mediators that can help account for the gap in science outcomes in the U.S. In particular, student perception of teacher interest in all students' learning appears to be an important mediator of gender and science achievement. Moreover, while OTL inquiry-based science, academic press, and order were significant mediators of both gender and intersectional student background and scientific literacy outcomes, some of the findings operated in the opposite direction than anticipated, which warrants further examination.

Girls perceived that teachers showed an interest in all students' learning in science classes less frequently than boys, and teacher interest was a positive predictor of science achievement. These findings suggest that a better understanding of potential gender bias among teachers in science classes, patterns of interaction with students, science instructional approaches that are responsive to student learning needs, how teachers communicate their priorities for student learning, and how students perceive these messages, might be important avenues for addressing gender disparities in science outcomes (Else-Quest et al., 2013; Riegle-Crumb et al., 2011; *The AAUW report*, 1992; Wang & Degol, 2017). Further, because gender could not be included as an intersectional student background indicator in the LCA, future research might examine potential interactions between gender and intersectional student background profiles on perceptions of teacher interest in all students' learning.

While sense of belonging to school was not a significant predictor of science achievement, and therefore not a significant mediator of student background and achievement, the disparities in reports of sense of belonging to school by gender and intersectional student background are potential avenues for further inquiry. One of the groups that was among the lowest in scientific literacy scores, more affluent Black or African American students, reported the highest agreement with sense of belonging to school compared to more affluent White students. Conversely, the groups with one of the smallest gaps in achievement compared to more affluent White students, the less affluent White group, reported some of the lowest agreement with sense of belonging to school. Given these conflicting results and the lack of relationship between sense of belonging to school and achievement, further research might focus on sense of belonging to school as an important affective outcome itself, apart from achievement, as well as the school practices and structures that promote student sense of belonging to school. This would require a multilevel

approach to examining student sense of belonging. Further, because the measures of sense of belonging to school used in this study focused primarily on a general sense of belonging and fitting in with peers, it would be beneficial to expand the scope of measures to include student orientation to academic aspects of the school, including coursework content, instructional practices, and academic identity. These dimensions of belonging might help untangle why students who have been historically underserved by schools through structures such as tracking might nonetheless experience a sense of belonging with peers while receiving inequitable educational opportunities (see Chambers, 2009).

While results for order operated in the expected direction, the results for OTL inquiry-based science and academic press were more conflicting and require additional examination. As expected, a more orderly climate for learning was associated with higher achievement, and all groups but one reported significantly less orderly environments than more affluent White students. Thus, order in the learning environment is a significant avenue of inequality in schools that translates to lower science outcomes for less affluent students and Students of Color. One possible explanation for this pattern of disorder might be that residential and school segregation patterns have contributed to inequities in access to qualified teachers, with Students of Color disproportionately attending overcrowded schools with less experienced and qualified teachers, fewer resources, and less rigorous learning opportunities (Berliner & Glass, 2014; Darling-Hammond, 2013; Flores, 2007; Orfield & Lee, 2006; Darling-Hammond, 2004a; Darling-Hammond, 2004b; Oakes, 1990). It is also possible that the problem of less experienced and qualified teachers is also exacerbated by inadequacies in teacher preparation programs – which are comprised of predominately White, middle class females (Sleeter, 2017) – to inculcate orientations and effective practices for teaching students from different backgrounds, including culturally

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responsive teaching, humanizing pedagogy (Camangian, 2015), and perspective taking (Warren, 2018). Thus, understanding patterns of access to qualified teachers, as well as instructional approaches by both student and teacher background, would be a useful agenda for future study.

Students from a majority of the intersectional background groups reported more frequent opportunities for inquiry-based science instruction compared to more affluent White students, as well as more frequent feedback related to science learning, both of which were negative predictors of scientific literacy. Notably, only the less affluent White group did not report significant differences in OTL or academic press compared to the more affluent White group, which might help explain the smaller gap in scientific literacy outcomes. The negative relationship between OTL inquiry-based science and achievement, and between academic press and achievement, has provided important insight into the ways that differential instructional approaches translate to lower academic performance. While research on OTL and academic climate has indicated that both OTL and academic press can support higher academic achievement, this study has helped identify potential constraints on these relationships. Because the PISA assessment focuses on scientific literacy, teachers could not "teach to the test" in the same way as for assessments more closely aligned with standards or curricular frameworks. Thus, it is possible that while Students of Color and students from less affluent backgrounds, and students at the intersections of these and other marginalized communities, reported more frequent exposure to OTL and academic press, these instructional practices might still be more closely aligned to a rote, testing emphasis with a focus on narrow knowledge or skills. The federal emphasis on educational accountability over the past several decades through the use of standardized curriculum and high-stakes assessments has dramatically influenced current practices, mindsets, and policies at all levels of education. For example, teachers have reported that they have been pressured to abandon the teaching practices

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that they learned in their teacher preparation programs in favor of scripted or "teacher proof" curriculum that is not responsive to the needs of students (Irizarry, 2011; Lipman, 2004; Stritikus & English, 2009). The tendency of U.S. education policy to focus on improving outcomes without addressing inequitable inputs or processes that produce them might also help explain why teachers have continued to be ill-prepared to effectively teach students from diverse backgrounds despite the changing demographics in U.S. schools (Sleeter, 2017).

This also raises important issues about the nature of the assessment with implications for equity. On one hand, the scientific literacy focus of PISA provides important evidence to supplement information from tests designed to assess attainment of minimum expectation for proficiency, such as state accountability tests. The focus on application in different situations and contexts provides an additional layer of evidence of inequity, particularly in higher level cognitive processes, that could help explain differential access to and attainment of postsecondary education and career opportunities (Giersch, 2016). This is born out in the results, which indicated a significant gap between all intersectional background groups and more affluent White students, as well as between girls and boys. While these results can help underscore the problem of access to opportunities that promote success in the application of higher-level science knowledge and skills, it is also important to critically evaluate the limitations of these standardized testing results. First, because of PISA's focus on application and lack of alignment with curriculum frameworks, these results are designed to reflect students' formal and informal learning, both inside and outside of school. This confounding of within-school and outside-of-school influences might help explain why sense of belonging to school was not a predictor of scientific literacy. While the purpose of this study is to examine malleable school characteristics that influence student success on these outcomes, it is important to acknowledge how systemic inequality outside of schools, and

perpetuated by schools, bears on these outcomes. This highlights the need for more comprehensive policy approaches to address disparities in academic achievement, as well as the need to engage in pedagogy that empowers students to identify and address issues of systemic inequality (Camangian, 2015; Freire, 2000; Irizarry, 2011; Schultz, 2018). It also underscores the critical orientation of this study to the term "achievement," which emphasizes how differential experiences and opportunities in school associated with student background, as a reflection of schools' complicity in social hierarchies of privilege and power (Bourdieu, 1977a,b), translate to gaps in student outcomes (Chambers, 2009). Finally, it is important to critically evaluate the limitations of the assessment in measuring what students know and how they apply their knowledge and skills. Just as the curriculum and related assessments have privileged some forms of knowledge over others (Milner, 2013), the PISA assessment does not reflect the full extent of valuable knowledge that students possess that might be more readily demonstrated in alternative assessment contexts (see Kanes, Morgan, & Tsatsaroni, 2014).

The need to identify a reference group for the regression of outcomes on intersectional student background is another important limitation of this methodological approach. Because the purpose of this study was to critically examine students' inequitable experiences in schools to explain science outcome gaps, the more affluent White group was selected as a reference group to highlight how school features reinforce hierarchies of privilege. Despite its critical intent, however, this approach has the potential to reinforce the more affluent White group as the normative group, a tendency that this study hopes to disrupt. Thus, an important next step for this line of critical research is to identify alternative models that more effectively center the experiences of marginalized groups while addressing issues of systematic inequity.

Implications for Policy, Practice, and Future Research

The logic of accountability policy over the past decades has relied on more of certain mechanisms to attempt to address outcome disparities – more testing, more accountability, more standards, and more teacher evaluation. The findings from this study highlight the important lesson that more is not necessarily better nor equitable. In this study, students from historically underserved backgrounds reported more frequent OTL inquiry-based science and feedback related to science performance. However, both of these instructional practices were negative predictors of achievement, which demonstrates that the "receivement gap" (Chambers, 2009) is not only perpetuated by lack of access to opportunities, but also by providing more of the wrong opportunities. Fundamentally, this calls for a critical reexamination of certain practices as "opportunities to learn". The challenge for policymakers, practitioners, and researchers is to disrupt the pattern of providing more interventions without critically evaluating the differential value and impact of those actions, particularly for students who have experienced dehumanizing curriculum, instructional practices, and educational structures connected to a history of systemic inequality and institutionalized racism. This requires attention to the needs, assets, and perspectives as articulated by students, families, and community members of oppressed groups to collaboratively problem-solve around issues of educational inequity (Freire, 2000). It also requires an approach to education that is student-centered and responsive to community cultural wealth (Yosso, 2005), which challenges the one-size-fits-all approach to teacher preparation, instruction, curriculum, and accountability that has dominated education policy, research, and practice.

Appendix A. List of variables

	Construct	PISA Index/Variable	Question/Item
student level	student background	ST004D01T	Are you female or male?
		RACETHC	NAT/Collapsed derived student race/ethnicity
		Immigration background (IMMIG)	In what country were you and your parents born?
		Language spoken at home (LANGN)	What language do you speak at home most of the time?
	student background: social class	Highest educational level of parents (HISCED)	What is the highest level of schooling (not including college) completed by your mother/father? Does your mother/father have any of the following degrees, certificates, or diplomas?
		Highest occupational status of parents (HISEI)	What is your mother's main job? What does your mother do in her main job? What is your father's main job? What does your father do in his main job?
		Family wealth (WEALTH)[1]	Which of the following are in your home? - A room of your own - A link to the internet How many of these are at your home? - Televisions - Cars - Rooms with a bath or shower - Computers - Tablet computers - E-book readers
	student background: cultural capital	Parents emotional support (EMOSUPS)[1]	Thinking about this school year: to what extent do you agree or disagree with the following statements? - My parents are interested in my school activities - My parents support my educational efforts and achievements - My parents support me when I am facing difficulties at school - My parents encourage me to be confident
		Cultural possessions at home (CULTPOSS)[1]	Which of the following are in your home? - Classical literature - Books of poetry - Works of art - Books on art, music, or design How many of these are there at your home? - A musical instrument
		Home educational resources (HEDRES)[1]	Which of the following are in your home? - A desk to study at - A quiet place to study - A computer you can use for your school work - Educational software - Books to help with your school work - Technical reference books or manuals - A dictionary
		ST013Q01TA	How many books are there in your home?

opportunity to learn	Inquiry-based science teaching and learning practices (IBTEACH)	When learning science topics at school, how often do the following activities occur? • Students are given opportunities to explain their ideas • Students spend time in the laboratory doing practical experiments • Students are required to argue about science questions • Students are asked to draw conclusions from an experiment they have conducted • The teacher explains how a science idea can be applied to a number of different phenomena (e.g. the movement of objects, substances with similar properties) • Students are allowed to design their own experiments • There is a class debate about investigations • The teacher clearly explains the relevance of science concepts to our lives	
student belonging	Sense of Belonging to School (BELONG)	Thinking about your school: to what extent do you agree with the following statements? • I feel like an outsider (or left out of things) at school. • I make friends easily at school. • I feel like I belong at school. • I feel awkward and out of place in my school. • Other students seem to like me. • I feel lonely at school.	
academic climate: teacher interest	ST100Q01TA	How often do these things happen in your science classes? • The teacher shows an interest in every students' learning	
academic climate: order	ST097Q01TA ST097Q02TA ST097Q03TA ST097Q04TA ST097Q05TA	How often do these things happen in your science classes? • Students don't listen to what the teacher says • There is noise and disorder • The teacher has to wait a long time for students to quiet down • Students cannot work well • Students don't start working for a long time after the lesson begins	
academic climate: academic press	ST104Q01NA ST104Q02NA ST104Q03NA ST104Q04NA ST104Q05NA	How often do these things happen in your classes for this science course? • The teacher tells me how I am performing in this course • The teacher gives me feedback on my strengths in this science subject • The teacher tells me in which areas I can still improve • The teacher tells me how I can improve my performance • The teacher advises me on how to reach my learning goals	
grade level	ST001D01T	What grade are you in?	
scientific literacy	PV1SCIE, PV2SCIE,	Plausible Values 1-10 in Science	

		PV3SCIE, PV4SCIE, PV5SCIE, PV6SCIE, PV7SCIE, PV8SCIE, PV9SCIE, PV10SCIE	

Notes: [1]Raw item responses used to create composites that align with PISA index

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ARTICLE 3

**"Complicating Cultural Reproduction Theory: A Critical Multilevel Analysis of
Systematic Inequality in U.S. Schools"**

Abstract

The purpose of the current study is to examine the malleable school practices and norms that
contribute to inequitable school learning environments based on student background. While
addressing inequities in education requires attention to broader structures and policies, it is
important to identify how educators can begin to address the factors that perpetuate disparities in
educational access and outcomes within their schools. Using multilevel structural equation
modeling (SEM) with the U.S. sample of PISA 2015, this study examines the extent to which
student-level access to inquiry-based science learning opportunities and academic press mediates
the relationship between intersectional student background and scientific literacy outcomes, as
well as the influence of school-level context, tracking, and academic climate variables on student
learning opportunities, perceptions of academic press, and science outcomes. After accounting for
variance explained at the school level, OTL was not a significant mediator of the relationship
between student intersectional background or gender and scientific literacy outcomes. However,
academic press was a significant mediator at the student level, and was a significant negative
predictor of science achievement. At the school level, while tracking was not a significant predictor
of mean school science achievement, tracking was a predictor of mean school academic press and
OTL inquiry-based science. There were significant differences in school academic climate based
on school context, and school-level perceptions of academic climate were significant predictors of
science achievement, findings that can inform education policy and practice.

Introduction

The democratic ideals of education as an equalizer have been disconnected from the reality of schooling throughout U.S. history (Nieto, 2005). The history of differential access to meaningful, high-quality educational opportunities has been shaped by, and has helped shape, the trajectory of discrimination and systemic inequality in the U.S. This is clearly illustrated by Southern legislation in the early 1800s that made educating enslaved people illegal (Spring, 2001), followed by a post-Civil War "system of second-class education for blacks" that "was the logical outgrowth of a social ideology designed to adjust black southerners to racially qualified forms of political and economic subordination" (Anderson, 1988, p. 3). The system of segregated schooling that was judicially sanctioned by the *Plessy v. Ferguson* ruling in 1896 perpetuated the practice of providing inadequate resources to schools attended by Students of Color until it was struck down by the *Brown v. Board of Education* decision in 1954 (Chambers, 2009; Cordasco, 1973; Spring, 2001). Over a decade after *Brown v. Board of Education*, the Supreme Court had to intervene to address the slow pace of desegregation efforts (Kantor & Lowe, 2013).

Latinx students have also experienced segregation (Alvarez, 1986) as a strategy of deculturalization, as well as the outright denial of education to some migrant children and the passive exclusion of Mexican children through the violation of school attendance laws (Spring, 2001). For Native American students, the U.S. adopted a strategy of isolation through the creation of boarding schools that removed children from their family and tribal language and customs (Spring, 2001). Thus, schools have played an important role in deculturalization efforts, and a focus on adopting the English language was a central focus of such policies (Spring, 2001). Other deculturalization strategies employed through education have involved the use of curriculum and textbooks aligned with the dominant culture and teachers who represented the dominant culture (Spring, 2001). By demonstrating the role of education as a product and tool of inequality and

oppression, this brief history provides a helpful contextual lens for considering contemporary issues around student background and opportunity to learn, as well as the school structures, policies, and practices that have perpetuated educational inequities.

Perpetuation of Inequality Through School Structures, Policies, and Practices

A review of contemporary school structures, policies, and practices reveals that the education system has shifted to more covert strategies for providing differential educational opportunities to students. Academic tracking represents one such mechanism by which students are purportedly sorted by ability into hierarchical courses or course sequences that vary in the level of rigor and engaging instruction, with disproportionate numbers of Students of Color and lower-SES students assigned to lower tracks (Bottia et al., 2016; Lucas & Beresford, 2010; Mickelson & Everett, 2008; Oakes, 1982; Oakes, 2005; Watanabe, 2008; Werblow et al., 2013).

Academic tracking reflects a social mobility goal for education that is predicated on competition and gaining individual advantages, which fundamentally requires the inequitable distribution of opportunities (Labaree, 1997). Further, this system of stratification is reinforced by those who benefit the most from it (Labaree, 1997) and seek to maintain their social privilege and power. Assignment of students to lower tracks is often made based on the assumption that those students will not pursue higher education, and consequently students do not develop the academic knowledge and skills, nor complete the course prerequisites, for attending college (Burciaga, Huber, & Solorzano, 2009; Irizarry, 2011). These decisions can be made on behalf of students without their knowledge, without parental input, and without explicitly communicating to students or their families how their course enrollment will affect their career and higher education opportunities upon graduation (Auerbach, 2002; Irizarry, 2011).

The view that education should play a key role in assimilating students from different cultures is still influential today (Boykin & Noguera, 2011), reflected in the evolution of federal English language policies since the 1960s that have impacted the education opportunities afforded to English learners (ELs). The most notable pattern in these federal policies is the shift from provision of bilingual education to an exclusive focus on English language proficiency (Gándara & Rumberger, 2009). Most ELs are second-generation immigrants, and Spanish is the native language of over 75% of ELs (Gándara & Rumberger, 2009). As a result of English language policies in education, Latinx students and their families have felt pressure to discontinue the use of Spanish as their primary language (Alemán, 2013) and schools have adopted subtractive approaches to language instruction (Gutiérrez, 2004; Stritikus & English, 2009). Subtractive approaches to schooling include programs that attempt to rapidly transition students into mainstream classrooms without adequate support for students' emerging language acquisition (Stritikus & English, 2009) and policies that discourage students from speaking their native languages even outside of formal learning spaces (Irizarry, 2011). Latinx students' acquisition of English is often prioritized over dual development of their native and second language despite evidence that suggests that students who are the most fluent bilinguals are also the most academically successful (Zentella, as cited in Nieto, 1998). Rather than encouraging and developing Latinx students' bilingualism, students have been punished for their resistance to English-only policies in schools and classrooms (Irizarry, 2011) and schools have "distort[ed] the academic and linguistic competence of Latino students" (Stritikus & English, 2009, p. 410). This has occurred despite evidence that maintaining bicultural identities supports students' academic, psychological, and social well-being (Carter, 2013).

In addition to tracking structures and language policies, curriculum has been used as a tool for social reproduction and student marginalization. Over the past several decades, many scholars have illustrated how school curriculum functions as an ideological tool. Anyon's (1980) analysis of the *hidden curriculum of work* provided insight into how curriculum and instruction can reproduce systems of power and social class relations by promoting knowledge and skills that prepare students to maintain their social class status. Further, Connell (1994) has referred to the *hegemonic curriculum* as a hierarchical system that legitimizes certain knowledge and experiences while marginalizing others. This is consistent with Anyon's (1979) conclusion that curriculum legitimizes certain forms of knowledge that serve ideological interests as a covert exercise of power. Similarly, according to Blanchett (2006), "Master Scripting is defined as the dominant culture's monopoly on determining the essential content of the official curriculum and subsequently the pedagogical practices used to deliver it" (p. 26). A key illustration of Master Scripting is the omission or distortion of histories or representations of People of Color from the curriculum, which subsequently reduces opportunities to challenge narratives and stereotypes that have marginalized Students of Color in schools (Blanchett, 2006; Irizzary, 2011). In classrooms, cultural mismatch, or differences in cultural backgrounds between students and educators (Carter, 2013), have lead to instructional approaches that fail to engage students, as well as disproportionate discipline referrals for less affluent students and Students of Color when their behavior conflicts with school norms (Milner, 2010).

Although scholars have called for the use of asset-based approaches to instruction (see Villegas & Lucas, 2002), such as culturally relevant pedagogy (Ladson-Billings, 1995, 2014), that acknowledge and affirm students' *funds of knowledge* (Irizarry, 2011; Moll, Amanti, Neff, & Gonzalez, 1992) and are more responsive to racially and ethnically diverse students' learning

needs, these calls have not been adequately addressed by teacher preparation programs and professional development coordinators (Blanchett, 2006; Irizarry & Raible, 2011). Despite shifting demographics in the U.S. and its schools, which reflects growing racial, ethnic, and linguistic diversity, as well as widening wealth disparities (Nieto, 2005), the majority of teachers and students enrolled in teacher preparation programs are White, monocultural, English-speaking women (Irizarry & Raible, 2011). According to Cochran-Smith, Davis, and Fries (2004), teacher preparation programs are approached from a "monocultural perspective (Zeichner & Hoeft, 1996) that eschews the pervasive impact of race, class, linguistic background, culture, gender, and ability (King & Castenell, 2001a) and emphasizes instead a universal knowledge base for teaching, learning, and schooling (Grant & Wieczorek, 2000; Nieto, 2001)" (p. 932). This is a particularly important issue given that the majority of teachers come from White, middle-class backgrounds because a monocultural perspective is less likely to conflict with their own educational and life experiences, and therefore less likely to be challenged, further reinforcing it as the dominant perspective. Further, many preservice teachers begin teaching "believing negative stereotypes about urban children and their schools and having scant knowledge of structural barriers to student achievement such as racism and classism" (Irizarry & Raible, 2011, p. 189; see Sleeter, 2001).

In sum, contemporary practices such as the hierarchical grouping of students, subtractive approaches to language instruction, narrow curriculum, and lack of preparation for culturally responsive teaching have contributed to the development of deficit perspectives among many educators and scholars, rather than a critical questioning of school assumptions, structures, and norms. Moreover, these school-centered, rather than student-centered, approaches to education must be examined as a reflection of, and perpetuator of, broader issues of systemic inequality in the U.S. In particular, patterns of segregation in the U.S. have contributed to vast inequalities

between schools serving more affluent students and schools serving lower-income students and Students of Color.

Systemic Inequality and Segregation

Rising racial segregation of schools reflects increasing residential segregation due to the persistent effects of *de jure* segregation and U.S. policymakers' failure to confront what Rothstein (2015) refers to as the myth of *de facto* segregation. Current patterns of residential segregation reflect the lasting impact of discriminatory policies again African Americans, including barriers to promotion, limited access to labor unions, exclusion from labor laws, and lower salaries, that have contributed to the Black-White wealth gap (Rothstein, 2015). According to Rothstein (2015), exclusionary zoning laws have also served to reinforce residential segregation. Further, school segregation has been exacerbated by the end of desegregation orders precipitated by Supreme Court decisions in the 1990s (Orfield, 2001).

Orfield and Lee (2006) have argued that segregation in schools involves a "syndrome of inequalities related to the double or triple segregation these schools typically face" (p. 29), including racial and linguistic segregation and concentrated poverty. Schools with high concentrations of low-income students and Students of Color are often located in urban districts, and comparisons between these urban districts and nearby affluent suburban districts illustrates how funding inequalities translate to opportunity gaps (Darling-Hammond, 2004a). Scholars have documented how Students of Color and low-SES students attending highly segregated, inadequately funded schools experience overcrowding, fewer facilities and resources, less qualified and experienced teachers, and less rigorous curricular opportunities (Berliner & Glass, 2014; Darling-Hammond, 2013; Flores, 2007; Orfield & Lee, 2006; Darling-Hammond, 2004a; Darling-Hammond, 2004b; Oakes, 1990).

Collectively, this history of inequality in education, overview of current structures and practices in schools, and influential policies that bear on education illustrate that the opportunity gaps in schools reflect a U.S. legacy of discrimination and systemic inequality. Paradoxically, schools have been complicit in social and cultural reproduction (Bourdieu, 1977a) even as "educational reform has been the federal government's favored solution to problems of poverty, inequality, and economic insecurity" (Kantor & Lowe, 2013, p. 25) in lieu of other social and economic supports. Rothstein and Wilder (2005) have suggested that the key to eliminating academic inequalities is not just addressing education in isolation, but rather there is a need to confront the system of inequalities that influence a range of outcomes (e.g. economic, unemployment). This requires attention to growing income inequality (García & Weiss, 2017) that contributes to residential segregation (Rothstein, 2015), food insecurity, disparities in access to healthcare and high-quality early childhood education, and differential exposure to language and educational resources, all of which influence students' academic success (Barnett & Lamy, 2013; Berliner & Glass, 2014; Darling-Hammond, 2013; Putnam, 2015; Royce, 2019; Weiss, 2014). Given that gaps in learning exist before students even start school (Alexander, Entwisle, & Olson, 2014; Barnett & Lamy, 2013; Jencks & Phillips, 1998; Royce, 2019) and continue to widen as students progress through school (Chatterji, 2006; Potter & Roksa, 2013), it is important to address both the out-of-school and in-school opportunity gaps that shape students' learning experiences and subsequent outcomes through a more comprehensive policy approach.

The purpose of the current study is to examine the malleable school practices and norms that contribute to inequitable school learning environments based on student background. While addressing inequities in education requires attention to broader structures and policies, it is important to identify how educators can begin to address the factors that perpetuate disparities in

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educational access and outcomes within their schools. This study examines the extent to which student-level access to inquiry-based science learning opportunities and academic press mediates the relationship between intersectional student background and scientific literacy outcomes, as well as the influence of school-level context, tracking, and academic climate variables on student learning opportunities, perceptions of academic press, and science outcomes.

Literature Review

Opportunity to Learn

Opportunity to learn (OTL) is a research construct and policy indicator that has been employed to evaluate student access to equitable learning conditions. While OTL has been defined and operationalized in different ways across scholarship and policies, it broadly refers to the learning conditions necessary for students to be successful in meeting expectations for academic performance (Dougherty, 1996; McDonnell, 1995). A substantial body of research has examined the content dimension of OTL, dating back to the First International Mathematics Study (FIMS) in 1964 (Floden, 2002; McDonnell, 1995). FIMS and subsequent iterations of International Association for the Evaluation of Educational Achievement (IEA) studies included measures of student exposure to content to ensure valid comparisons of student achievement between countries (Floden, 2002; McDonnell, 1995). More recently, Schmidt et al. (2015) have similarly employed content coverage OTL measures to examine within-school and between-school OTL disparities in math. This work has pointed not only to high levels of within-school inequality in math OTL in the U.S. compared to other countries, but also the mediating role of math content OTL in the relationship between SES and student math achievement (Schmidt et al. 2015).

Other scholars have employed expanded indicators of OTL to include teacher expertise and experience (Aguirre-Muñoz & Boscardin, 2008; Goertz, 1994), educational resources (Boykin & Noguera, 2011; Elliot, 1998; Herman & Klein, 1996; Kimura-Walsh, Yamamura, Griffin, & Allen,

2009; Oakes, 1990), and instructional practices (Kurz, Elliott, Lemons, Zigmond, Kloo, & Kettler, 2014; Smithson, Porter, & Blank, 1995). Building on this work, Urick and colleagues (Urick, Liu, Ford, & Wilson, 2019; Urick, Wilson, Ford, Frick, & Wronowski, 2018) have argued that to better understand inequities in OTL, it is important to examine the instructional dimension of OTL, particularly student access to high levels of cognitive demand (see Porter, 2002). Thus, while findings across the OTL literature have demonstrated the relationship between OTL and student achievement (Arehart, 1979; Boscardin, Aguirre-Muñoz, Chinen, Leon, & Shin, 2004; Boscardin, Aguirre-Munoz, Stoker, Kim, Kim, & Lee, 2005; Schmidt et al., 2011a; Schmidt et al., 2013; Schmidt et al., 2001; Wang, 1998; see Elliott & Bartlett, 2016), as well as differential access to OTL by student background (Abedi, Courtney, Leon, Kao, & Azzam, 2006; Abedi & Herman, 2010; Darity, Castellino, Tyson, Cobb, & McMillen, 2001; Heafner, 2015; Kim & Hocevar, 1998; Minor, 2015; Schmidt et al., 2015; Wang, 2010; Wang & Goldschmidt, 1999), there is a need to further examine patterns of OTL instruction, a potential policy lever for addressing educational inequity. Moreover, less attention has been paid to science OTL and outcomes, which parallels a U.S. accountability context that has prioritized math and reading over science instruction (Anderson, 2012; Berliner, 2011; Milner et al., 2012). Understanding access to OTL in science could provide important insight about the narrowing of science opportunities due to broader U.S. policy emphases (Anderson, 2012; Berliner, 2011; Milner et al., 2012), as well as inequitable OTL access across subject areas required for success in science, such as math and literacy (Pearson et al., 2010; Fang & Wei, 2010; Lee & Buxton, 2013; Wang & Degol, 2017), that corresponds with student background (Morgan et al., 2016; Schmidt et al., 2015). Attending to higher-level science instruction could also inform policy efforts aimed at closing gaps in science outcomes beyond minimum learning standards (NRC, 2012), to include participation and success in postsecondary

education and science careers (Else-Quest et al., 2013; Kanter & Konstantopoulos, 2010; Wang & Degol, 2017).

In sum, efforts to define and operationalize OTL have spanned decades and produced important insight about the mediating role of OTL in the relationship between student background and student achievement. Given the findings across the OTL literature, an important question is how schools structure curricular and instructional inequities. One key mechanism identified in the OTL literature is academic tracking (Callahan, 2005; Gamoran, 1987; Gamoran, Porter, Smithson, White, 1997; Guiton & Oakes, 1995; Murphy, 1988; Oakes, 1990; Schmidt & McKnight, 2012), a practice deeply embedded in the U.S. education system.

Academic Tracking

Academic tracking is a key stratification mechanism in schools that has continued to shape U.S. students' educational experiences despite longstanding criticism of its consequences for students (Oakes, 1985, 1994). At the elementary school level, tracking typically is implemented in the form of ability grouping, but at the high school level, tracking practices have evolved such that they are different today than they were in the early- to mid-20th century. Prior to the 1960s, classical tracking – "a system in which students are formally assigned to overarching programs that allow virtually no mobility across programs and that determine the level of all of their academic courses" (Lucas & Beresford, 2010, p. 43) – required students to choose between, for example, rigid college preparatory, general, or vocational programs. This form of tracking is comparable to that still employed by many European countries (Brunello & Checchi, 2007), but began to wane in the U.S. towards the latter half of the 20th century so that it was uncommon by the turn of the 21st century (Lucas & Beresford, 2010).

Today, tracking at the secondary level typically consists of "sequences of courses within given subject domains that are differentiated by the rigor of their content and the nature of their instruction" (Bottia et al., 2016, p. 40). For example, students might be assigned to remedial, special education, general education, Advanced Placement, honors, or International Baccalaureate courses. Often, placement in upper track courses is associated with certain requirements such as course prerequisites, minimum grades or tests scores, or recommendations (Harris, 2011), and this can constrain student choice and movement to higher tracks (Kelly, 2007). Oakes (2005) has described tracking as a process by which "students are identified in a rather public way as to their intellectual capabilities and accomplishments and separated into a hierarchical system of groups for instruction" (p. 3), resulting in labelling of students that not only influences academic content and instruction, but also perceptions of students, both of themselves and of others. Although tracking in the U.S. purportedly sorts students based on ability (Lucas & Beresford, 2010), Black, Latinx, and low-SES students tend to be disproportionately enrolled in lower tracks (Mickelson & Everett, 2008; Oakes, 1982; Watanabe, 2008; Werblow et al., 2013).

Proponents of tracking have argued that it is an efficient way to channel resources and promote student development (Ansalone, 2009, 2010; Ansalone & Biafora, 2010). Some have suggested that tracking helps improve student self-concept and motivation by reducing harmful comparisons between students and their more able peers (Ansalone, 2009). Many parents also support tracking, perceiving it as a way to meet their respective concerns by providing faster-paced, challenging content for higher track students and more individualized attention and care for lower track students (Ansalone & Biafora, 2010). More influential parents from high-socioeconomic status (SES) backgrounds tend to particularly support tracking, viewing it as a way

to separate their children from other low achievers, gain a competitive advantage for their children, and position their children for higher education (McGrath & Kuriloff, 1999).

The educational environment differs between low vs. high track classes in several important ways. One area is the difference in teacher quality between track levels. Lower track students tend to be assigned to less experienced teachers with lower levels of perceived efficacy (Kelly, 2004; Rubin & Noguera, 2004). The distinctions between teacher qualifications across tracks are further complicated by differential access to qualified teachers between schools, with more affluent schools having greater access to qualified teachers (Oakes, 1990). Reinforcing this inequitable distribution of teacher quality, Akiba et al. (2007) found that the opportunity gap between low- and high-SES students' access to qualified teachers was one of the highest in a comparison of 39 countries.

Instructional practices also vary across tracks. According to Ansalone (2009), tracking promotes labelling and lower expectation for lower track students, which translates to differential curriculum, such as slower-paced instruction and less material covered in the lower tracks (Harris, 2011). Lower track students are also exposed to more repetitious, fragmented, and rote content and fewer opportunities for creativity and critical thinking compared to their high track peers (Oakes, 2005), in part due to more time spent on test preparation (Watanabe, 2008). This is supported by Donaldson et al.'s (2017) recent findings that students in lower tracks received less instructional support, including lower support for content understanding and analysis and problem solving, as opposed to the more rigorous instruction experienced by high track students. Donaldson et al. (2017) also found lower quality organizational support for students in lower tracks, such as less classroom structure and less variety in instructional learning formats.

In addition to differences in teacher quality and instruction, the affective environment differs for students according to track placement. Students in higher tracks have more positive, supportive classroom experiences in contrast to the negative, self-concept lowering experiences faced by students in lower tracks (Oakes, 1982; Oakes, 2005). Moreover, teacher expectations, which tend to be lower for students in lower tracks, can "function as self-fulfilling prophecies" (Brophy & Good, 1970, p. 373) that shape students' academic self-perceptions (Rubie-Davies, 2006). This is supported by Karlson's (2015) finding that the signals sent through track placement can prompt students to change their educational aspirations. Donaldson et al. (2017) have also documented the lower levels of emotional support provided in lower track classes, including more reliance on punitive control and sarcasm, lower levels of teacher sensitivity, and less regard for student perspectives. Further, academic tracks contribute to the development of social networks that influence students' behaviors and attitudes towards school, such that high track students receive peer support and motivation to take challenging classes (Chambers, 2009; Gamoran, 1992).

The disparate academic outcomes associated with track placement have also been documented. Giersch (2016) has demonstrated that for higher track students, the same increases in test scores were associated with higher GPAs in college compared to lower track students due to higher track students' exposure to different learning opportunities that better equip them for college. In further support of the achievement differences that stem from tracking, Gamoran (1992) has found that schools with more rigid tracking systems produced lower overall math achievement and wider gaps in math and verbal achievement than systems with more mobility. Lastly, Werblow et al. (2013) have found that lower track students were around 60% more likely to drop out of high school, a finding that has important implications for lower track students' future education and career prospects.

Finally, it is important to consider how tracking influences family-school relations, and explore possible differences in parents' attitudes and expectations around tracking. In a study involving Latinx parents' experiences with school personnel, Auerbach (2002) demonstrated how bureaucratic school structures can exacerbate parents' experience of marginalization and social exclusion, creating barriers for parent advocacy for more equitable educational opportunities (see also Lareau & Horvat, 1999). More affluent parents tend to be knowledgeable about the tracking system and intervene in their child's track placement (Baker & Stevenson, 1986; Useem,1992), and are generally more supportive of tracking according to ability (Ansalone & Biafora, 2010). Parents' own educational experiences can also inform their attitudes towards tracking. According to Ansalone & Biafora (2010), parents who were assigned to lower tracks during their own schooling tended to report more negative consequences of tracking.

In sum, the findings from the tracking literature indicate that expectations for student learning and performance differ across tracks, and this translates to instructional approaches that differentially prepare students for postsecondary success. Moreover, in addition to academic outcomes, track placement influences students' perceptions of themselves and others, including their abilities, potential for success, and position within the hierarchical system. This suggests that attention to features of the school learning environment, including academic norms, could help identify paths that influence student outcomes.

Academic Climate

Given that perceptions of students' academic abilities and expectations for performance are differentiated by track, Werblow et al. (2013) has suggested that school academic climate reflects underlying beliefs that can help us better understand the relationship between tracking and student outcomes. Academic climate is a measure of a school's emphasis on high academic

achievement, and the learning environment and morale created through supportive relationships and norms (Bryk et al., 2010; Sebastian & Allensworth, 2012; Urick & Bowers, 2011, 2014; Werblow et al., 2013). This includes high academic expectations and press for achievement, supportive relationships between students and teachers, student and teacher morale, and safety and order (Bryk et al., 2010; Sebastian & Allensworth, 2012; Urick & Bowers, 2014).

Student and principal perceptions of academic climate have been found to predict student achievement (Urick & Bowers, 2014), and it is through learning climate that principal leadership indirectly influences instructional quality and student achievement (Sebastian & Allensworth, 2012). This suggests that supports for school leaders to facilitate a strong academic climate might be a potential policy lever for addressing students' differential learning experiences and outcomes. The salience of school climate measures for analyzing the achievement gap is also reinforced by Berkowitz et al.'s (2017) synthesis of studies that pointed to school climate as mitigating the effects of student background on academic outcomes. Thus, understanding how students with different demographic backgrounds perceive their school academic climate, as well as how school-level academic climate perceptions vary by school demographics, could provide important information about learning environment inequities both within and between schools (see Urick & Bowers, 2014).

Theoretical and Conceptual Framework

This study employs a critical quantitative lens (Dixon-Román, 2017; Stage, 2007; Stage & Wells, 2014) to identify patterns of systematic inequality in schools based on intersectional student backgrounds. Critical quantitative research provides alternative models to traditional positivist approaches that better capture how systemic inequities are perpetuated by societal institutions such as schools while illuminating the experiences of marginalized individuals or groups in context

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(Dixon-Román, 2017; Stage, 2007; Stage & Wells, 2014). This study builds on Bourdieu's (1977a,1977b) cultural reproduction theory, which has demonstrated the role of schools in privileging students who possess symbolic capital aligned with the dominant culture, while marginalizing those who do not, to reinforce hierarchical power relations (see also Grenfell & James, 1998). Despite the critique of this covert mechanism of social and cultural reproduction and the illusion of meritocracy that perpetuates it (Bourdieu, 1977a), which is inherent in Bourdieu's theory, many scholars have examined the effects of student capital on achievement while omitting the role of schools (see Wilson & Urick, in press). By integrating the cultural reproduction theory literature, opportunity to learn literature, tracking literature, and scholarship on academic climate, this study provides an alternative model that examines how the relationship between student background and achievement is mediated by students' learning opportunities and experiences within schools, and how students' experiences and outcomes are influenced by school context, practices, and norms (see Figure 1). By examining systematic inequities in patterns of access to rigorous learning opportunities and supportive learning environments, this study endeavors to shift the focus from the achievement gap to the opportunity gap in U.S. schools (Chambers, 2009; Darling-Hammond, 2013).

This study is also informed by an understanding that inequities in schools are situated in broader systems of inequality. With this in mind, an intersectionality framework is incorporated to examine how students at the intersections of marginalized group membership experience inequality in schools. Crenshaw's (1989, 1991) seminal work on intersectionality, as well as the field of Critical Race Theory (CRT), have demonstrated how power and privilege are not afforded to individuals according to discrete categories of identity, such as race and gender, but that the centrality of race and racism in the U.S. must also be understood alongside its intersections with

other forms of subordination (Yosso, 2005). In addition to the intersections of race and gender, some of the other systems of power that have been examined in the field of intersectionality have been social class, language, and immigration background (Collins, 2015; Landale et al., 2017). Thus, intersectionality facilitates a more complex analysis of inequities in students' educational experience and outcomes and provides an important extension of cultural reproduction theory (see Giroux, 1983). By integrating these two bodies of literature, this study seeks to illuminate not just how narrow forms of student capital are privileged in schools, but also how these inequitable school experiences intersect with race, ethnicity, social class, language, and immigration background as a function of broader systemic inequality in the U.S. (see Figure 1)
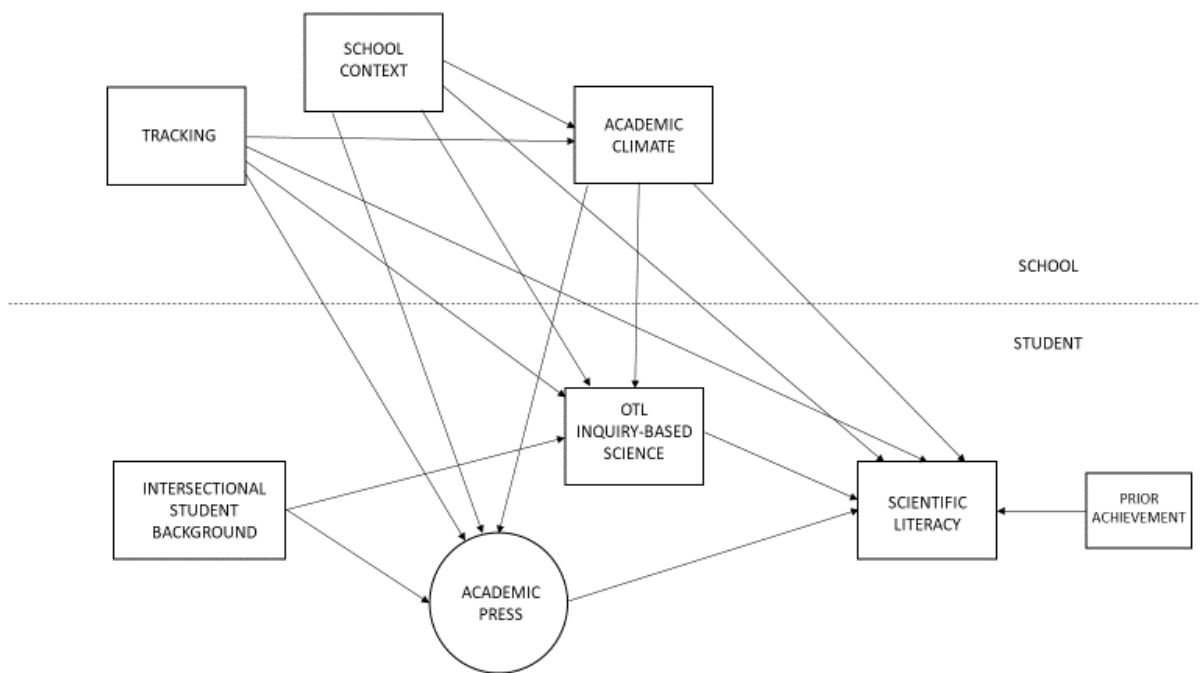

Figure 1. Conceptual and theoretical framework

Research Questions

1) While accounting for variance at the school level, does OTL inquiry-based science mediate the relationship between intersectional student background profiles and scientific literacy outcomes?

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2) While accounting for variance at the school level, does student perception of academic press mediate the relationship between intersectional student background profiles and scientific literacy outcomes?

3) To what extent do school-level perceptions of academic climate influence OTL inquiry-based science, student perceptions of academic press, and scientific literacy outcomes?

4) To what extent does school tracking influence OTL inquiry-based science, student perception of academic press, and scientific literacy outcomes?

Method

Data Sources

This study is a secondary data analysis of the 2015 Program for International Student Assessment (PISA), an international assessment that has been administered every three years since 2000 (OECD, 2017). PISA is coordinated by the Organization for Economic Cooperation and Development (OECD) and conducted by the National Center for Education Statistics (NCES) in the United States (NCES, n.d.). In contrast to other assessments that yield nationally generalizable data, PISA is an age-based sample that focuses on 15-year-old students' real-life application of skills and knowledge in reading, mathematics, and science (OECD, 2017; NCES, n.d.). While all three core subjects are covered in the assessments, the major domain of study rotates with each administration and receives more focus (OECD, 2017; NCES, n.d.). For PISA 2015, science was the major domain of study.

In addition to the assessments, student and school questionnaires are administered in all participating countries, and optional parent and teacher questionnaires are available (OECD, 2017). The teacher questionnaire was a new option in PISA 2015 (OECD, 2016), and included surveys for both general teachers and science teachers. For PISA 2015, the U.S. implemented the

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mandatory student and school questionnaires, as well as both teacher questionnaires. These questionnaires provide important information about student background and multiple perceptions of the school learning environment to supplement the assessment. For this reason, it is a useful dataset to explore how students' educational experiences and outcomes in the U.S. are situated within school structures, norms, policies, and practices.

PISA 2015 utilized a two-stage, stratified systematic sampling design. Schools were sampled in the first stage using systematic probability proportional to size (PPS) sampling (NCES, n.d.; OECD, 2017). In the second stage, students within these schools had an equal probability of being selected. At least 10 science teachers and 15 non-science teachers eligible to teach the modal grade (i.e. 10th grade) were sampled within schools; all science and non-science teachers were sampled if the school had fewer than the target sample number (OECD, 2017). Systematic sampling procedures were used to select teachers, with teachers in each group having an equal probability of being selected (OECD, 2017). Final student and school weights were calculated to adjust for probability of selection, nonresponse, and other estimation errors related to school size and enrollment number of eligible students (NCES, 2014; OECD, 2017). These weights must be applied to an analysis to obtain nationally representative results.

For this study, the student questionnaire and assessment were used for all student-level items, and teacher and school questionnaire items were used for school-level items. The sample for this study includes U.S. students (n=5,712), teachers (n=3,680), and schools (n=177). See Table 1 for descriptives.

Measures and Instrumentation

Student-level Measures

Intersectional Student Background. Intersectional student background groups were identified and interpreted in a previous study that utilized latent class analysis (LCA) (see Wilson & Urick, 2019). LCA was performed with indicators of student background, including race/ethnicity, immigration background, language spoken at home, social class, and traditional forms of cultural capital aligned with Bourdieu's cultural reproduction theory (see Appendix A for full list of variables), to identify underlying distinct, homogeneous groups. Many of these indicators were selected as categories commonly explored in the field of intersectionality, including race/ethnicity, immigration background, language spoken at home, and social class because they reflect differential power relationships in society (Collins, 2015; Landale et al., 2017). Indicators of cultural capital were selected because, as extensions of social class, they are consistent with intersectionality in affording individuals different levels of power and privilege in society (Bourdieu, 1977a; Yosso, 2005).

Results of the LCA indicated that the best-fitting model was a 6-class model and the six groups were interpreted according to response patterns on the indicator items: a *more* and *less affluent Hispanic or Latinx* group, a *more* and *less affluent Black or African American* group, and a *more* and *less affluent White* group (see Wilson & Urick, 2019). These groupings acknowledge that individuals do not experience discrimination along mutually exclusive background categories because hierarchies of privilege exist within these categories (Crenshaw, 1989). Instead, it is important to understand issues of injustice at the intersections of systems of power (Collins, 2015). For the current study, each of the categories was dummy coded with *more affluent White* as the reference group.

Gender. Despite its alignment with an intersectionality framework (Crenshaw 1989, 1991), gender was not included as an intersectional student background indicator in the LCA

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because of concerns about model identification problems (see Landale et al., 2017; Wilson & Urick, 2019). Instead, it was included in both studies as a separate covariate. OECD categories for student gender [ST004D01T] were recoded to *male* (0) and *female* (1) to make male the reference group.

Prior Achievement. Consistent with other studies (Marteleto & Andrade, 2014), student grade level [ST001D01T] was the measure used to control for prior achievement. The grade level categories were recoded as dummy variables to *below grade 10* and *above grade 10*, with *grade 10* (the modal grade, see OECD, 2017) as the reference group.

Opportunity to Learn. A PISA derived IRT scale -- inquiry-based science teaching and learning practices [IBTEACH] – was used as the indicator of OTL for this study. This PISA scale was based on students' responses to the frequency that they engaged in higher-level learning activities in science lessons (OECD, 2017; see Appendix A), which is aligned with OTL literature and studies that have focused on academic rigor (Urick et al., 2018; Porter, 2002) and the instructional domain (Kurz, Elliott, Lemons, Zigmond, Kloo, & Kettler, 2014; Smithson, Porter, & Blank, 1995). As a measure of active student engagement in science learning (Minner et al., 2010), OTL inquiry-based science was also selected as an appropriate predictor of the outcome measure in PISA, scientific literacy, which reflects the assessment's emphasis on real-life application. Construct validation procedures conducted by OECD (OECD, 2017) indicated high reliability for this scale in the U.S. sample (IBTEACH, $\alpha = .89$).

Academic Press. An important dimension of academic climate is high academic expectations and press for achievement (Bryk et al., 2010). Academic press was a latent variable with five continuous indicators [ST104Q01NA-ST104Q05NA] that captured how frequently students received feedback from teachers on their learning and goals in science class (see Appendix

A for the full list of items). These items were selected as indicators of academic press because of their emphasis on students' academic performance and improvement. Item responses were ordered so that higher values reflected more frequent feedback related to student performance, *never or almost never* (1) to *every lesson or almost every lesson* (4). Descriptives for each of the Likert-style questionnaire items were evaluated for skewness and kurtosis prior to including them in the model as continuous indicators (Muthen, 2015; Norman, 2010). As seen in Figure 2, standardized factor loadings for these indicators ranged from 0.77-0.93. R^2 values for the indicators were satisfactory, ranging from 0.60-0.87 (Kline, 2011).
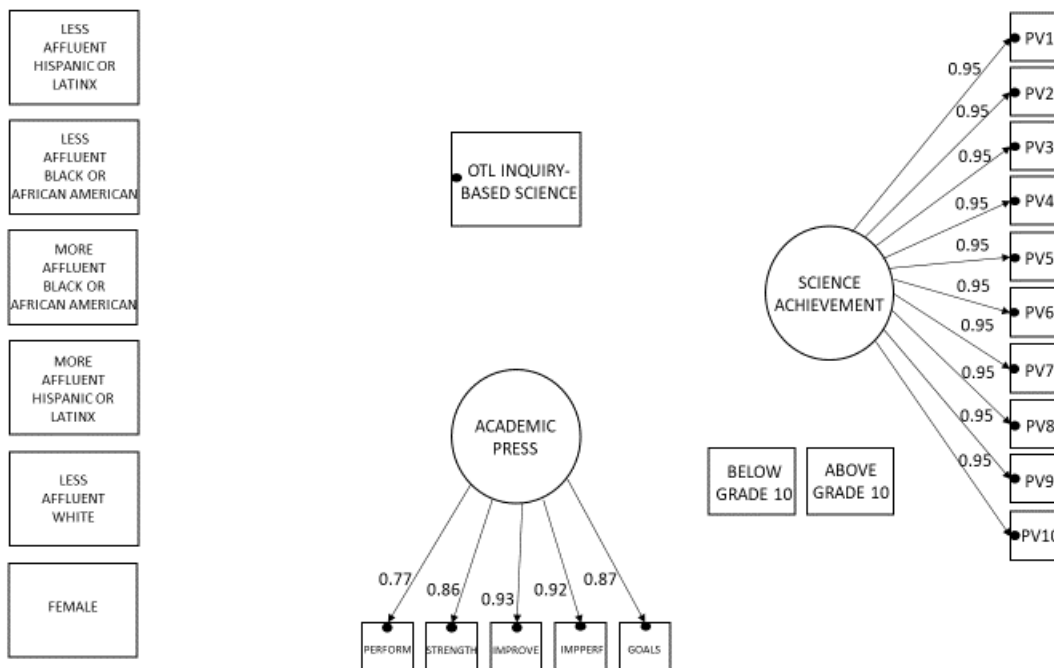

Figure 2. CFA standardized solution for the within part of the model. Partial findings are presented for readability. See Figure 3 for the full model tested.

Science Achievement. Because students only answered a subset of assessment items, multiple imputation based on IRT scaling and questionnaire information was used to generate plausible values for each student (OECD, 2017). All ten plausible values for science [PV1SCIE-

PV10SCIE] were included in the model. In line with other studies, these plausible values were treated as continuous indicators of a latent variable, science achievement (see Urick et al., 2019). This measure of student achievement reflects students' scientific literacy, or ability to engage in higher-level cognitive processes as they apply their learning to real-world situations (OECD, 2017). As seen in Figure 2, standardized factor loadings for the plausible value indicators were each 0.95. R^2 values for each of the indicators were also satisfactory, ranging from 0.90-0.91 (Kline, 2011).

School-level Measures

School Context. School-level context controls included in the model are community in which the school is located (e.g. rural, town, large city) [SC001Q01TA]; class size [CLSIZE]; percentage of students eligible for free/reduced price lunch [FRPL]; and public or private school designation [PUBPRIV].

The OECD school community categories were recoded to a create a dummy variable, *city or large city* (0) and *rural or town* (1), so that city or large city was the reference group.

Class size was a simple PISA index based on principals' reports of the average size of 10th grade English classes at the school. This variable was grand mean centered in the model.

The OECD categories for free/reduced price lunch were recoded to dummy variables *24.9% or less free/reduced price lunch* and *75% or more free/reduced price lunch*, with *25-74.9% free/reduced price lunch* as the reference group.

School designation was recoded as a dummy variable, *public* (0) and *private* (1), so that public school was the reference group.

School Academic Climate. Measures of school academic climate included principals' perceptions of hindrances to the learning environment, such as students' lack of respect for teachers [SC061Q03TA] or student bullying and intimidation [SC061Q05TA]. Additionally,

teachers' perceptions of their enjoyment working at the school [TC026Q05NA] and professional interactions with the principal [TC060Q07NA] are included as measures of academic climate. These are aligned with dimensions of academic climate identified in the literature, including student and teacher morale, and safety and order (Bryk et al., 2010; Sebastian & Allensworth, 2012; Urick & Bowers, 2014).

Principals responded to a Likert-style item with the extent to which student learning was hindered by students' lack of respect for teachers. They responded on the same scale with the extent to which student bullying or intimidation hindered student learning. The responses for each of these items were reverse coded, *a lot* (1) to *not at all* (4), so that higher values reflected a more positive academic climate. Descriptives were examined for evidence of normality, and both variables were treated as continuous (Norman, 2010).

Both science and non-science teachers indicated on a Likert-style scale how strongly they disagree or agree with the statement "I enjoy working at this school." Non-science teachers also indicated their extent of disagreement or agreement with the statement "The principal treats teaching staff as professionals." The responses for both items were coded from *strongly disagree* (1) to *strongly agree* (4) so that higher values reflected stronger agreement and a more positive perception of the school academic climate related to teacher satisfaction and morale. Responses were then aggregated to the school level by creating a school mean variable for each item.

Tracking. School tracking was measured by principals' response to whether or not students are grouped by ability into different classes [SC042Q01TA] (see Appendix A). OECD categories were recoded into a dummy variable, *some or all subjects* (0) and *none* (1) so that *some or all subjects* was the reference group. The school's use of ability grouping into different classes is consistent with the U.S. approach to tracking (Lucas & Beresford, 2010).

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Table 1. Descriptives

Variables	N	Minimum	Maximum	Mean	SD
STUDENT LEVEL					
Reference Groups					
More affluent White	5662	0	1	0.36	-
Male	5712	0	1	0.50	-
Grade 10	5712	0	1	0.72	-
Student Background					
Less affluent Hispanic or Latinx	5662	0	1	0.19	-
Less affluent Black or African American	5662	0	1	0.05	-
More affluent Black or African American	5662	0	1	0.08	-
More affluent Hispanic or Latinx	5662	0	1	0.18	-
Less affluent White	5662	0	1	0.14	-
Female	5712	0	1	0.50	-
Below grade 10	5712	0	1	0.10	-
Above grade 10	5712	0	1	0.17	-
Endogenous Variables					
OTL inquiry-based science	5097	-3.34	3.18	0.34	1.04
Academic Press (latent variable)					
Performing in course	5076	1.00	4.00	2.37	0.93
Feedback on strengths	5067	1.00	4.00	2.26	0.98
Areas to improve	5064	1.00	4.00	2.30	0.99
Improve performance	5056	1.00	4.00	2.35	0.99
Learning goals	5044	1.00	4.00	2.35	1.01
Science Achievement (latent variable)					
Plausible value 1	5712	203.66	856.62	496.19	98.18
Plausible value 2	5712	181.97	862.68	495.75	98.17
Plausible value 3	5712	191.09	881.78	497.16	99.68
Plausible value 4	5712	164.12	806.81	496.79	99.07
Plausible value 5	5712	170.25	820.67	496.28	97.89
Plausible value 6	5712	191.36	834.00	496.38	98.27
Plausible value 7	5712	145.19	837.91	496.27	99.34
Plausible value 8	5712	182.14	829.40	496.54	98.94
Plausible value 9	5712	141.97	800.89	495.67	97.99
Plausible value 10	5712	153.75	802.08	495.41	98.76
SCHOOL LEVEL					
Reference Groups					

|					
City	177	0	1	0.34	-
Public	177	0	1	0.81	-
25 to 74.9% free/reduced price lunch	177	0	1	0.50	-
Tracking in some/all subjects	163	0	1	0.76	-
School Context Controls					
Class size	177	13	38	20.21	6.61
Rural or town	177	0	1	0.66	-
Private	177	0	1	0.19	-
24.9% or less free/reduced price lunch	177	0	1	0.16	-
75% or more free/reduced price lunch	177	0	1	0.34	-
School Academic Climate					
Teachers enjoy working at school	148	2.00	4.00	3.46	0.31
Principal treats staff as professionals	144	2.17	4.00	3.31	0.46
Learning hindered by lack of respect	167	1.00	4.00	2.89	0.88
Learning hindered by bullying	167	1.00	4.00	2.98	0.75
Tracking					
No tracking	163	0	1	0.24	-

Analytic Technique

Because the theoretical and conceptual framework (see Figure 1) posited mediating paths as well as student-level and school level predictors, multilevel structural equation modeling (SEM) was the most appropriate approach to this analysis. Both a measurement model and structural model are specified in multilevel SEM to evaluate the validity of latent constructs while examining the direct and indirect relationships between observed or latent variables (Bollen, 1989; Bowen & Guo, 2012; Hox et al., 2018; Kaplan, 2009; Kline, 2011; Schumacker & Lomax, 2016). Like other regression-based approaches such as hierarchical linear modeling (HLM), incorporating multilevel analysis accounts for the hierarchical nature of the data with students nested within schools (Asparouhov & Muthen, 2005) to produce appropriate estimates of standard errors (Geiser, 2013; Hox et al., 2018). In multilevel SEM, each level is analyzed separately for fit and adjusted, and then the models are combined and estimated simultaneously (Hox et al., 2018).

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For this study, the level-one model, which involved both measurement and structural components, was tested separately first and evaluated for satisfactory fit with the final student weight applied [W_FSTUWT]. The level-two model was then tested separately with the final school weight applied [W_SCHGRNRABWT], and non-significant paths were removed for parsimony before combining the two levels in the final model. All analyses were conducted using Mplus v.7.4. The final student weight [W_FSTUWT] and school weight [W_SCHGRNRABWT] were applied for representativeness in the final multilevel SEM model.

As seen in Figure 3, the final measurement and structural model was a combination of two-level path analysis and two-level confirmatory factor analysis (CFA) with random intercept factors. While the chi-square test of model fit was not interpreted because of its sensitivity to sample size, other fit statistics consistently indicated excellent model fit (RMSEA = 0.01; CFI = 0.99; TLI = 0.99; SRMR within = 0.01; SRMR between = 0.07) (Kline, 2005; Hooper et al., 2008).

At the within level, academic press was a latent variable regressed on student-level covariates, intersectional student background and gender, with the intercept of the factor fixed at zero (Muthén & Muthén, 1998-2017). The intercepts for the academic press indicators were random, or varied across clusters (Muthén & Muthén, 1998-2017). OTL was an observed variable regressed on intersectional student background and gender with intercepts that varied across clusters and a fixed slope (Muthén & Muthén, 1998-2017). Science achievement was a latent variable regressed on intersectional student background, gender, OTL, and academic press with the intercept of the factor fixed at zero (Muthén & Muthén, 1998-2017). The intercepts for the science achievement indicators were random, or varied across clusters (Muthén & Muthén, 1998-2017). The indirect effects of intersectional student background and gender on achievement via OTL and academic press were also tested.
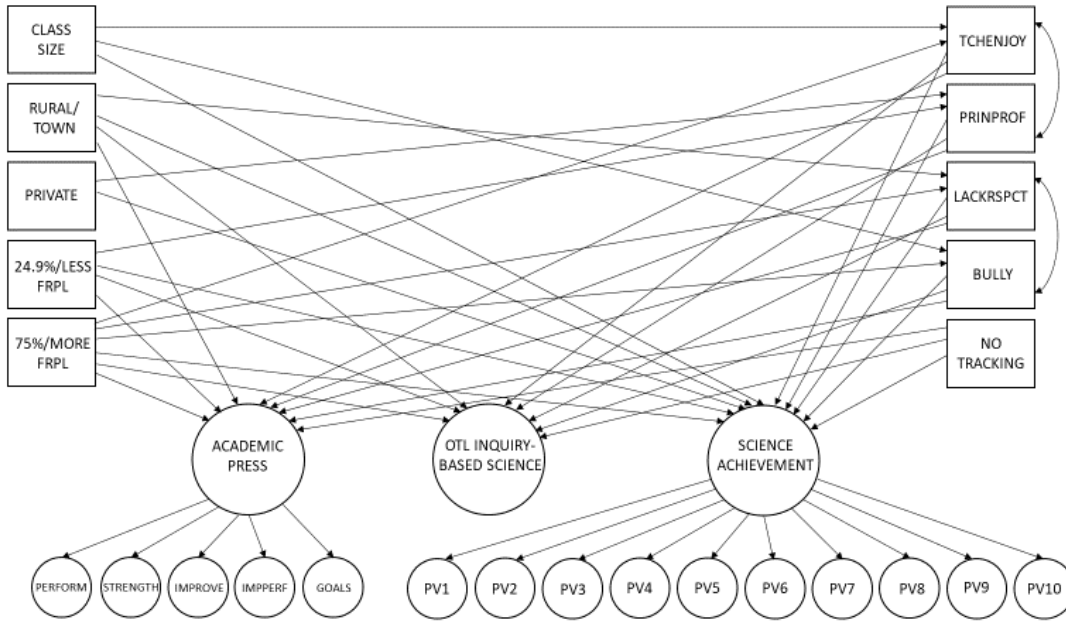
Between

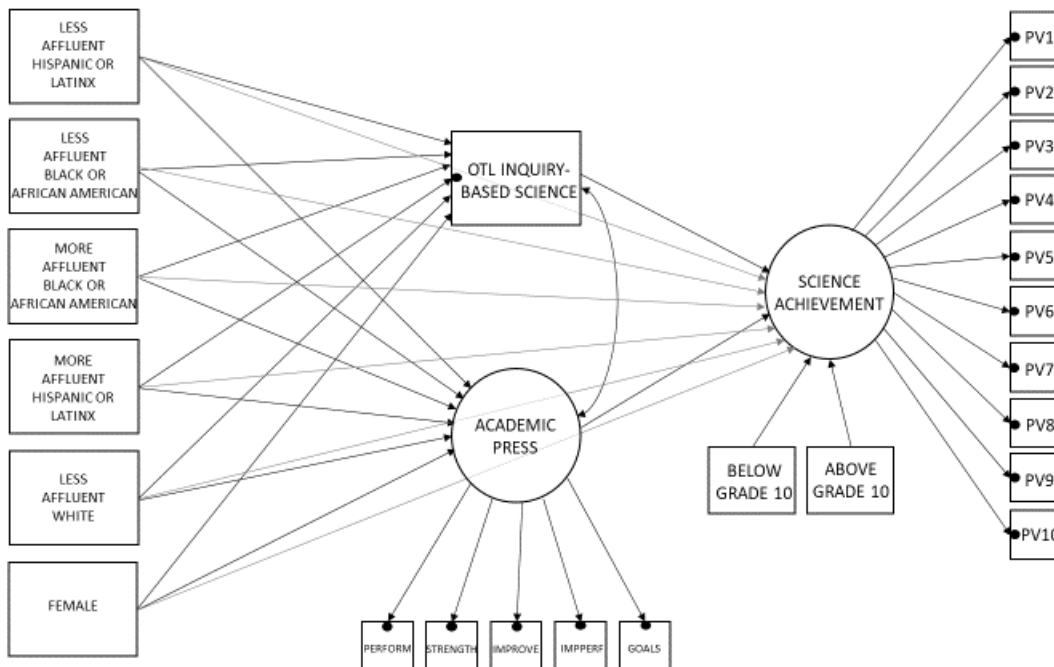**Within**

Figure 3. Full measurement and structural model for multilevel SEM

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At the between level, continuous school-level academic climate variables were regressed on select school context variables based on the separate level-2 test. Academic press and science achievement were random intercept factors, or factors that were measured by the random intercepts of their level-1 indicators (Muthén & Muthén, 1998-2017). The residual variances of the factor indicators were set to zero and the intercept of the factor was fixed at zero (Muthén & Muthén, 1998-2017). The academic press random intercept factor was regressed on school-level academic climate variables, the tracking variable, and select school context variables. The science achievement random intercept factor was regressed on school-level academic climate variables, the tracking variable, and all school context variables. The random intercept OTL was also regressed on school-level academic climate variables, the tracking variable, and select school context variables.

Results

Within Level

Direct Effects for Student Background, Prior Achievement, and Science Achievement

The test of direct effects of student background on science achievement demonstrated that each of the intersectional student background groups in the model – less affluent Hispanic or Latinx students (β = -0.57, $p \leq$ .001), less affluent Black or African American students (β = -0.84, $p \leq$ .001), more affluent Black or African American students (β = -0.82, $p \leq$ .001), more affluent Hispanic or Latinx students (β = -0.43, $p \leq$ .001), and less affluent White students (β = -0.26, $p \leq$ .001) – had significantly lower scientific literacy scores on the PISA assessment than more affluent White students (see Figure 4). The outcome gap between the more affluent White group and the other intersectional groups was smallest for the less affluent White group (around a quarter of a deviation lower than more affluent White students), followed by the more affluent Hispanic or Latinx group (just under half of a standard deviation lower than more affluent White students).

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Less affluent Hispanic or Latinx students scored just over half of a standard deviation lower than more affluent White students. The largest gap between more affluent White students was for less affluent Black or African American students, very closely followed by more affluent Black or African American students (both over four-fifths of a standard deviation lower than more affluent White students).
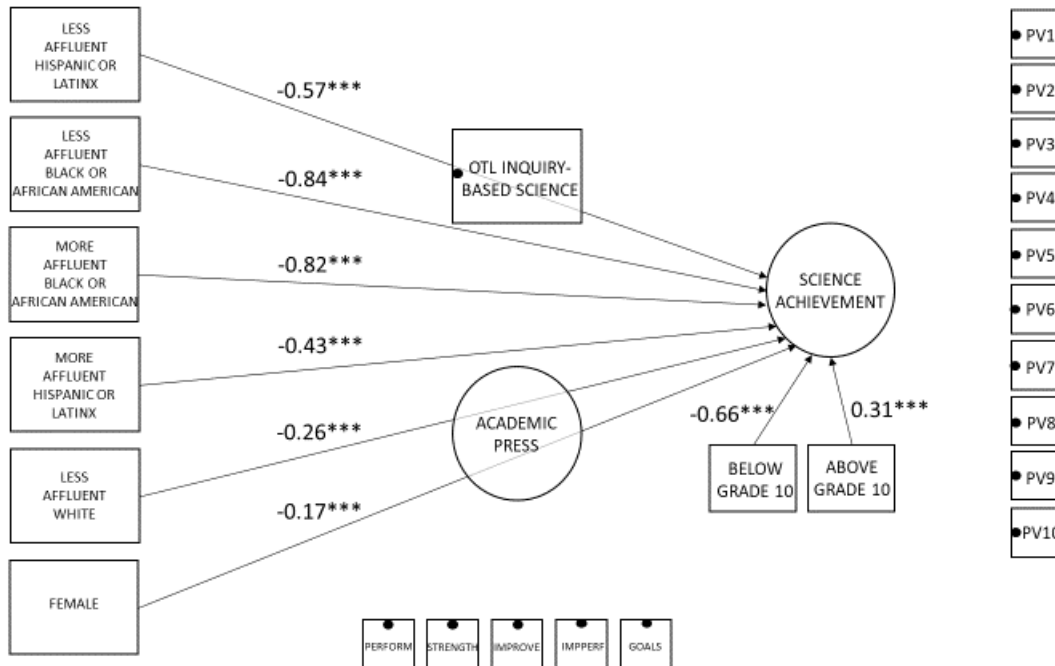

Figure 4. Standardized path coefficients for the within part of the multilevel SEM model: direct effects of student background and prior achievement on science achievement. Partial findings are presented for readability. See Figure 3 for the full model tested. Statistically significant paths are in black and nonsignificant paths are in grey. * p ≤ .05, ** p ≤ .01, *** p ≤ .001

Gender was also a significant predictor of science achievement. Females scored significantly lower on the scientific literacy assessment than males (β = -0.17, p ≤ .001).

Controls for prior achievement also indicated differences in scientific literacy outcomes based on student grade level (see Figure 4). 15-year-old students who were below grade 10 had a little over half of a standard deviation lower scientific literacy scores compared to students in grade

10 ($\beta = -0.66, p \leq .001$), while students above grade 10 scored over a quarter of a standard deviation higher than grade 10 students ($\beta = 0.31, p \leq .001$).

Table 2. Standardized indirect effects for the within part of the model: student background to achievement

	Standardized Indirect Effect	
Less Affluent Hispanic or Latinx to Science Achievement		
via OTL	-0.001	
via Academic Press	-0.019	*
Sum of indirect effects	-0.020	
Less Affluent Black or African American to Science Achievement		
via OTL	-0.008	
via Academic Press	-0.026	*
Sum of indirect effects	-0.034	*
More Affluent Black or African American to Science Achievement		
via OTL	-0.009	
via Academic Press	-0.018	
Sum of indirect effects	-0.027	
More Affluent Hispanic or Latinx to Science Achievement		
via OTL	-0.010	
via Academic Press	-0.023	*
Sum of indirect effects	-0.032	**
Less Affluent White to Science Achievement		
via OTL	-0.001	
via Academic Press	-0.019	*
Sum of indirect effects	-0.020	*
Female to Science Achievement		
via OTL	0.008	
via Academic Press	0.017	**
Sum of indirect effects	0.025	***

Note: * p ≤ .05, ** p ≤ .01, *** p ≤ .001

Direct and Indirect Effects for OTL

As seen in Figure 5, more affluent Hispanic or Latinx students ($\beta = 0.20, p \leq .05$) reported significantly more frequent opportunities for inquiry-based science instruction (OTL) than more affluent White students. Females reported significantly less frequent inquiry-based science practices (OTL) than males ($\beta = -0.16, p \leq .001$).

OTL inquiry-based science was not a significant predictor of science achievement (see Figure 5); therefore, there were no significant indirect relationships between intersectional student background or gender and achievement via OTL.
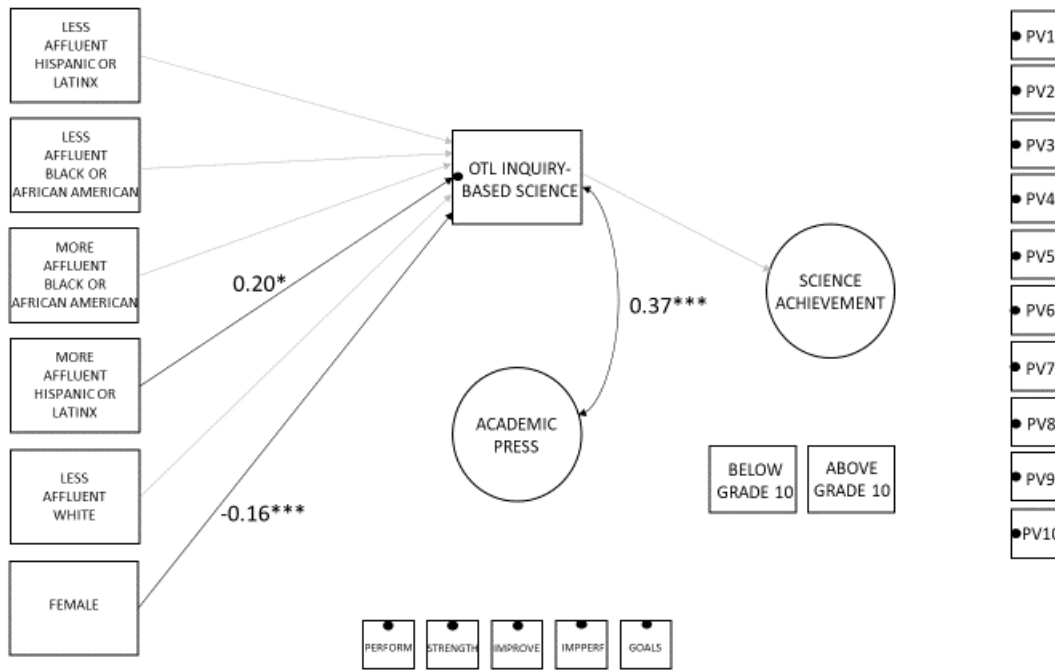

Figure 5. Standardized path coefficients for the within part of the multilevel SEM model: direct effects of student background on OTL and OTL on science achievement. Partial findings are presented for readability. See Figure 3 for the full model tested. Statistically significant paths are in black and nonsignificant paths are in grey. * p ≤ .05, ** p ≤ .01, *** p ≤ .001

Direct and Indirect Effects for Academic Press

As seen in Figure 6, less affluent Hispanic or Latinx students ($\beta = 0.18$, $p \leq .05$), less affluent Black or African American students ($\beta = 0.23$, $p \leq .01$), more affluent Hispanic or Latinx students ($\beta = 0.21$, $p \leq .01$), and less affluent White students ($\beta = 0.17$, $p \leq .05$) reported more frequent academic press, or feedback from teachers on their learning progress and goals in science

class, compared to more affluent White students. Females reported less frequent academic press in science class than males (β = -0.16, p ≤ .001).

Academic press had a significant, negative direct effect on science achievement (β = -0.11, p ≤ .001) (see Figure 6). In other words, students who reported more frequent feedback related to their performance in science class had lower scientific literacy scores.
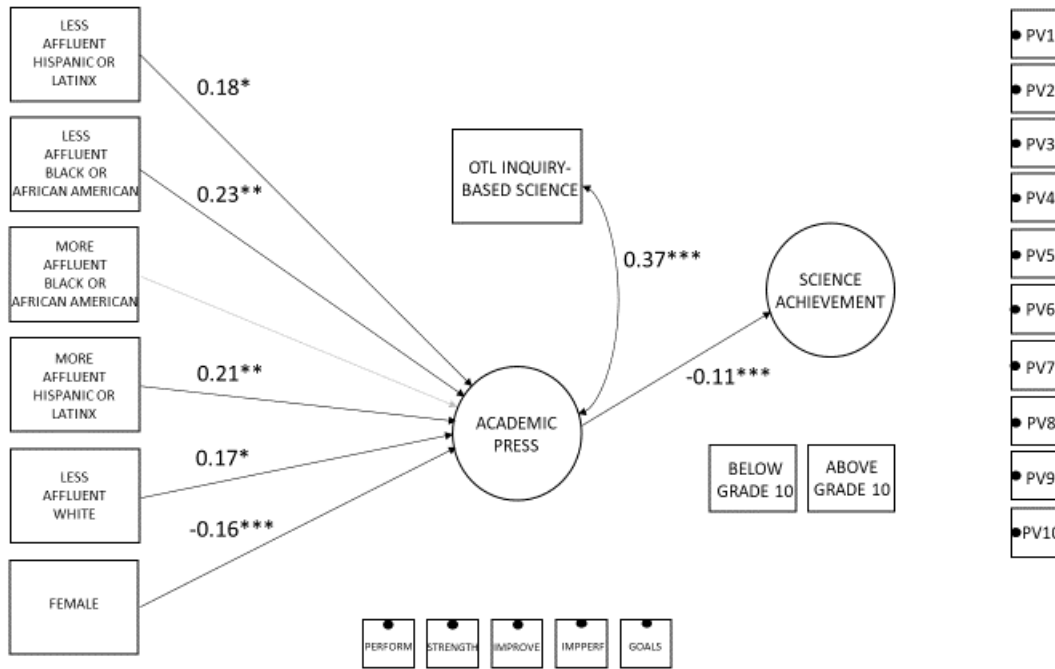

Figure 6. Standardized path coefficients for the within part of the multilevel SEM model: direct effects of student background on academic press and academic press on science achievement. Partial findings are presented for readability. See Figure 3 for the full model tested. Statistically significant paths are in black and nonsignificant paths are in grey. * p ≤ .05, ** p ≤ .01, *** p ≤ .001

Academic press was also a significant partial mediator of intersectional student background and science achievement for most of the groups (see Table 2). There was a significant, negative indirect relationship between intersectional student background and scientific literacy outcomes via academic press for less affluent Hispanic or Latinx students (β = -0.019, p ≤ .05), less affluent

Black or African American students (β = -0.026, p ≤ .05), more affluent Hispanic or Latinx students (β = -0.023, p ≤ .05), and less affluent White students (β = -0.019, p ≤ .05). The indirect relationship was negative because each of these groups reported more frequent academic press compared to more affluent White students, and academic press was a negative predictor of scientific literacy.

There was a significant, positive indirect relationship between gender and science achievement via academic press (β = 0.017, p ≤ .01). This indirect relationship was positive because females reported less frequent academic press in science class than males, and academic press was a negative predictor of scientific literacy.

Between Level

Direct Effects for School Context and School Academic Climate

At the school level, the community in which the school was located was a significant predictor of one of the school academic climate measures, principal perception of students lacking respect for teachers (see Figure 7). Principals at schools located in a rural area or town reported that hindrances to student learning due to students lacking respect for teachers happened to a greater extent than principals at schools located in a city or large city (β = -0.30, p ≤ .05).

The proportion of students eligible for free/reduced price lunch (FRPL) was also a significant predictor of several school academic climate measures (see Figure 7). Non-science teachers at schools with under 25% of students eligible for FRPL reported significantly greater agreement that their principal treated teaching staff as professionals compared to teachers at schools with 25-74.9% of students eligible for FRPL (β = 1.44, p ≤ .001). The extent of agreement was almost 1.5 standard deviations higher.

Science and non-science teachers at schools with 75% or more students eligible for FRPL reported significantly less agreement that they enjoyed working at their school (β = -0.76, p ≤ .05)

compared to teachers at schools with 25-74.9% of students eligible for FRPL. Principals at schools

serving 75% or more students eligible for FRPL also reported that hindrances to student learning

due to students lacking respect for teachers ($\beta = -1.36$, $p \leq .001$) and intimidating or bullying other

students ($\beta = -0.75$, $p \leq .001$) occurred to a greater extent than principals at schools with 25-74.9%

of students eligible for FRPL. The differences in perceptions of teacher enjoyment and students

intimidating or bullying others was around three-quarters of a standard deviation. The difference

in perception of students lacking respect for teachers was well over a standard deviation.
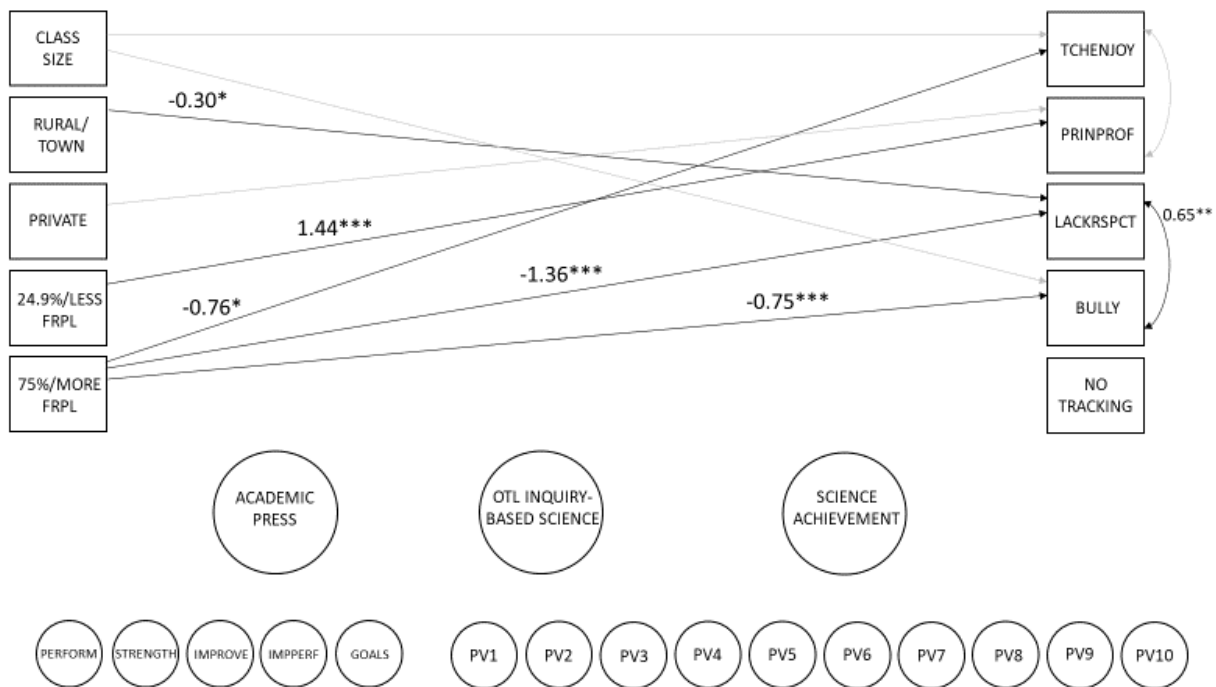

Figure 7. Standardized path coefficients for the between part of the multilevel SEM model: direct effects of school context control variables on dimensions of school academic climate. Partial findings are presented for readability. See Figure 3 for the full model tested. Statistically significant paths are in black and nonsignificant paths are in grey. * $p \leq .05$, ** $p \leq .01$, *** $p \leq .001$

Direct Effects for School Context, Academic Press, and OTL

Of the school context variables, only the community in which the school was located was

a significant predictor of academic press and OTL at the school level (see Figure 8). Schools

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located in a rural area or town had lower school academic press and OTL means than city schools. In other words, schools in rural areas or towns on average engaged in less frequent feedback related to student science performance (β = -1.15, p $\leq$ .001) and provided less frequent opportunities for inquiry-based science (β = -0.72, p $\leq$ .01) compared to schools located in cities or large cities. The difference was over a standard deviation for academic press and close to three-quarters of a standard deviation for OTL.
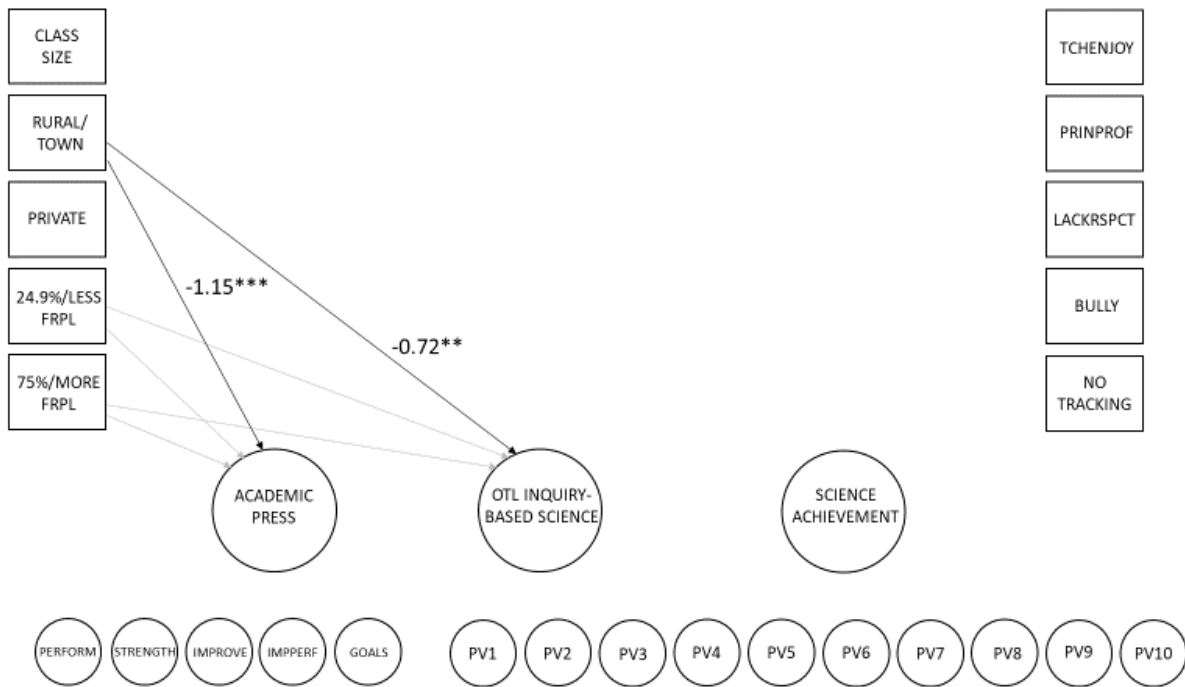

Figure 8. Standardized path coefficients for the between part of the multilevel SEM model: direct effects of school context control variables on academic press (random intercept factor) and OTL (random intercept). Partial findings are presented for readability. See Figure 3 for the full model tested. Statistically significant paths are in black and nonsignificant paths are in grey. * p $\leq$ .05, ** p $\leq$ .01, *** p $\leq$ .001

Direct Effects for School Context and Science Achievement

School designation was a significant predictor of the school cluster mean for science achievement (see Figure 9). Private schools had a mean scientific literacy score that was around three-quarters of a standard deviation lower than public schools (β = -0.78, p $\leq$ .001).

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Percentage of students eligible for FRPL was also a significant predictor of the school mean for science achievement (see Figure 9). Schools with less than 25% of student eligible for FRPL had a significantly higher mean score on scientific literacy compared to schools with 25-74.9% of students eligible for FRPL ($\beta = 0.38$, $p \leq .001$). The mean difference was slightly over a third of a standard deviation. Schools with more than 75% of students eligible for FRPL had a significantly lower mean score on scientific literacy compared to schools with 25-74.9% of students eligible for FRPL ($\beta = -0.51$, $p \leq .001$). The mean difference was around half of a standard deviation.
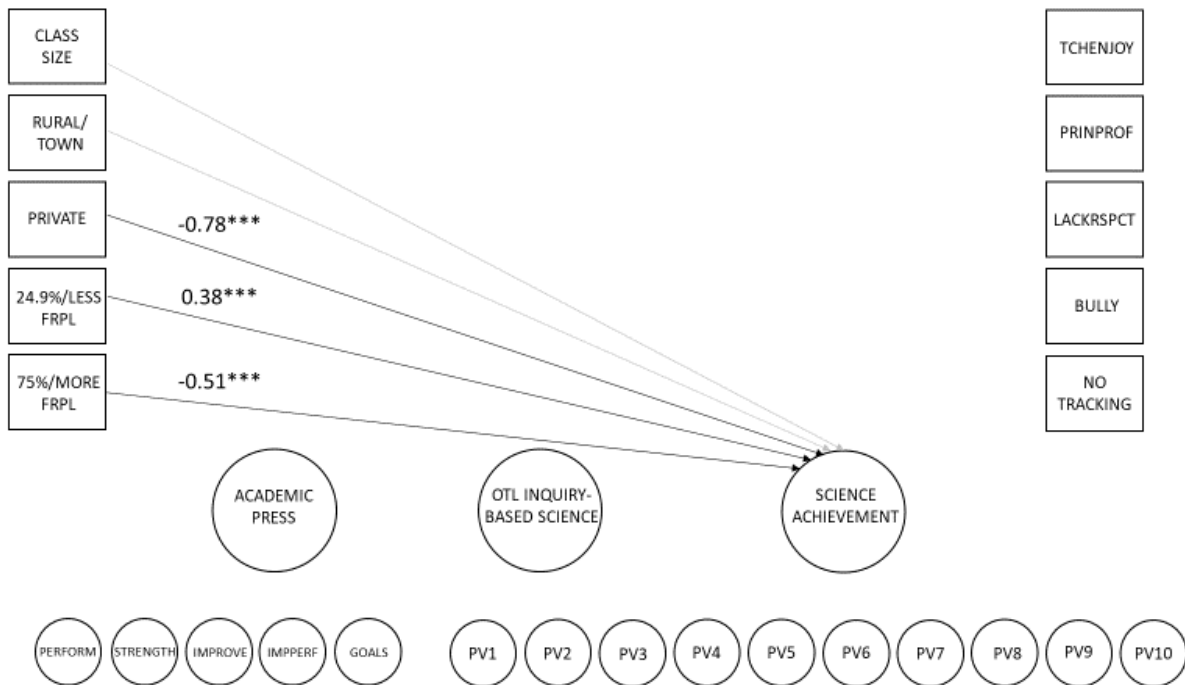

Figure 9. Standardized path coefficients for the between part of the multilevel SEM model: direct effects of school context control variables on science achievement (random intercept factor). Partial findings are presented for readability. See Figure 3 for the full model tested. Statistically significant paths are in black and nonsignificant paths are in grey. * $p \leq .05$, ** $p \leq .01$, *** $p \leq .001$

Direct Effects for School Academic Climate, Tracking, and Academic Press

Principal perception of students lacking respect for teachers was a significant negative predictor of academic press at the school level (see Figure 10). Less extensive problems with

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students' lack of respect hindering learning (i.e. a higher value reported by the principal) was associated with a lower school mean on academic press (β = -0.50, p $\leq$ .01), or less frequent feedback related to student science performance.
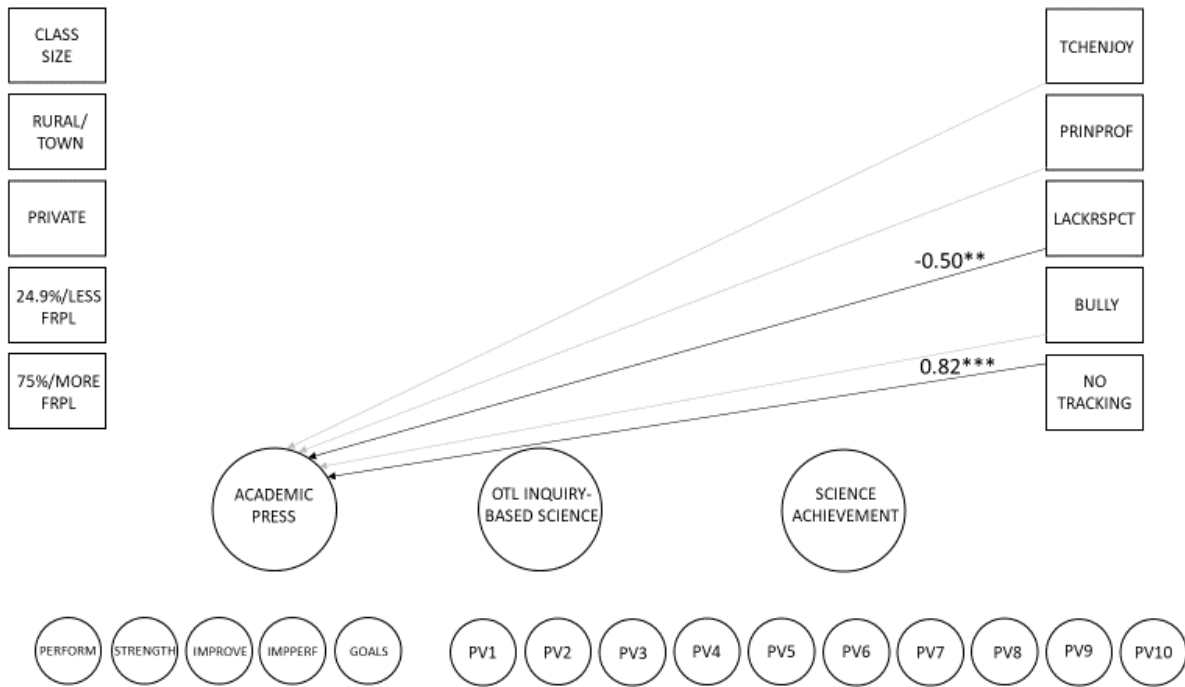

Figure 10. Standardized path coefficients for the between part of the multilevel SEM model: direct effects of school academic climate dimensions and tracking on academic press (random intercept factor). Partial findings are presented for readability. See Figure 3 for the full model tested. Statistically significant paths are in black and nonsignificant paths are in grey. * p $\leq$ .05, ** p $\leq$ .01, *** p $\leq$ .001

Tracking was also a significant predictor of academic press at the school level (see Figure 10). Schools that did not practice tracking had a higher mean on academic press than schools that grouped students by ability into different classes for some or all subjects (β = 0.82, p $\leq$ .001). In other words, non-tracking schools on average engaged in more frequent feedback related to student science performance than schools that practiced tracking.

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Direct Effects for School Academic Climate, Tracking, and OTL

Tracking was a significant predictor of OTL inquiry-based science at the school level (see Figure 11). Schools that did not practice tracking had a higher mean on OTL than schools that grouped students by ability into different classes for some or all subjects ($\beta = 0.57$, $p \leq .05$). This means that, on average, non-tracking schools engaged in more frequent inquiry-based science teaching and learning practices than schools that practiced tracking.
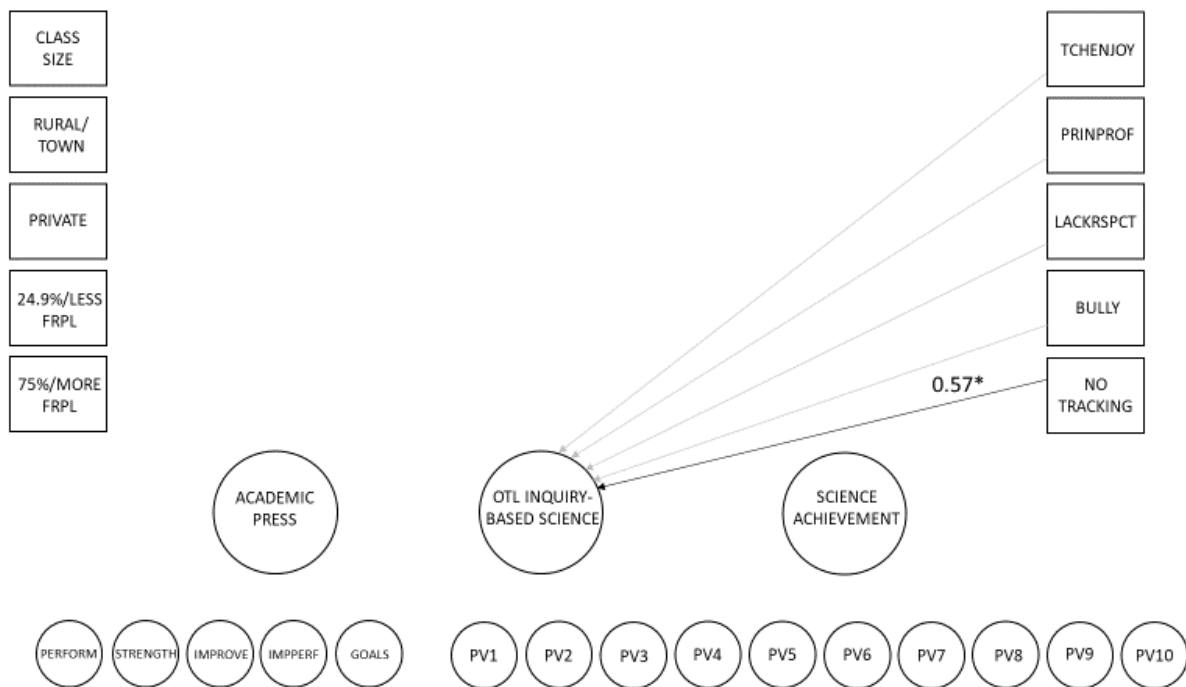

Figure 11. Standardized path coefficients for the between part of the multilevel SEM model: direct effects of school academic climate dimensions and tracking on OTL (random intercept). Partial findings are presented for readability. See Figure 3 for the full model tested. Statistically significant paths are in black and nonsignificant paths are in grey. * $p \leq .05$, ** $p \leq .01$, *** $p \leq .001$

Direct Effects for School Academic Climate, Tracking, and Science Achievement

While tracking was not a significant predictor of science achievement at the school level, each of the school academic climate measures were significant predictors of school cluster means

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for science achievement, although the direction of the relationship varied (see Figure 12). Stronger agreement among science and non-science teachers that they enjoyed working at the school (β = 0.06, p ≤ .001) and stronger agreement among non-science teachers that the principal treated teaching staff as professionals (β = 0.16, p ≤ .01) were both associated with higher school means for scientific literacy scores.
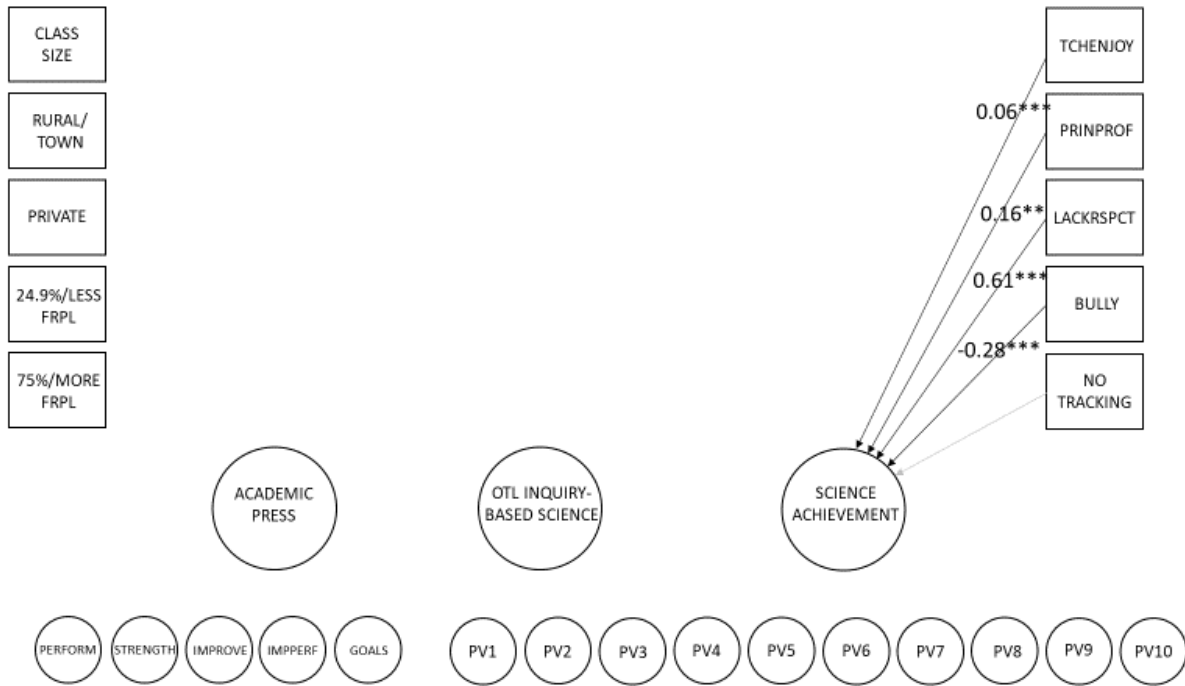

Figure 12. Standardized path coefficients for the between part of the multilevel SEM model: direct effects of school academic climate dimensions and tracking on science achievement (random intercept factor). Partial findings are presented for readability. See Figure 3 for the full model tested. Statistically significant paths are in black and nonsignificant paths are in grey. * p ≤ .05, ** p ≤ .01, *** p ≤ .001

Principal perception of students lacking respect for teachers was a significant positive predictor of school cluster means for science achievement (see Figure 12). Less extensive problems with student learning being hindered by lack of respect for teachers (i.e. higher reported values) were associated with higher school scientific literacy means (β = 0.61, p ≤ .001). However,

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principal perception of problems with bullying or intimidation hindering student learning was a negative predictor of science achievement at the school level. Less extensive problems with students bullying or intimidating others (i.e. higher reported values) was associated with lower school means for scientific literacy ($\beta = -0.28$, $p \leq .001$).

Discussion

The findings from this study have provided important evidence for how students' educational experiences within schools mediate the relationship between student background and achievement, as well as the school norms and structures that contribute to these differential experiences and outcomes. First, after accounting for variance explained at the school level, OTL was not a significant mediator of the relationship between student intersectional background or gender and scientific literacy outcomes. However, academic press was a significant mediator at the student level, and was a significant negative predictor of science achievement. At the school level, while tracking was not a significant predictor of mean school science achievement, tracking was a predictor of mean school academic press and OTL inquiry-based science, results that warrant further examination. There were also important differences in academic climate between schools that might help explain students' inequitable school experiences.

First, schools that did not practice academic tracking, or did not sort students into different classes by ability, had higher means for academic press and OTL inquiry-based science than schools that sorted students into classes by ability for some or all subjects. This means that non-tracking schools engaged on average in more feedback related to students' learning and academic goals in science class and also provided more frequent opportunities for inquiry-based science instruction. Given the detrimental effects of tracking highlighted in the literature over decades of research, such as less supportive affective environments for students in lower tracks (Donaldson

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et al., 2017), the potential for students to internalize messages about their ability (Rubie-Davies, 2006; Karlson, 2015), and less engaging and rigorous instruction in lower tracks (Harris, 2011; Oakes, 2005; Watanabe, 2008), it would seem likely that non-tracking schools might have higher achievement due to more equitable learning environments and practices. However, tracking was not a significant predictor of mean school scientific literacy outcomes, and at the student level, higher academic press was associated with lower science achievement. One possible explanation for this could be found in the detracking literature. Although detracking seems like a straightforward solution, the research on detracking efforts has revealed the challenges that have emerged through this type of reform, many of which are similar to the issues posed by tracking. First, prioritizing social integration of students over academic equity can fail to address the instructional disparities and subsequent outcome gaps that stem from tracking (Rubin & Noguera, 2004). Further, Rubin and Noguera (2004) have pointed out that resegregation within classes can occur through seating and group arrangements; students might still experience differences in the quality of feedback and positive or negative attention they receive from teachers; there is potential for less demanding work to be expected of lower achieving students; and some activities might reinforce students' views about themselves and their abilities. Clearly, many of these concerns echo the problems associated with tracking. Further, teachers might struggle to meet the range of student needs and consequently adopt a "teach to the middle" approach (Rubin & Noguera, 2004). These challenges illustrate how the differential instruction in classrooms across tracks is not just a function of structural aspects of student grouping, but is informed by attitudes, assumptions, and practices that must be addressed for more equitable approaches, such as detracking, to be successful. Another possible explanation is that a lack of tracking structures reflects differential resources between schools and districts (Berliner & Glass, 2014; Darling-Hammond, 2013; Flores,

2007; Orfield & Lee, 2006; Darling-Hammond, 2004a; Darling-Hammond, 2004b; Oakes, 1990), rather than a more equitable orientation towards students' abilities and performance. For examples, some schools or districts might opt for more heterogeneous class assignments because they lack resources for differentiated programs such as Advanced Placement or International Baccalaureate courses.

Next, an important line for future inquiry is how and why student perception of academic press, as measured in this study, partially explains the relationship between intersectional student background or gender and scientific literacy outcomes. The less affluent Hispanic or Latinx, less affluent Black or African American, more affluent Hispanic or Latinx, and less affluent White groups all reported that they received more frequent feedback on their performance in science class than the more affluent White group, and more frequent performance feedback was associated with lower scientific literacy scores. The negative relationship runs counter to past research that has demonstrated a positive relationship between academic press and achievement (Bryk et al., 2010). One possible explanation is that the operationalization of academic press in this study did not adequately capture a fundamental component of academic climate – high expectations for all students' learning. While some of the indicator items were related to recognizing students' strengths and improving student learning, it is possible that teachers were nonetheless implicitly or explicitly communicating low expectations for students, or were failing to acknowledge the full range of students' assets (Irizarry, 2011; Moll, Amanti, Neff, & Gonzalez, 1992; Yosso, 2005) that could promote their academic success. This calls attention to another aspect of academic climate – relationships between teachers and students (Urick & Bowers, 2011, 2014) – and findings at the school level that might help explain these results. At the school level, principal perception of less extensive problems with students' lack of respect for teachers was related to less frequent student

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performance feedback in science (i.e. academic press). This might suggest that more supportive relationships between students and teachers bear on the types of interactions students and teachers have around academic feedback and learning goals. The measures of academic press used in this study might be indicative of the patterns of feedback used by teachers in schools that have not facilitated strong relationships and morale among students. Indeed, Bryk et al. (2010) have pointed to the weaker-than-expected effects of academic press on achievement and posited that academic press might capture "social-psychological phenomena" (p. 202), a possibility reinforced by the current study that could be addressed by future research. In particular, the association between student-teacher relationships and various dimensions of academic press are potential avenues for further inquiry.

The findings also pointed to key differences in academic climate between schools with higher concentrations of more or less affluent students. Teachers at schools with less than 25% of students who qualified for free/reduced price lunch (FRPL) had significantly higher agreement that their principals treated teaching staff as professionals, an indicator of strong academic climate, compared to teachers at schools with a more moderate percentage of students qualifying for FRPL. Conversely, teachers at schools with a higher concentration of students qualifying for FRPL – 75% or more – indicated less agreement that they enjoyed working at their school, and principals reported that students' lack of respect for teachers and bullying hindered student learning to a greater extent than schools with a more moderate proportion of students qualifying for FRPL. The weaker academic climate at schools serving a high percentage of less affluent students might be explained by issues with teacher recruitment and retention for segregated schools serving predominately Students of Color and students living in poverty (see Wronowski, 2018). This makes salient the issue of equitable student access to qualified, experienced teachers (Akiba et al.,

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2007; Darling-Hammond, 2004b; Oakes, 1990) who have been adequately prepared to teach students from a culturally responsive, asset-based pedagogical framework (see Camangian, 2015; Ladson-Billings, 1995, 2014; Villegas & Lucas, 2002; Warren, 2018). This requires an acknowledgement on the part of educators and policymakers of the covert ways that white privilege and aversive racism (Dovidio et al, 2019; McIntosh, 1988; Vaught, 2009), as well as intersectional systems of privilege (Collins, 2015), have contributed to dehumanizing educational experiences for students (Camangian, 2015), particularly students in segregated schools. It also requires a commitment to systemically provide support for a more humanizing approach to education that empowers students to challenge structural inequities. As Camangian (2015) has noted, "humanizing education is complex because it tries to move, in beautifully contested ways, children and communities to where they want to go while grappling with the painful pasts that they have to confront to get there" (p. 427).

Finally, the results from this study have reinforced the potential of school academic climate to be leveraged by school leaders and policymakers to promote student success in science. Stronger teacher agreement that they enjoy working at the school and are treated by their principals as professionals were both associated with higher school mean scientific literacy scores. This suggests that teacher morale is an important facet of a school's academic success. Given the school context differences on these academic climate indicators, this might point to the need for teacher preparation programs to more effectively prepare pre-service teachers for different school contexts and challenge the monocultural perspective (see Cochran-Smith, Davis, & Fries, 2004) that has historically been employed, as well as a need for better context-specific professional development for in-service teachers (Irizarry & Raible, 2011). This also has implications for building school leadership capacity given the principal's influence on school academic climate (Sebastian &

Allensworth, 2012). Moreover, principal perceptions of less extensive problems related to students lacking respect for teachers were associated with higher school mean scientific literacy scores. Again, this underscores the importance of supportive, mutually respectful relationships between teachers and students grounded in authentic care (Newcomer, 2018) and perspective-taking (Matthews, 2020; Warren, 2018). One interesting finding was that principal reports of less extensive problems with bullying were negatively related to science achievement. A possible explanation is that schools with weaker academic climates failed to recognize or underreported incidences of student bullying and intimidation. However, given the unexpected direction of the relationship for this school-level academic climate indicator, this might be an important line for future study.

Implications for Policy, Practice, and Future Research

The findings from this study have provided important insight into the "receivement gap" (Chambers, 2009), which can help explain and address disparities in student outcomes that reflect a history of systemic inequality and institutionalized racism. Namely, the findings suggest the need for policymakers, practitioners, and researchers to critically reexamine what constitutes opportunity to learn (OTL) in terms of equity. OTL inquiry-based science was not a significant mediator of intersectional student background or gender and science achievement. Moreover, more frequent feedback related to science performance was associated with lower science achievement. Collectively, these findings highlight that what might on the surface appear to be enhanced instructional opportunities for historically underserved students might, at best, be ineffective, and at worst, be detrimental to student learning and self-perception in school. This study focused on the instructional dimension of OTL to extend the concept beyond content as a minimum requirement for learning. An orientation towards equity requires us to think beyond students

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meeting minimum proficiency and consider the range of outcomes, including postsecondary access and success, that all students should equitably be supported to attain. However, this study further complicates the conceptualization and implementation of OTL by suggesting that enhanced opportunity in itself is not an effective way to address educational inequities or outcomes gaps. It is important to critically examine the nature of the opportunity and its responsiveness to the experiences and needs of students, particularly students who have been marginalized or oppressed by instructional practices, curriculum, structures, and policies in schools. This points to the need to understand the differential effects of various dimensions of OTL on both student academic and affective outcomes, as well as the need to move the concept forward. In particular, incorporating culturally responsive and humanizing pedagogical practices, and exploring the school-level features that facilitate more equitable and socially just practices, are important lines for future research on OTL. To be clear, this is not a call for students to receive fewer opportunities in schools. Rather, it is a call for schools and policymakers to disrupt the pattern of providing the same forms of dehumanizing educational opportunities in various doses and instead challenge the deeply rooted norms, assumptions, practices, and structures that have perpetuated educational inequality. In other words, opportunity to learn that does not intentionally and meaningfully challenge academic and social hierarchies of power and privilege does not actually constitute opportunity.

Appendix A. List of variables

		Construct	PISA Index/Variable	Question/Item
student level		student background	ST004D01T	Are you female or male?
			RACETHC	NAT/Collapsed derived student race/ethnicity
			Immigration background (IMMIG)	In what country were you and your parents born?
			Language spoken at home (LANGN)	What language do you speak at home most of the time?
		student background: social class	Highest educational level of parents (HISCED)	What is the highest level of schooling (not including college) completed by your mother/father? Does your mother/father have any of the following degrees, certificates, or diplomas?
			Highest occupational status of parents (HISEI)	What is your mother's main job? What does your mother do in her main job? What is your father's main job? What does your father do in his main job?
			Family wealth (WEALTH)[1]	Which of the following are in your home? • A room of your own • A link to the internet How many of these are at your home? • Televisions • Cars • Rooms with a bath or shower • Computers • Tablet computers • E-book readers
		student background: cultural capital	Parents emotional support (EMOSUPS)[1]	Thinking about this school year: to what extent do you agree or disagree with the following statements? • My parents are interested in my school activities • My parents support my educational efforts and achievements • My parents support me when I am facing difficulties at school • My parents encourage me to be confident
			Cultural possessions at home (CULTPOSS)[1]	Which of the following are in your home? • Classical literature • Books of poetry • Works of art • Books on art, music, or design How many of these are there at your home? • A musical instrument
			Home educational resources (HEDRES)[1]	Which of the following are in your home? • A desk to study at • A quiet place to study • A computer you can use for your school work • Educational software • Books to help with your school work • Technical reference books or manuals • A dictionary
			ST013Q01TA	How many books are there in your home?

	opportunity to learn	Inquiry-based science teaching and learning practices (IBTEACH)	When learning science topics at school, how often do the following activities occur? • Students are given opportunities to explain their ideas • Students spend time in the laboratory doing practical experiments • Students are required to argue about science questions • Students are asked to draw conclusions from an experiment they have conducted • The teacher explains how a science idea can be applied to a number of different phenomena (e.g. the movement of objects, substances with similar properties) • Students are allowed to design their own experiments • There is a class debate about investigations • The teacher clearly explains the relevance of science concepts to our lives
	academic climate: academic press	ST104Q01NA ST104Q02NA ST104Q03NA ST104Q04NA ST104Q05NA	How often do these things happen in your classes for this science course? • The teacher tells me how I am performing in this course • The teacher gives me feedback on my strengths in this science subject • The teacher tells me in which areas I can still improve • The teacher tells me how I can improve my performance • The teacher advises me on how to reach my learning goals
	grade level	ST001D01T	What grade are you in?
	scientific literacy	PV1SCIE, PV2SCIE, PV3SCIE, PV4SCIE, PV5SCIE, PV6SCIE, PV7SCIE, PV8SCIE, PV9SCIE, PV10SCIE	Plausible Values 1-10 in Science
school level	school context	SC001Q01TA	Which of the following definitions best describes the community in which your school is located?
		Class size (CLSIZE)	What is the average size of English classes in the 10th grade in your school?
		FRPL	NAT/Percentage Free/Reduced Price Lunch
		PUBPRIV	NAT/Public/Private School
	tracking	SC042Q01TA	Some schools organize instruction differently for students with different abilities. What is your school's policy about this for students in tenth grade? • Students are grouped by ability into different classes
		SC061Q03TA	In your school, to what extent is the learning of students hindered by the following phenomena?

	school academic climate		• Students lacking respect for teachers
		SC061Q05TA	In your school, to what extent is the learning of students hindered by the following phenomena? • Students intimidating or bullying other students
		TC026Q05NA[2]	We would like to know how you generally feel about your job. How strongly do you agree or disagree with the following statements? • I enjoy working at this school
		TC060Q07NA[2]	To what extent do you disagree or agree with the following statements regarding your school? • The principal treats teaching staff as professionals

Notes: [1]Raw item responses used to create composites that align with PISA index, [2]Teacher questionnaire items aggregated to the school level

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