UNIVERSITY OF CALIFORNIA,
IRVINE

Three Studies on the Patterns and Contextual Predictors of Adolescents' STEM Motivational Beliefs

DISSERTATION

submitted in partial satisfaction of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

in Education

by

Ta-yang Hsieh

Dissertation Committee:
Professor Sandra Simpkins, Chair
Assistant Professor Jade Jenkins
Chancellor's Professor Emerita Deborah Vandell

2021

DEDICATION

To

my village

for believing in me

Once it's in your head, no one can steal your education. You getting more education doesn't mean someone needs to get less either.

-my mom

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ACKNOWLEDGEMENTS

First and foremost, my utmost gratitude goes to my advisor Dr. Sandi Simpkins who mentors (not just supervises) my professional and personal growth. All the good things that come with this degree I owe them to Sandi. Words also cannot describe how grateful I am to my labmates, Drs. (or soon-to-be Drs.) Yangyang Liu, Stephanie Soto-Lara, Su Jiang, Kayla Puente, Glona Lee, Perla Ramos Carranza, Mark Yu, Christy Starr, Zehra Gülseven, and Fuko Kiyama. Their support spans far beyond this dissertation; wherever life takes each of us, I would always remember the years we shared. I also want to thank all my colleagues and faculty at UCI School of Education, as well as our amazing program managers Geneva and Sarah. I want to specifically thank Dr. Deborah Vandell and Dr. Jade Jenkins for serving on my dissertation committee; thank you for guiding me through this major milestone.

Most of the writing for this dissertation was done in year 2020 and 2021. I want to acknowledge those were stressful times with a global pandemic as well as political unrests both within the U.S. and internationally. I thank all the frontline workers and human right fighters for keeping the world from entirely collapsing while I write this dissertation with the safety and comfort of my apartment. Speaking of apartment, shoutout to my partner slash room-office-mate for cooking me nice food and making sense of my rants. Lastly, and as always, thanks to my parents for supporting me to live the life as I wanted.

VITA

Ta-yang Hsieh

Education

2016	**University of Wisconsin-Madison**	B.S. Psychology (Honors) and Human Development & Family Studies Certificate in Criminal Justice
2021	**University of California-Irvine**	Ph.D. Education

Dissertation: *Three Studies on the Patterns and Contextual Predictors of Adolescents' STEM Motivational Beliefs* (Advisor: *Dr. Sandra Simpkins*)

Selected Awards and Honors

2020	Most Promising Future Faculty Award	University of California-Irvine
2018	Emerging Scholar Student Travel Award	Society of Research on Adolescence
2016	Graduation with highest distinction	University of Wisconsin-Madison
2015	Hilldale Undergraduate Research Fellowship	University of Wisconsin-Madison
2015	Meyerhoff Excellence Award for Leadership, Service and Scholarship	University of Wisconsin-Madison, (nominated by the International Student Services)

Publications

PB 6 **Hsieh, T.,** Simpkins, S. D., & Eccles, J. S. (under review). Gender by Racial/Ethnic Intersectionality in the Patterns of Adolescents' Math Motivation and Their Math Achievement and Engagement. *Contemporary Educational Psychology.* doi:10.1016/j.cedpsych.2021.101974

PB 5 Yu, M. B. V., Liu, Y, **Hsieh, T.**, Lee, G, Simpkins, S. D., & Pantano, A. (2020). "Working together as a team really gets them fired up": Afterschool program mentoring strategies to promote collaborative learning among adolescent participants. *Applied Developmental Science*. doi:10.1080/1088691.2020.1800467

PB 4 **Hsieh, T.**, & Liu, J. C. (2020). Lessons from the Taiwan Syllabus Project: Findings and new directions. *International Journal of Taiwan Studies, 3,* 145-156. doi:10.1163/24688800-00301010

PB 3 Simpkins, S. D., Liu, Y., **Hsieh, T**., & Estrella, G. (2019). Supporting Latino high school students' science motivation: Examining the unique and collective contributions of family, teachers, and friends. *Educational Psychology, 40*, 409-429. doi:10.1080/01443410.2019.1661974

PB 2 **Hsieh, T.,** Liu, Y., & Simpkins, S. D. (2019). Changes in United States Latino/a high school students' science motivational beliefs: Within group differences across science subjects, gender, immigrant status, and perceived support. *Frontiers in Psychology, 10,* 380. doi:10.3389/fpsyg.2019.00380

PB 1 Fredricks, J., **Hsieh, T**., Liu, Y., & Simpkins, S. D. (2019). Spilling over: How participating in after-school organized activities predicts students' engagement. In Fredricks, J. A., Reschly, A. L., & Christenson, S. L., *Handbook of student engagement interventions: Working with disengaged students* (pp. 231-243). doi:10.1016/B978-0-12-813413-9.00016-4

Papers under Review

Hsieh, T., & Simpkins, S. D. (revise & resubmit). Longitudinal associations between parent degree/occupation, parent support, and adolescent motivational beliefs in STEM

Hsieh, T., & Simpkins, S. D. (revise & resubmit). The patterns of adolescents' math and science motivational beliefs: Examining within-racial/ethnic group changes and relation to STEM outcomes

Yu, M. B. V., **Hsieh, T.**, Lee, G, Jiang, S., Simpkins, S. D., & Pantano, A. (revise & resubmit). Promoting adolescents' math motivational beliefs: Competence-supportive practices in an after-school program

Oral Presentations

OP6 **Hsieh, T.,** Kang, H., & Simpkins, S. D. (2021). Exploring Leverage Points to Increase Latinx High School Students' Identification with STEM: Differences Across Race/Ethnicity. Paper accepted to the American Educational Research Association Annual Meeting, Online Conference.

OP5 **Hsieh, T.,** & Simpkins, S. D. (2019, May). Profiles of high school students' perception of math teacher predicting math interest and achievement. In H-Y, Chan (Chair), Ecological factors of math/science motivational beliefs, resilience to challenges, and college aspiration for high school freshmen: A person-centered approach. Symposium conducted at the Association for Psychological Science Annual Convention, Washington D. C.

OP4 **Hsieh, T.,** & Soohoo, J. (2019, February). Possibilities and limitations of a summer camp to address summer learning loss: A mixed method study. Paper presented at the American Camp Association National Conference, Nashville, TN.

OP3 **Hsieh, T.,** & Simpkins, S. D. (2018, August). Pattern-centered approach to high school math motivation. Paper presented at the Gender & STEM Network Conference, Eugene, OR.

OP2 **Hsieh, T.,** & Wang, Y. (2018, May). How to teach Taiwan: Findings from the Taiwan Syllabus Project. Roundtable presentation at the North American Taiwan Studies Association Conference, Austin, TX.

OP1 **Hsieh, T.** (2016, April). The link between adolescents' peer sexual harassment victimization and math engagement. Paper presented at the Undergraduate Symposium, Madison, WI.

Selected Poster Presentations

Hsieh, T., Ramos Carranza, P., Yu, M. V., & Simpkins, S. D. (2021). STEM Extracurricular Activities and Adolescents' STEM Performance, Motivational Beliefs, and Aspirations in High School. Poster accepted to the American Educational Research Association Annual Meeting, Online Conference.

Hsieh, T., Vandell, D. L., & Simpkins, S. D. (2020, March). After-school Time Use and Adolescent Substance Use as Precursors to Problematic Substance Use at Age 26. Poster accepted to the Society of Research on Adolescence Biennial Meeting, San Diego, CA. (conference canceled due to COVID-19 pandemic)

Hsieh, T., & Soohoo, J. (2019, May). Mixed-method evidences for a summer camp in addressing summer learning loss. Poster presented at the Building Partnerships to Improve Education Symposium, Irvine, CA.

Liu, Y., **Hsieh, T.**, Soto-Lara, S., Simpkins, S. D., Vandell, D. L., & Luo, H. (2018, October). Effects of After-School Programs in Promoting Performance Character: A Systematic Meta-Analysis. Poster presented at the Character Development Special Meeting of the Society for Research in Child Development, Philadelphia, PA.

Hsieh T., Liu, Y., & Simpkins, S. D. (2018, August). Trajectories of science and math motivation among Latino/a adolescents. Poster presented at the Gender & STEM Network Conference, Eugene, OR.

Soto-Lara, S., **Hsieh, T**., & Simpkins, S. D. (2018, March). Latina/o parents' positive and negative responsiveness and their adolescents' academic aspirations. Poster presented at the Society of Research on Adolescence Biennial Meeting, Minneapolis, MN.

Hsieh, T., Hyde, S. J., & Clarke, E. K. (2016, August). *The link between adolescents' peer sexual harassment victimization and math engagement.* Poster presented at the American Psychological Association Annual Convention, Denver, CO.

Hsieh, T., Schmidt, N. L, & Goldsmith, H. H. (2016, April). *Early temperament predicting adolescent callous/unemotional behavior.* Poster presented at the Undergraduate Symposium, Madison, WI.

Grants

Hsieh, T., Jhang, J., & Wu, C-H. CS004-A-19 Keywording Taiwan (Conference hosted by the North American Taiwan Studies Association), Chiang Ching-kuo Foundation for International Scholarly Exchange ($25,000), January 2020 - June, 2021.

Assisted with grant writing:

Simpkins, S. D. (Principal Investigator), & Eccles, J. DRL-1760757 Family support of math and science: Examining an untapped source of resilience for diverse high school students, National Science Foundation ($979,734), 10/1/2018-9/30/2021

Practitioner-Oriented Outputs

PO4 Vandell, D. L., Simpkins, S. D., **Hsieh, T.,** Soto-Lara, S., & Ramos Carranza, P. (2020, July). A Portrait of the 21st CCLC Program (2005-2018): A Preview. Presentation to the 21st CCLC state education agency (SEA) coordinators meeting.

PO3 **Hsieh, T.,** & Simpkins, S. D. (2019, February 13). Is There Correlation Between After-school Programs, Delinquency? It's Complicated [Blog Post at Youth Today].

PO2 Camp Phoenix 2018 Program Evaluation Report. (Link)

PO1 Math Circle- Mentorship and Partnership Program Summary and Final Report- AY 2016-2017. Report prepared with the Mathematical Sciences Research Institute.

Teaching ** (U) = undergraduate level course, (G) = graduate level course **

California Community College Internship Program (CCCIP) intern 2019 Fall and 2020 Winter

- With Dr. Yemmy Taylor in **Irvine Valley College, Department of Psychology (U)**
  - Guest lectured "Motivation and Emotion" in Introductory Psychology
  - Guest lectured "Substance Use" in Abnormal Psychology

Lab instructor/TA of **Applied Regression (G)** 2018 Spring, 2019 Winter, 2020 Winter

- Under Dr. Rachel B. Baker at UC-Irvine
- A required quantitative course for UC-Irvine School of Education Ph.D. students

Co-instructor of **Human Development in Education (U)** 2017 Spring

- With Dr. Brandi Schumacher at UC-Irvine
- An introductory level 90-students class attended by mostly educational science majors

Co-instructor of **Family, School and Community in Early Childhood (U)** 2017 Spring

- With Dr. Brandi Schumacher at UC-Irvine
- An introductory level 60-students class attended by mostly educational science majors

Guest lectures

- **Peer Relationships** (May 1st, 2018 for Dr. Janice Hansen's **Adolescent Development in Education (U)** at UC-Irvine)
- **Out-of-school time education: Comparison between U.S. and Taiwan** (invited for December 17th, 2020 for Dr. Shu-Ling Huang's **Teacher Education Program (G)** at the National Chi Nan University)

Education Related Work Experiences

Search Institute (Supervisor: Dr. Amy Syvertsen) Minneapolis, MN
Incoming Research Scientist starting July, 2021

- To conduct applied research on positive youth development with a focus on education

Mott Synthesis Study on Out-of-School time (PI: Dr. Deborah Vandell) Irvine, CA
Graduate Research Assistant September 2017-Present

- Conducted literature review and co-authored reports on 21st Century Community Learning Programs
- Conducted literature review and created a database of studies on the effects of out-of-school time programs on academic, social-emotional, character, and delinquency outcomes

Math CEO (community educational outreach) Irvine, CA
Mentor, Research Assistant March 2017-Present

- Mentored students from under-resourced middle schools through weekly math afterschool sessions
- Created professional development materials for mentors of middle school students
- Co-author mixed-method empirical studies on the effectiveness and promising practices of the program

Camp Phoenix San Gregorio, CA
Evaluation Specialist July-August 2018

- Qualitatively (observations and interview) and quantitatively (pre-post questionnaires) evaluated a 3-week summer camp on middle schooler's character, academic, and socioemotional development
- Taught math to eighty (twelve at a time) middle schoolers in an outdoor setting; including creating, administering, and reviewing daily math assessments

Mathematical Sciences Research Institute USA
Research Intern (Summer) June-September 2017

- Evaluated nation-wide ‘Math Circles’ afterschool programs with quantitative and qualitative measures
- Wrote literature summaries for a grant proposal on the theories, associated outcomes, and gender and racial disparities of math motivation

Latino Families and Science Project (PI: Dr. Sandra Simpkins) Irvine, CA
Graduate Research Assistant September 2016-2017

- Developed video coding protocol to examine Latina/o parents’ positive and negative responsiveness and their adolescents’ academic aspirations
- Trained and supervised undergraduate research assistants to complete reliable qualitative coding

Teach for Taiwan Taipei, Taiwan
Research Intern (Summer) June-July 2016

- Developed culturally relevant measurement of motivation for elementary students in Taiwan
- Transcribed interviews of in-training-teachers and elementary students for program assessment

Adventure Learning Programs (ALPs) University of Wisconsin-Madison
Facilitator January 2015-May 2016

- Applied experiential education through rope courses, problem-solving activities, and intentional debriefings to foster community building and personal growth
- Demonstrated flexibility to worked with groups ranging from 7 to 150 participants

Selected Trainings

Undocumented Student Ally Training	UC Irvine	Feb 24, 2017
Certificate in Mentoring Excellence Program	UC Irvine	April-May, 2017
Certificate in Teaching Excellence Program	UC Irvine	July, 2017
Asian Caucus Pre-conference	Society of Research on Adolescence	April 11, 2018
Post-conference workshop on meta-analysis	Society of Research on Adolescence	April 15, 2018
Camps on Campus Pre-Conference	American Camp Association	Feb 19, 2019
Latent Class Analysis	Stats Camp (summer)	June 3-7, 2019
UC Adolescent Consortium	University of California system	Aug 14-16, 2019
Certificate in Improv for Teaching	UC Irvine	May 8-29, 2020
Inclusive Excellence Certificate	UC Irvine	Sep-Dec, 2020

ABSTRACT OF THE DISSERTATION

Three Studies on the Patterns and Contextual Predictors of Adolescents' STEM Motivational Beliefs

by

Ta-yang Hsieh

Doctor of Philosophy in Education

University of California, Irvine, 2021

Professor Sandra Simpkins, Chair

This dissertation examined the development and contextual correlates of Asian, Black, Latina/o, and White adolescents' STEM motivational beliefs. This is an important topic because STEM is increasingly critical for our daily lives and advances in the economy, but the U.S. struggles with stark racial/ethnic inequities in STEM. In Study 1, through person-centered analyses, I identified four and five patterns of math and science motivational beliefs in 9th and 11th grade, respectively. For each racial/ethnic group, I also charted the stability and changes in those patterns for 9th to 11th grade, in addition to testing how the patterns at 11th grade were associated with adolescents' STEM performance and career aspirations. Study 2 examined the relations between race/ethnicity, parents' STEM support, parents' STEM degree/occupation, and adolescents' STEM motivational beliefs. Findings suggested that parents' STEM support could be leveraged to promote adolescents' STEM motivational beliefs, with the most pronounced benefit observed among parents without a STEM degree/occupation. Study 3 examined how adolescents' STEM motivational beliefs and GPAs were associated with STEM indicators from two related contexts, neighborhoods and schools. Findings suggested that the direct and indirect effects of neighborhood STEM jobs and school STEM indicators on adolescents' STEM motivational beliefs and performance were largely nonsignificant. Across Studies 2 and 3, findings suggested several racial/ethnic differences in the mean levels of family, school, and adolescent STEM indicators. However, results also showed substantial racial/ethnic similarities regarding the associations between contextual factors and adolescents' STEM motivational beliefs, aspirations, and performances. All three studies in this dissertation were guided by the situated expectancy-value theory and utilized the High School Longitudinal Study dataset (from the National Center for Educational Statistics). Each study, however, incorporated additional theoretical frameworks and used specific subsamples from the dataset that best matched their research aims.

CHAPTER 1

Overarching Introduction to the Dissertation

Motivation plays an important role in explaining *why* we engage in a task and *how well* we do a task. Examining motivation opens the door to many interesting questions. For example, why do people with comparable abilities aspire and pursue widely different paths? How do significant social agents, such as parents and teachers, influence students' motivation in certain subjects? To what extent do our motivational beliefs change or remain stable over time? Importantly for my dissertation, I also examine those questions with a focus on race/ethnicity. What are the existing racial/ethnic differences in adolescents' motivational beliefs? How much variation exists within racial/ethnic groups? How is race/ethnicity related to other critical social markers such as parent education? Jointly, the three studies in this dissertation examined the interrelatedness or patterns of motivational beliefs and some of their contextual predictors.

Importance of STEM motivational beliefs

Among the infinite number of topics that one can examine regarding motivation, I focus on motivational beliefs toward STEM (science, technology, engineering, mathematics) in the U.S. context for several reasons. Firstly, STEM is a high-paying field that is experiencing growth in jobs (Bøe et al., 2011; Jones, 2014; Xue & Larson, 2015), which has implications for individuals' upward mobility. However, not everyone has equal access to STEM. STEM education and occupations are marked by stark disparities, including unequal gender representations and racial/ethnic inequities. Multiple structural inequities contribute to these disparities, including lack of representation, inequitable access to advanced STEM resources and opportunities, colorblind curriculum, discrimination, and implicit biases, to name a few (Beasley & Fischer, 2012; Grossman & Porche, 2014; McGee, 2016; Museus & Liverman, 2010; Nasir &

Vakil, 2017; Walls, 2016). Simply put, people in STEM are increasingly rewarded in terms of pay and prestige; yet, STEM fields continuously lack diversity in terms of the kind of people the field recruits and retains. In other words, motivation toward STEM is not only a matter of individual upward mobility but also relates to societal equity and fairness.

STEM motivation is also of interest given its positive association with STEM achievement and performance. Only one in four adolescents reach the proficiency levels of math and science by the time they graduate high school (U.S. Department of Education, 2015, 2019). From an international perspective, the U.S. has been one of the top countries in per-pupil spending on primary and secondary education; however, the U.S. is still not among the top-performing countries on international math and science assessments (Desilver, 2017; Mullis et al., 2020; OECD, 2020). Though STEM motivational beliefs do not perfectly correlate with STEM performance or achievement, it is an important aspect to understand STEM performance and achievement (Eccles & Wigfield, 2020; Michaelides, Brown, Eklöf, & Papanastasiou, 2019). It should be noted that the goal of this dissertation is not necessarily to encourage adolescents to go into or stay in the STEM pipeline. In fact, doing so could be promising for some but toxic for others. For example, disproportionally pushing people of certain demographic characteristics, for example Asian Americans, into the STEM field might be psychologically harming in addition to socially reinforcing a discriminatory narrative (Chen & Buell, 2018; McGee, Thakore, & LaBlance, 2017). Relatedly, the field of STEM sometimes pushes racial/ethnic underrepresented minorities to comprise their cultural identities (McGee, 2013). The goal of this dissertation, rather, is to better understand the developmental processes and contextual antecedents of STEM motivational beliefs for adolescents of different racial/ethnic groups.

For this dissertation, I follow the National Center for Education Statistics' (NCES) definition of STEM, which pertains to fields involving research, innovation, or development of new technologies using mathematics, natural science, engineering, and computer/information sciences (U.S. Department of Education, 2017). I chose this definition for this dissertation for three reasons. Firstly, the four STEM subjects in this definition are consistently included in the definitions of various other major organizations (e.g., Homeland Security, National Science Foundation). Secondly, these four STEM subjects require the most concentrated knowledge in math and science, unlike some more distantly-related STEM subjects such as psychology and economics that are sometimes included as STEM. Lastly, the definition of STEM I follow pertains to subjects that often have more limited diversity as described earlier, for example, in terms of gender and racial/ethnic representation (NSF, 2019).

Although STEM includes multiple subjects, the measures in my dissertation studies focus on math and science. Math is particularly central to STEM and often functions as a gateway or prerequisite to other STEM subjects (National Mathematics Advisory Panel, 2008; Watt et al., 2017). Science, as referred to by the measures in my dissertation dataset, does not specify which science subject and thus is assumed to be interpreted by adolescents as science generally. I acknowledge that adolescents' motivational beliefs might differ across the different science subjects (e.g., Hsieh et al., 2019; Wang et al., 2017), but the measures in this dissertation cannot speak to such nuances.

Importance of Adolescence

Acknowledging that STEM motivational beliefs develop throughout the lifespan, I chose to focus on adolescence as a critical developmental period for three main reasons. First, adolescence is a stage when individuals are focused on their identity, namely who they are and who they want to be (Arnold, 2017; Erikson, 1972; Klimstra et al., 2010; Steinberg & Morris, 2001). In Erikson's model (1972), the lifespan is divided into eight stages, each with a "conflict" to resolve that is most salient for that particular developmental period. The "conflict" for adolescence (defined as age 12-19 in Erikson's model) is identity versus confusion where the major questions we ask ourselves during adolescence are ones like "Who am I?" and "What do I want to do with my life?" Consequently, adolescence is marked by an increasing sense of autonomy as they explore their possible selves, among which include how they see themselves as a STEM person. Indeed, adolescents actively *construct* their science identity based on their interactions across various contexts. In this developmental process, adolescents *negotiate* the extent to which STEM is part of their identity (Brickhouse, Lowery, & Schultz, 2000; Eccles, 2009; Horn, 2008; Kang et al., 2018; Tan, Calabrese-Barton, Kang, & O'Neill, 2013).

Secondly, adolescence is a period typically marked by declines in individuals' STEM motivational beliefs (Gottfried et al., 2007; Jacobs et al., 2002; Wang et al., 2017). There are several reasons for these declines, including adolescents acquiring more accurate knowledge about what STEM actually is as they gain more formal exposure in schools (Wigfield et al., 2015). That said, there are also substantial individual differences in the trajectories of STEM motivational beliefs, meaning that not everyone's STEM motivational beliefs decline nor decline at the same rate (Fredricks & Eccles, 2002; Hsieh, Liu, & Simpkins, 2019; Musu-Gillette et al., 2015). Taken together, heterogeneities around the average declining trend of adolescents' STEM motivational beliefs make contextual influences, such as parental support that might help maintain or promote STEM motivational beliefs, particularly important (Alfaro & Umaña-Taylor, 2015; Legewie & DiPrete, 2014).

Lastly, adolescence is the time when students make decisions with significant consequences for their future STEM opportunities. More than 50% of the states in the U.S. require less than four years of math and science coursework to graduate. Specifically, 31 states require less than four years of math and 10 states require less than three years of science courses (National Center for Education Statistics, 2018). Opting out of science courses during high school has direct implications for later STEM options and opportunities (Adamuti-Trache & Andres, 2008; Maltese & Tai, 2011). For example, scholars have argued that math and science high school courses are the gateway into STEM college majors and eventually the STEM workforce (Maass et al., 2019; Miller & Kimmel, 2012; Watt et al., 2017). Relatedly, many high schools offer multiple levels of math and science classes (ExcelinEd Civil Rights Data Collection Analysis, 2018), ranging in difficulty from remedial/fundamental to Advanced Placement courses. Adolescents' advanced STEM course-taking is associated with later STEM outcomes, such as college major selection (Maltese & Tai, 2011; Robinson, 2003). The variations in terms of STEM coursework (e.g., taking STEM courses or not, what level of STEM courses) in educational settings during adolescence have implications for their later STEM opportunities and pathways.

The Situated Expectancy-Value Theory

With the importance of studying STEM motivational beliefs during adolescence established, each of my three dissertation studies tackled different research topics and thus drew from different theories. Nonetheless, one theory—the situated expectancy-value theory—served as the overarching framework for all three studies. The situated expectancy-value theory is one of the more prominent theories used to understand individuals' motivational beliefs as well as their antecedents and consequences (Bøe et al., 2011; Eccles & Wigfield, 2020; Wang & Degol, 2013). Situated expectancy-value theory has roots in Atkinson's theory of achievement motivation, which posited that motivation ('impulse' in original wording) for doing a particular achievement-oriented activity is a function of one's perceived probability of succeeding or failing that activity, the incentive value one places on succeeding or failing that activity, and one's tendency to approach the activity, in addition to a vaguely described 'extrinsic tendency' factor that tried to capture contextual influencers (Maehr & Sjogren, 1971). Building upon Atkinson's theory and related frameworks that the theory inspired (e.g., Feather, 1992), Eccles and colleagues delineated a theory with more nuanced contextual influences on individuals' motivational beliefs and also emphasized domain specificity (Wigfield, 1994). It should also be noted that the situated expectancy-value theory was initially developed to understand women's versus men's pursuit and performance in math (Wigfield & Eccles, 2000). Although the theory's application nowadays reaches much more broadly than math (e.g., sports motivation, motivation for altruistic behaviors, etc.), the theory's math/STEM focus makes it a particularly fitting framework for my dissertation.

According to the situated expectancy-value theory (Eccles & Wigfield, 2020), people are more likely to choose a domain and perform better on an achievement task in that domain if they are more confident in their ability to accomplish the task (i.e., 'expectancy'; "can I do it?") *and also* see greater value in the task or domain (i.e., 'value'; "do I care to do it? Is it interesting? Is it useful?"). In other words, expectancy and value beliefs are theorized as antecedents[1] of achievement-related behaviors and choices. This part of the theory highlights the influential role that motivational beliefs play in explaining why individuals pursue something or perform well on

[1] The situated expectancy-value theory also posits the reciprocal relationship between motivational beliefs to achievement-related behavior and choices (e.g., Marsh et al., 2005), but my dissertation studies mostly speak to the path from motivational beliefs to achievement, rather than the path from achievement to motivational beliefs.

a task. The situated expectancy-value theory conceptualizes expectancy and value beliefs as each consisting of multiple motivational beliefs, which I summarize next in regard to STEM. Expectancy beliefs, the first main category of motivational beliefs, are also known as ability self-concepts and are theorized to encompass how good individuals think they are currently in STEM and how well they expect themselves to do in the future. Ability self-concepts as conceptualized in the situated expectancy-value theory are related to self-efficacy as conceptualized in the social cognitive theory (Bandura, 1977; Schunk, 1991). Both ability self-concept and self-efficacy involve perceptions or judgments of one's competency. The distinction between the two constructs has been more well-documented conceptually than empirically. Whereas ability self-concept tends to be based on comparing the self to others (e.g., compared with people in my class, I am good at math/science) including one's younger self or one's self in other domains, self-efficacy tends to be based on accomplishing certain tasks or mastering particular abilities (e.g., I am confident in doing well on a math/science assessment) (Bong & Skaalvik, 2003; Jansen, Scherer, & Schroeders, 2015; Zimmerman, 2000). In the empirical literature, self-efficacy and ability self-concept are often used interchangeably.

Value beliefs, the second main category of beliefs, include three positive components: interest, utility value, and attainment value. Interest, which pertains to how enjoyable individuals find STEM to be, is related to intrinsic motivation as conceptualized in other motivational theories such as the self-determination theory (Ryan & Deci, 2000). Utility value pertains to how useful individuals find STEM to be for their future. Attainment value pertains to how important individuals regard STEM for their personal identities. In fact, attainment value as conceptualized in the situated expectancy-value theory is arguably equivalent to identity at the domain level; for example, attainment value for STEM is synonymous with STEM identity (Osborne & Jones, 2011). In other words, it pertains to how central being a STEM person is to who individuals are. Furthermore, there is a negative component of value beliefs—cost, which pertains to what individuals anticipate or have to give up by doing a particular task. For example, by investing in math/science, one necessarily has less time to devote to other pursuits. My dissertation focused on ability self-concept and the three positive value beliefs: interest, utility value, and attainment value.

The situated expectancy-value theory not only outlines the various motivational beliefs as described above, it also posits that those motivational beliefs work in conjunction (as opposed to in isolation) with each other. This theorized interrelatedness of motivational beliefs, however, is relatively under-studied because common analytical methods such as moderated regressions become cumbersome to interpret once three or more motivational beliefs interact with each other. To this end, Study 1 of my dissertation used person-centered analyses to identify the prevalent patterns of math and science motivational beliefs.

Strength-based contextualism

In addition to theorizing about multiple motivational beliefs and their interrelatedness, the "situated" part of the situated expectancy-value theory also states that motivational beliefs are influenced by contextual factors (e.g., socializers' beliefs and behaviors), the cultural milieu (e.g., stereotypes, family demographics), as well as individual social position factors, such as race/ethnicity. This attention to contextual predictors aligns with the principle of contextualism. Other theories grounded in the principle of contextualism include, for example, Urie Bronfenbrenner's ecological theory of human development (Bronfenbrenner & Morris, 1998).

The ecological systems theory emphasized that individuals' development is shaped by the nested social contexts that they are embedded in and the social interactions they have in these context (Bronfenbrenner & Morris, 1998, 2006). According to this theory, individuals are directly and indirectly influenced by multiple contexts simultaneously. Contexts are categorized in terms of distance from an individual 'like a Russian doll' into the microsystem (direct interactions individuals have with their immediate contexts), mesosystem (interactions between two or more microsystems), exosystem (more distant contextual factors that an individuals do not directly or regularly interact with but are nonetheless influential), macrosystem (most remote contexts that individuals are embedded in such as cultural norms, stereotypes, and ideologies), and chronosystem (change or stability overtime). Ecological systems theory complements situated expectancy-value theory such that it provides a conceptual framework for understanding motivational beliefs in relation to multiple contexts. For example, although most studies guided by situated expectancy-value theory focus on family and school contexts, ecological systems theory also emphasizes the nested nature between multiple contexts such as schools being embedded within neighborhoods. Below I elaborated on three microsystems included in my dissertation: families, schools, and neighborhoods.

Family. Out of the various contextual factors that influence adolescents' STEM motivational beliefs, one of the most salient is families (Simpkins et al., 2015b; Wigfield et al, 2015). In adolescence, parent educational support might be less frequent or hands-on as earlier in development (Hill & Tyson, 2009), but parents are nonetheless still a critical source of support to leverage. For example, the parent socialization model of the situated expectancy-value theory argues (Eccles, 2005), and prior studies suggest that parents' STEM support positively predicts their adolescents' math and science motivational beliefs (Jacobs & Bleeker, 2004; Mujtaba et al., 2018; Simpkins et al., 2015b; Simpkins, Fredricks & Eccles, 2012; Stake, 2006; Turner, Steward, & Lapan, 2004). The situated expectancy-value theory further states that parents' support and adolescents' motivational beliefs can be shaped by family demographics. In fact, parent education and occupation have been theorized and supported by prior studies to play a major role in shaping adolescents' STEM motivational beliefs (Bourdieu, 1986; DeWitt et al., 2016; Gilmartin et al., 2006). Intervention studies also suggest that promoting parents' familiarity with math is associated with increases in adolescents' STEM motivational beliefs (Harackiewicz et al., 2012; Rozek et al., 2017).

School. Another undoubtedly important contextual factor of adolescents' STEM motivational beliefs and performance is their schools. High schools in the U.S. exhibit substantial variation in their STEM affordances; for example, in terms of advanced STEM course offerings, access to enrichment programs, and math/science teacher experience (e.g., Adelman, 2006; Allen et al., 2019; Clotfelter, Ladd, & Vigdor, 2007; ExcelinEd Civil Rights Data Collection Analysis, 2018; Sahin, 2013; Kini & Podolsky, 2016; Lee & Mamerow, 2019). This variation is important for my dissertation as math/science accomplishments during high school have implications for adolescents' later STEM enrollment such as whether they can pursue a STEM major or not.

Neighborhood. Lastly, a contextual factor that is more distant than family and school but nonetheless relevant for adolescents' STEM development is adolescents' neighborhoods. Neighborhoods are important contexts during adolescence as adolescents gain more autonomy and spend more their time in neighborhoods without their parents (Bronfenbrenner & Morris, 2006; Urban et al., 2009). Prior studies that examine neighborhood effects on adolescents' educational development mostly have done so from a policy perspective using general neighborhood indicators, such as income level. Although prior studies show that general neighborhood characteristics matter for adolescents' educational and STEM development

(Bustamante et al., 2018; Hassinger-Das et al., 2020; Johnson Jr, 2012; Leventhal & Brooks-Gunn, 2000; Nieuwenhuis & Hooimeijer, 2016), researchers have yet to examine STEM-specific neighborhood indicators at a national scale.

Race/ethnicity

The above reviewed contextual factors and their relations with adolescents' STEM motivational beliefs are all influenced by adolescents' social position factors, including their race/ethnicity. In the U.S., there are not only disproportionate racial/ethnic representation in STEM, but also inequities in the access and quality of STEM resources available to students of different racial/ethnic groups. (e.g., McGee, 2016; Museus & Liverman, 2010; Nasir & Vakil, 2017; NSF, 2019; Walls, 2016). Overall, I am intentional about examining and discussing contextual factors from a strength-based perspective. Given that there is a robust body of literature focusing on the systemic barriers that deter adolescents of certain racial/ethnic groups from STEM, I examine the heterogeneity within each racial/ethnic group and the positive correlates among groups that have been traditionally marginalized in STEM. That is, I positioned my studies to complement, not to argue against, the body of studies that clearly shows STEM as a field filled with disparities, inequitable access, and systemic barriers. This perspective gives each racial/ethnic group the attention they deserve without subjecting them to comparison that entails one group is superior and others as more inferior or marginalized. More concretely in my dissertation studies, I conducted some between-racial/ethnic group comparisons to show existing racial/ethnic disparities, and also conducted within-racial/ethnic group analysis to examine how contextual correlates might be promotive for each racial/ethnic group.

Overview of the Three Dissertation Studies

My dissertation consists of three studies that jointly examine the development and contextual antecedents of adolescents' STEM (science, technology, engineering, and math) motivational beliefs. Situated expectancy-value theory (Eccles & Wigfield, 2020) serves as an overarching framework to tie all three studies together, and each study incorporates additional theories that best match the specific research aims. Particular attention was paid to race/ethnicity in explaining differences in STEM motivational beliefs and the contextual resources for Asian, Black, Latina/o, and White adolescents.

Study 1 examined the interrelatedness or patterns of multiple math and science motivational beliefs (i.e., interest, utility value, attainment value, and expectancy). Using person-centered analyses, I addressed the gap in the literature, namely that although multiple motivational beliefs are theorized to function in conjunction with each other (Dietrich & Lazarides, 2019; Eccles & Wigfield, 2020; Ing & Nylund-Gibson, 2017), they are often analyzed independently. I identified the prevalent patterns of math and science motivational beliefs in 9^{th} and 11^{th} grade, as well as mapping out the stability/changes in these patterns between the two time points for Asian, Black, Latina/o, and White adolescents. Furthermore, I tested how the 11^{th} grade patterns of math/science motivational beliefs were associated with adolescents' STEM GPAs and career aspirations for each racial/ethnic group.

In Study 2 was guided by the parent socialization model (Eccles, 2005) and examined the relations between parents' STEM support and their adolescents' STEM motivational beliefs. I tested these associations separately among parents with and without STEM degrees/occupations, which are critical social markers that might influence not only the mean levels but also the associations between parent STEM support and adolescents' STEM motivational beliefs (Bourdieu, 1986; DeWitt et al., 2016; Gilmartin et al., 2006; Harackiewicz et al., 2012; Rozek et al., 2017). Lastly, racial/ethnic differences in the above-mentioned parent and in adolescent STEM indicators and their hypothesized associations were tested. Through this paper, I bridged the literature on parent STEM support and parent STEM degree/occupation to better understand how STEM motivational beliefs of Asian, Black, Latina/o, and White adolescents can be promoted.

Study 3, guided by the institutional resource theory (Leventhal & Brooks-Gunn, 2000), examined how related contexts— neighborhood and school—were associated with Asian, Black, Latina/o, and White adolescents' STEM motivational beliefs and performance. First, I tested how neighborhood STEM jobs, and separately school STEM indicators (AP STEM course offerings, number of STEM enrichment programs, and math/science teachers' experience), were associated with adolescents' STEM motivational beliefs and performance. Then, I examined the indirect effects of school STEM indicators in explaining the associations between neighborhood STEM employment rates and adolescents' STEM motivational beliefs and performance.

Data for all three studies came from the High School Longitudinal Study of 2009 (HSLS; see Ingels et al., 2014 for more detail), which is a recent, nationally representative dataset designed with a specific focus to understand adolescent STEM development during high school and beyond, hence ideal for my studies. HSLS started with more than 25,000 adolescents in 9th grade from 944 high schools, and surveyed them three, four, and eight years later. HSLS included reports from adolescents, their parents, their school administrators and counselors, their math and science teachers, in addition to their high school transcript data. Each study utilized a specific sub-sample that best matches the research questions. The three studies are related but written as separate journal articles that could be published independently[2].

[2] At the time of submitting this dissertation, Study 1 received revise & submit from *AERA Open*, Study 2 received revise & submit from *Journal of Adolescence*, and Study 3 has not yet been submitted to a journal.

CHAPTER 2

The Patterns of Adolescents' Math and Science Motivational Beliefs: Examining Within-Racial/Ethnic Group Changes and their Relation to STEM Outcomes

Abstract

The racial/ethnic disparities and average declines in STEM (science, technology, engineering, mathematics) motivation during adolescence are worrisome. Although STEM motivational beliefs are theorized to function in conjunction with one another, such interrelations and how they unfold over time for different racial/ethnic groups remain understudied. Using data from the High School Longitudinal Study (*N*=10,320), I identified four and five *patterns* of math and science motivational beliefs in 9th and 11th grade, respectively, and examined their prevalence among Asian, Black, Latina/o, and White adolescents. I found homogeneous patterns (*Overall High* or *Low*) and patterns with varying levels of motivational beliefs (*STEM is Useful but Not for Me*), and patterns characterized by domain differentiation (*Not Math Maybe Science*). Then, I charted the stability and changes in those patterns from 9th to 11th grade for each racial/ethnic group, and how the patterns at 11th grade were associated with adolescents' STEM performance and career aspirations.

Keywords: STEM motivation, latent transition analysis, race/ethnicity, STEM performance, STEM career aspirations

The patterns of adolescents' math and science motivational beliefs: Examining within-racial/ethnic group changes and their relation to STEM outcomes

Racial/ethnic disparities in STEM (science, technology, engineering, and mathematics) arise in the U.S. due to a range of structural issues such as lack of representation, inequitable access to advanced STEM resources and opportunities, colorblind curricula, discrimination, and implicit biases (Beasley & Fischer, 2012; Grossman & Porche, 2014; McGee, 2016; Museus & Liverman, 2010; Nasir & Vakil, 2017; Walls, 2016). The resulting STEM landscape is one marked with stark racial/ethnic disparities in both attainment and performance, which has substantial negative implications for the advancement and fundamental STEM literacies at both the societal and individual levels (Jones, 2014; NSF, 2019; Taningco et al., 2008). One of the critical factors predicting individuals' pursuit of STEM in college and the workforce is their math and science motivational beliefs during high school (Eccles, 2011; Wang & Degol, 2013); thus, it is crucial to understand the development of math and science motivational beliefs among high school adolescents of diverse racial/backgrounds.

Individuals hold multiple motivational beliefs, such as expectancy and value beliefs, that are interrelated and theorized to function in conjunction to shape individuals' performance and choices (Eccles & Wigfield, 2020). Although emerging work examines the interrelatedness of multiple math and science motivational beliefs (e.g., Andersen & Chen, 2015; Snodgrass Rangel et al., 2020), how the patterns of individuals' math and science motivational beliefs change over time remains understudied (e.g., Dietrich & Lazarides, 2019; Ing & Nylund-Gibson, 2017). Those changes are particularly critical to examine during adolescence because math and science motivational beliefs typically decline during this developmental period, yet more studies are needed to describe other nuanced changes beyond the average trend (e.g., Dietrich & Lazarides, 2019; Hsieh et al., 2019; Lazarides et al., 2020; Wang et al., 2017). Hence, my goal was to examine the complex interrelatedness or patterns of multiple math and science motivational beliefs at 9th and at 11th grade and the changes in those patterns for Asian, Black, Latina/o, and White adolescents. My second goal was to examine how adolescents' final patterns (in 11th grade) were associated with their STEM performance and career aspirations within each racial/ethnic group.

Situated Expectancy-Value and Dimensional Comparison Theories

One of the prominent motivational theories developed to understand individuals' pursuit of and performance in STEM is the situated expectancy-value theory (Eccles & Wigfield, 2020). According to this theory (Eccles, 2011; Eccles & Wigfield, 2020), people are more likely to pursue and perform better in a domain if they are more confident in their ability to accomplish a task (i.e., expectancies) and see greater value in that domain. Individuals' value beliefs include three positive or promotive aspects: interest (i.e., how enjoyable people find something to be), utility value (i.e., how useful people find something to be), and attainment value (i.e., how central something is to who people are).

The situated expectancy-value theory states that expectancy and value beliefs within a single domain influence each other and co-determine individuals' outcomes. For example, studies suggest that the effect of one math/science motivational belief on performance and career aspirations is contingent on other motivational beliefs (Durik et al., 2015; Guo et al., 2015; Lauermann et al., 2017; Nagengast et al., 2011; Trautwein et al., 2012; Wang et al., 2015). Expressions such as "I can but I don't want to" and "STEM is useful but too hard for me" succinctly capture how the contingency or interrelatedness of multiple expectancy and value beliefs offers more insight than examining motivational beliefs in isolation (Andersen & Chen, 2015; Ing & Nylund-Gibson, 2017; Lazarides et al., 2019; Simpkins & Davis-Kean, 2005). In addition to examining multiple motivational beliefs within a single domain, dimensional comparison theory suggests that individuals' motivational beliefs in related domains, like math and science, should reciprocally strengthen each other over time and should positively predict individuals' performance in the related domains (Helm et al., 2016; Jansen et al., 2015). Taken together, situated expectancy-value theory and dimensional comparison theory suggest a more comprehensive approach is necessary to understand individuals' motivational beliefs across math and science.

The Patterns of Adolescents' Math and Science Motivational Beliefs

Several specific patterns of math and science motivational beliefs are expected based on theory and prior work (Andersen & Chen, 2015; Chittum & Jones, 2017; Ng et al., 2016; Lin et al., 2018; Perez et al., 2018; Van Soom & Donche, 2014). The positive correlations between expectancy and value beliefs in situated expectancy-value theory and the positive relations between math and science theorized by dimensional comparison theory should yield patterns of overall high and overall low motivational beliefs (Denissen et al., 2007; Eccles, 2009; Helm et al., 2016; Jansen et al., 2015; Phelan et al., 2017; Snodgrass Rangel et al., 2020). In addition, previous research suggests that patterns should emerge where some motivational beliefs are relatively high, whereas other motivational beliefs are relatively low (Durik et al., 2015; Lauermann et al., 2017). For example, children see a difference between "doing" science versus "being" a scientist (Archer et al., 2010). Thus, some individuals might find math/science both useful and within their ability but have a low attainment value if the subjects are perceived as discriminatory toward or incompatible with their other social identities (McGee, 2013; Shanahan, 2009). Patterns driven by attainment value might be prominent in high school as adolescents actively construct who they are and want to be (Aschbacher et al., 2010; Eccles & Wigfield, 2020; Tan et al., 2013).

Lastly, patterns might be characterized by domain-driven differences (Gaspard et al., 2020; Helm et al., 2016; Jansen et al., 2015; Umarji et al., 2018). Although dimensional comparison theory argues for positive relations between math and science, a recent meta-analysis showed mixed correlations (i.e., sometimes positive, sometimes negative) between the math and science expectancies (Möller et al., 2020). Moreover, scholars have empirically found that some individuals have high math but low science beliefs (Ing & Nylund-Gibson, 2017; Snodgrass Rangel et al., 2020). More work is needed to untangle this inconsistency between the empirical findings and dimensional comparison theory.

Changes in the Patterns of Adolescents' Math and Science Motivational Beliefs

Motivational beliefs change over time as individuals develop and gain more experience with each subject (Wigfield, 1994; Wigfield et al., 2015). Research suggests that each of these motivational beliefs typically declines or remains stable during adolescence (Denner et al., 2019; Hsieh et al., 2019; Jacobs et al., 2002; Köller et al., 2001; King & McInerney, 2014; Musu-Gillette et al., 2015; Wang et al., 2017). Examining development in terms of the changes in the patterns of adolescents' motivational beliefs, however, can uncover more meaningful nuances that would otherwise be masked by looking at average changes of each belief separately.

Only a handful of studies have examined changes in the patterns of individuals' motivational beliefs. Those studies suggested four patterns of change, namely stability, changing to a less favorable pattern, domain coalescence, and domain differentiation. Firstly, stability is a common pattern in U.K. adolescents' physics motivational beliefs (Sheldrake et al., 2017) and German adolescents' math motivational beliefs (Dietrich & Lazarides, 2019). Secondly, Ing and

Nylund-Gibson (2017) found 7th and 10th grade adolescents often shifted away from math and science to a less favorable pattern of their math and science interest and utility value over a 2- or 3-year period. Lastly, findings suggest two opposing domain-driven changes where for some adolescents, motivational beliefs across domains become more similar or coalescence, whereas for other adolescents, beliefs across domains diverge or differentiate over time. Based on dimensional comparison theory and the expectation that math is a gateway for many science fields, individuals' math and science motivational beliefs should be more similar and coalesce over time (Helm et al., 2016; Jansen et al., 2015; Maass et al., 2019; Watt et al., 2017). In contrast, although math and science are related, they are distinct domains and math is more prominent in some science subjects versus others (e.g., physics vs. biology). As adolescents are exposed to more subjects in math and science (e.g., statistics, sports medicine), they may increasingly identify with one specific domain but not another (e.g., identifying with statistics and as a math person more broadly), thus demonstrating increasingly domain-specific motivation (Denissen et al., 2007; Gaspard et al., 2020; Snodgrass Rangel et al., 2020).

Patterns of Motivational Beliefs Predicting STEM Performance and Career Aspirations

Adolescents' STEM math and science motivational belief patterns should map onto their performance and career aspirations for STEM (Wigfield & Eccles, 2020). Hence, an important follow-up analysis is to examine how the patterns at the later time point relate to adolescents' STEM performance and career aspirations. Situated expectancy-value theory and prior studies suggested that *Overall High* patterns should be associated with the highest STEM achievement and career aspirations (Durik et al., 2015; Lauermann et al., 2017; Phelan et al., 2017). For patterns characterized by a relative difference in motivational beliefs, those with greater math/science expectancy than value beliefs are expected to be associated with strong STEM performance because achievement is more strongly predicted by expectancy than value beliefs (Crombie et al., 2005; Rosenzweig et al., 2019; Jones et al., 2010). In contrast, patterns characterized by relative high value beliefs are expected to be associated with high STEM career aspirations (Rosenzweig et al., 2019). For patterns characterized by math/science domain differences, Snodgrass Rangel and colleagues (2020) found adolescents who were more motivated in math than science reported greater STEM achievement and course-taking than those who were more motivated in science than math. Lastly, the *Overall Low* pattern was found to be associated with either the lowest level of STEM performance and career aspirations, or not statistically different from that of mixed-level patterns (e.g., Ing & Nylund-Gibson, 2017; Phelan et al., 2017; Snodgrass Rangel et al., 2020).

These Processes Within Each Racial/Ethnic Group

Racial/ethnic disparities permeate STEM in the U.S. Not only are STEM educational degrees and occupations obtained disproportionally by more White and Asian individuals than Black and Latina/o individuals, the same racial/ethnic disparities are observed in terms of math and science performance as early as middle and high school (NSF, 2019; U.S. Department of Education, 2015, 2017). Studies also showed similar racial/ethnic disparities in terms of math and science motivational beliefs (Andersen & Ward, 2014; Bouchey & Harter, 2005; Brown & Leaper, 2010; Seo et al., 2019; Shanahan, 2009; Nasir & Cobb, 2002; Wenner, 2003). Though most research focuses on comparing racial/ethnic groups to identify differences, analyses within each racial/ethnic group refocus the narrative away from a comparative or deficit orientation and emphasize the rich variability within each group (Causadias et al., 2018). For example, studies that examined gender differences in math and science motivational beliefs within Asian, Black, Latino/a, and White adolescents effectively showed that there is significant variation within each racial/ethnic group (e.g., Else-Quest et al., 2013). Focusing on within- rather than between-race/ethnicity variations gives space to adolescents who show high STEM outcomes but are nonetheless often labeled marginalized in STEM due to their race/ethnicity. Thus, within-group studies identify what supports help adolescents succeed within each racial/ethnic group.

Even fewer studies examined the racial/ethnic representations in the changes in patterns of math and science motivational beliefs over time. This is an important research question, though, because changes provide insight into how disparities might emerge, close, or persist. Mapping out developmental changes provides richer information than the sum of each snapshot in time. Ing and Nylund-Gibson (2017) found that while there were no racial/ethnic differences in the proportion of female adolescents who remained in an overall positive pattern of math and science motivational beliefs, the proportion changing from an ambivalent pattern to a less positive pattern were greater among those who identified with an underrepresented race/ethnicity than their White and Asian peers. The current study used the same analytical approach as Ing and Nylund-Gibson (2017) to examine the patterns of math and science motivational beliefs as well as the changes and correlates of those patterns within each race/ethnic group, instead of comparing across race/ethnic groups.

Current Study

My first research question aims to identify the most prevalent patterns of adolescents' math and science interest, utility value, expectancy, and attainment value in 9^{th} and 11^{th} grade. I expect the following groups: overall high and overall low motivational belief patterns and patterns where motivational beliefs vary in level by belief type or domain (e.g., low value beliefs but high expectancy, high motivational beliefs for math but low for science).

Then, I examined the stability and changes in the patterns of math and science motivational beliefs between 9th and 11th grade. Based on prior studies, I expect at least four patterns of change from 9th to 11th grade, namely stability (i.e., no change), change to a less favorable pattern, and coalescence or differentiation by domain.

Lastly, I examined how 11th grade patterns of math and science motivational beliefs were associated with adolescents' STEM performance. Patterns of overall high math and science motivational beliefs are expected to be related to higher STEM performance and career aspirations than overall low patterns. For other patterns, those characterized by relatively high expectancy beliefs are expected to be associated with higher STEM performance, whereas those characterized by relatively high value beliefs are expected to be associated with higher STEM career aspirations.

Given my goal to examine the processes within each racial/ethnic group, I described the prevalence of patterns that were identified in the first research question separately for Asian, Black, Latina/o, and White adolescents. Similarly, I conducted race/ethnicity-specific models for the last two research questions.

Method

Dataset and Participants

Adolescents in the current study participated in the High School Longitudinal Study (HSLS) collected by the National Center for Educational Statistics (NCES). HSLS was designed with the particular aim to examine adolescents' STEM development, for example, by including measures of math and science motivational beliefs that match the conceptualization of the expectancy-value theory and do so across two time points (i.e., 9th and 11th grade). Because some of the motivational beliefs refer to their current math or science class (e.g., 'you are confident that you can do an excellent job on math assignments'), only participants in the HSLS dataset who took math and science classes in both 9th and 11th grade were included (n = 13,770 out of 25,210 excluded). Additionally, I excluded 1,110 participants whose racial/ethnic group is too small (e.g., Native American) or heterogeneous (e.g., multiracial), yielding a sample size of 10,320. The analysis sample consisted of 5% (n = 500) Asian, 13% (n = 1,300) Black, 22% (n = 2,310) Latina/o, 60% (n = 6,200) White adolescents. The adolescents in the analysis sample were 51% female and averaged age 14.40 in the year 2009 (i.e., first wave of data collection).

As shown in Appendix 1, the analysis and excluded sample had several significant differences, but they were typically small in size. The analysis sample reported higher math and science motivational beliefs than the excluded sample ($p < .001$; d = .03-.16). The analysis sample also had higher STEM GPAs (d = .52) and STEM career aspirations (d = .13), had fewer Black adolescents (d = .04), and had more Asian (d = .11) and White (d = .54) adolescents.

Measures

Math and science motivational beliefs. Adolescents reported four motivational beliefs in math and separately science using the same items in both 9th and 11th grade, which was collected in the year 2009 and 2011 respetively (see Appendix 2 for detailed items). The measures were based on the situated expectancy-value theory, and these or similar items have been used in prior studies (Jacobs et al., 2002; Shanahan, 2009; Simpkins et al., 2015; Snodgrass Rangel et al., 2020). Math/science interest was a composite of three items (α = .78, .80 for 9th and 11th grade math respectively, .81, .83 for science; e.g., "you enjoy math/science classes very much"). Math/science utility value was a composite of three items (α = .77, .81 for math and .74, .82 for science; e.g., "math/science is useful for everyday life"). Math/science attainment value was a composite of two items (α = .84, .88 for math and .84, .89 for science; e.g., "you see yourself as a math/science person”). Math/science expectancy was a composite of four items (α = .90, .88 for math and .88, .92 for science; e.g., “you are certain that you can master math/science skills”). All the measures were originally rated on a 4-point Likert scale (1 = *strongly disagree*, 4 = *strongly agree)*. I dichotomized each composite based on a meaningful cutoff such that 1 includes agree or strongly agree whereas 0 includes disagree or strongly disagree.

STEM outcomes. Two STEM outcomes were examined, namely STEM performance (GPA) and STEM career aspirations. Firstly, STEM GPA (range 0 to 4) is their cumulative high school GPA across all of their STEM classes. STEM GPA was weighted for course level (e.g., remedial, regular, versus advanced) and came from transcript data collected at the end of high school directly from schools. Secondly, adolescents were asked open-endedly in 11^{th} grade about their career aspirations for age 30. Their responses were dichotomized by HSLS into whether (0 = *no*, 1 = *yes*) the career aspirations fall in a STEM domain based on Standard Occupational Classification codes (Bureau of Labor Statistics, 2012).

Race/ethnicity. Adolescents’ race/ethnicity were recoded into dummy variables, namely Asian, Black, Latina/o, or White. Adolescents who did not identify with one of the four racial/ethnic groups were not included in the analysis sample.

Analysis Plan

Data analyses were executed in Mplus version 7 (Muthén & Muthén, 1998-2012). To focus on heterogeneities within race/ethnicity, all the analyses conducted were conditional on the four racial/ethnic groups using the Mplus KNOWNCLASS command. In other words, race/ethnicity (i.e., 4 dummy variables for Asian, Black, Latina/o, and White) functioned as a grouping variable that allowed the estimated prevalence of patterns and changes in patterns to vary for each racial/ethnic group (Lanza & Collins, 2008). Missing data were imputed for the analysis sample (missing ranged from .07% for 9^{th} grade math attainment value to 5% for STEM GPA) via the full information maximum likelihood (FIML) procedure. See Table 1 for bivariate correlations and descriptive statistics.

Table 1.
Descriptive statistics and bivariate correlations

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.
Grade 9 motivational beliefs																		
1. Math interest	1																	
2. Math utility value	.37***	1																
3. Math expectancy	.37***	.30***	1															
4. Math attainment value	.31***	.25***	.44***	1														
5. Science interest	.28***	,21***	.18***	.13***	1													
6. Science utility value	.212**	.34***	.20***	.15***	.38***	1												
7. Science expectancy	.20***	.19***	.36***	.22***	.34***	.31***	1											
8. Science attainment value	.23***	.20***	.36***	.59***	.25***	.28***	.37***	1										
Grade 11 motivational beliefs																		
9. Math interest	.22***	.17***	.20***	.22***	.15***	.12***	.13***	.18***	1									
10. Math utility value	.16***	.14***	.27***	.24***	.12***	.11***	.20***	.21***	.42***	1								
11. Math expectancy	.18***	.24***	.20***	.22***	.12***	.16***	.15***	.17***	.33***	.32***	1							
12. Math attainment value	.19***	.15***	.29***	.40***	.08***	.08***	.16***	.29***	.37***	.42***	.36***	1						
13. Science interest	.14***	.12***	.13***	.10***	.20***	.16***	.15***	.16***	.22***	.16***	.19***	.12***	1					
14. Science utility value	.13***	.17***	.17***	.15***	.19***	.25***	.22***	.22***	.21***	.24***	.46***	.23***	.34***	1				
15. Science expectancy	.10***	.10***	.18***	.14***	.15***	.14***	.23***	.19***	.14***	.30***	.21***	.18***	.46***	.32***	1			
16. Science attainment value	.09***	.10***	.16***	.16***	.20***	.22***	.25***	.30***	.14***	.22***	.20***	.23***	.34***	.44***	.40***	1		
STEM outcomes																		
17. High school STEM GPA	.11***	.02	.20***	.23***	.09***	.07***	.17***	.23***	.18***	.21***	.17***	.27***	.14***	.19***	.12***	.17***	1	
18. STEM career aspirations	.07***	.08***	.08***	.10***	.09***	.14***	.11***	.14***	.11***	.11***	.14***	.14***	.16***	.28***	.12***	.25***	.19***	1
Mean	.35	.46	.34	.21	.34	.31	.26	.17	.25	.27	.51	.20	.34	.38	.27	.19	2.68	.39
SD	.48	.50	.47	.41	.48	.46	.44	.38	.43	.44	.50	.40	.47	.49	.44	.39	.82	.49
Skewness	.65	.17	.70	1.44	.66	.81	1.11	1.76	1.13	1.04	-.04	1.49	.67	.48	1.03	1.61	-.38	.47

Note. N =10,320. All variables ranged from 0 to 1, except STEM GPA, which ranged from 0 to 4. SD = Standard deviation.
* p <.05. ** p < .01. p < .001.
SOURCE: U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, High School Longitudinal Study of 2009 (HSLS:09), Base Year and First Follow-Up.

To address Research Question 1, namely the patterns of math and science motivational beliefs, latent class analysis with race/ethnicity as the grouping variable was estimated separately for 9th and 11th grade. Latent class analysis was chosen over latent profile analysis as the motivational beliefs were dichotomized at meaningful cutoffs (1 = *agree or strongly agree*, 0 = *disagree or strongly disagree*). Because replication is particularly crucial for pattern-centered analysis, I randomly divided the sample into two random subsamples to check validity. The selection of the profile solution was based on theoretical significance and parsimony of the solutions, in addition to several fit indices (Masyn, 2013; Nylund et al., 2007); AIC (Akaike Information Criterion), sample saBIC (size-adjusted Bayesian Information Criterion), and AWR (Approximate Weight of Evidence Criterion) are calculated based on loglikelihood values and the number of parameters. They describe the trade-off between adding more parameters to be estimated and better fit to the data as the number of classes increases; the criteria is to select the number of classes with the lowest marginal reduction on those indices. RI (relative improvement) is an index of how fitting the current model is compared with the model with one more pattern; the ideal model shows the smallest marginal reduction in RI. The size of the smallest class is recommended to be no smaller than 2% of the sample, which corresponds to approximately 115 individuals for each random half of the sample for this study. Correct model probability is an index of relative fit; the criterion is to select the solution with the highest correct model probability. Once the final solution is selected, the prevalence of each pattern was estimated among each racial/ethnic group, in addition to the averaged prevalence across race/ethnicity.

To address Research Question 2, namely the change in STEM motivational belief patterns from 9th to 11th grade, latent transition analysis (LTA) was conducted using the profiles identified from Research Question 1 (Asparouhov & Muthén, 2014; Nylund-Gibson et al., 2014). Estimates of interest from the latent transition analysis are transition probabilities, which are the conditional probability of exhibiting a specific 11th grade pattern given the individual's 9th grade pattern. Similar to Research Question 1, the transition probabilities were estimated for each racial/ethnic group as well as with all of them combined.

STEM GPA and career aspirations were added to the latent transition analysis with their means allowed to vary by profiles of 11th grade motivational beliefs, which addresses Research Question 3. Comparing the means of STEM GPA and career aspirations by profile, thus, is statistically analogous to running an ANCOVA but with latent instead of observed groups (Nylund-Gibson et al., 2019).

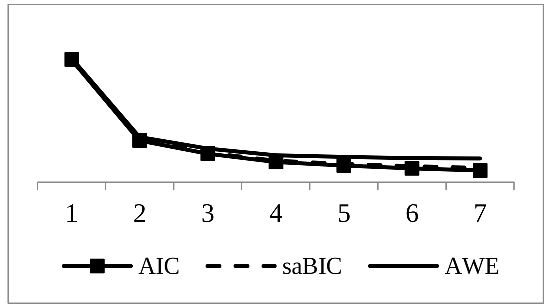
Results

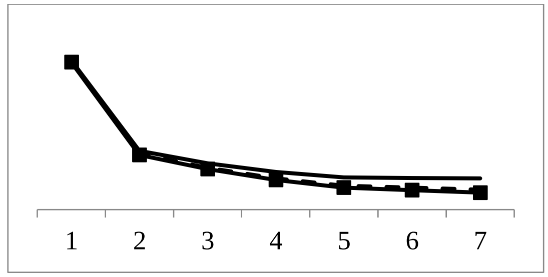
Model identification

As shown in Table 2, the overall model fit indices (AIC, saBIC, AWR) changed with every additional number of patterns. The changes, however, were not as pronounced after four patterns. For example, the change in AIC from the two- to the three-pattern model was 1130.56, while the change in AIC between the four- and the five-pattern model was 467.96. As a result, I selected the four-pattern solution as the final model for 9th grade. In 11th grade, changes in overall model fit indices suggested either the four- or five-pattern solution. A theoretically meaningful pattern (*STEM is Useful but Not for Me*; discussed in more detail below) did not emerge until the five-pattern solution; hence I selected the five-pattern solution as the final model. Model identification replicated on the two random half samples (Appendix 3); for parsimonious presentation, the results from this point on are based on the full analytic sample.

Table 2.
Model fit indices

Number of patterns	AIC	saBIC	AWR	RI	cmP	Smallest class size
9th grade						
1	118465.25	118509.96	118679.57	1	<.001	100%
2	107610.93	107704.40	108059.05	.17	<.001	32%
3	105826.16	105968.40	106508.08	.11	<.001	20%
4	104695.60	104886.61	105611.33	.05	<.001	12%
5	104227.64	104467.42	105377.18	.04	<.001	9%
6	103850.63	104139.18	105233.98	.03	<.001	8%
7	103568.89	103906.20	105186.03		1	6%
11th grade						
1	116730.00	116774.70	116944.32	1	<.001	100%
2	106215.39	106308.86	106663.51	.16	<.001	41%
3	104589.55	104731.79	105271.48	.12	<.001	16%
4	103367.45	103558.46	104283.19	.09	<.001	13%
5	102491.54	102731.32	103641.08	.03	<.001	11%
6	102191.15	102479.69	103574.49	.03	<.001	7%
7	101930.38	102267.69	103547.53		1	7%





Note. Ideal AIC (Akaike Information Criterion), saBIC (sample size-adjusted Bayesian Information Criterion) and AWR (Approximate Weight of Evidence Criterion) have the lowest marginal reduction. Ideal RI (relative improvement) has the smallest marginal reduction. The size of the smallest class is recommended to be no smaller than 2%. The greater cmP (correct model probability), the more ideal.
SOURCE: U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, High School Longitudinal Study of 2009 (HSLS:09), Base Year and First Follow-Up.

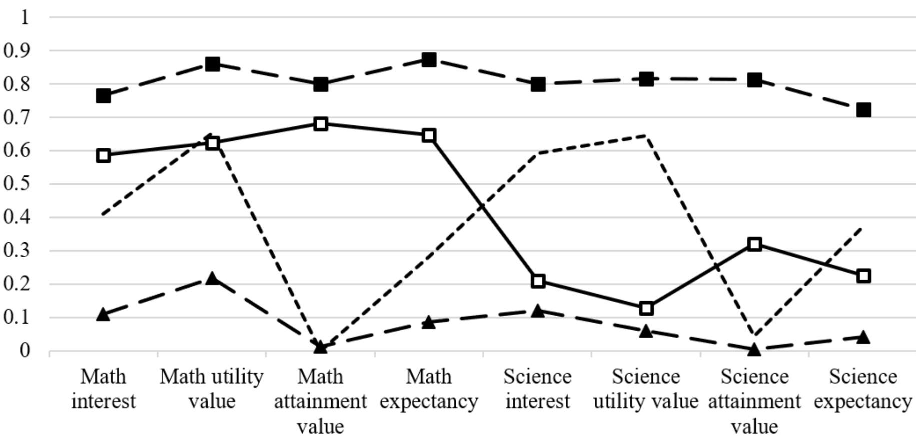
Patterns of Motivational Beliefs in 9th and 11th Grade Overall and by Race/Ethnicity

To interpret the patterns of math and science motivational beliefs, each line in Figures 1 and 2 represented a pattern. The y-axis represents the probability of endorsing each motivational belief. The convention for interpretation is that endorsement greater than seventy percent (.7) is referred to as high, endorsement less than thirty percent (.3) is referred to as low, whereas endorsement in between is considered mixed (or ambivalence, unsure) endorsement (Masyn, 2003).

9th grade. Figure 1 shows the four patterns of math and science motivational beliefs identified in 9th grade (i.e., data collected in year 2009). The pattern *Overall Low* shown in the dashed line with solid triangle marker, characterized by overall low motivational beliefs, was on average the most common pattern (47% of all adolescents). The pattern shown in the dashed line with solid square marker, *Overall High*, in contrast, was the smallest group (11% of all adolescents). In addition to *Overall High* and *Overall Low*, two patterns emerged in which the math and science motivational beliefs differed in their relative level. Accounting for around one in four adolescents, the pattern *Not Who I Am* (shown in dashed line with no marker) was characterized by low math and science attainment value but otherwise mixed level of the other math and science motivational beliefs. Lastly, the pattern *Not Science Maybe Math* (16% of all adolescents; shown in the solid line with hollow square marker) exhibited low level for all four science motivational beliefs, whereas motivational beliefs toward math were high or mixed.

Figure 1.

Math and science motivational beliefs patterns in 9th grade



Pattern name	Graphic	*Proportion* Across race/ethnicity	*within Asian*	*within Black*	*within Latina/o*	*within White*
Overall High		11%	19%	12%	9%	11%
Not Who I Am		26%	28%	32%	30%	23%
Not Science Maybe Math		16%	17%	18%	15%	16%
Overall Low		47%	36%	39%	46%	50%

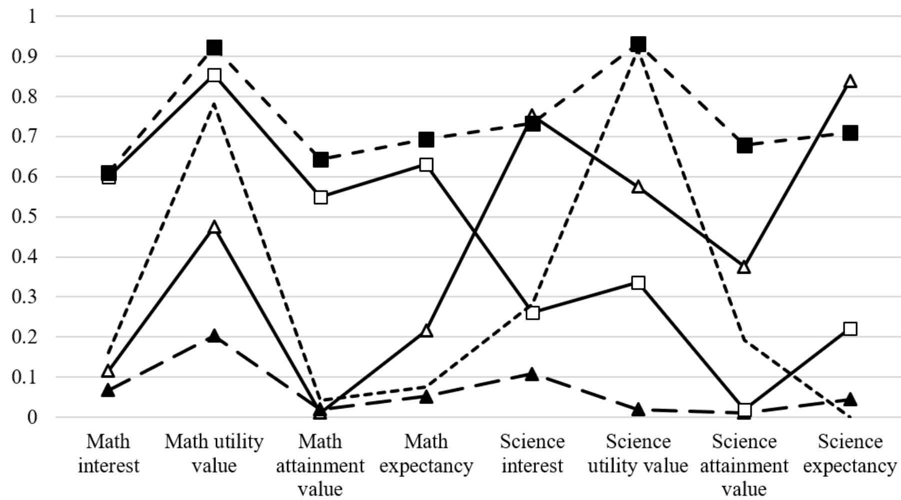
SOURCE: U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, High School Longitudinal Study of 2009 (HSLS:09), Base Year and First Follow-Up.

While the general descriptions above regarding math and science motivational belief patterns are helpful, next I examine the distribution of those patterns within each race/ethnicity, which are shown in the bottom half of Figure 1. Among Asian adolescents, almost one in five (19%) showed the *Overall High* pattern, and a little over one in three (36%) showed the *Overall Low* pattern. Twenty-eight percent of Asian Adolescents showed *Not Who I Am*, and 17% showed the *Not Science Maybe Math* pattern. Among Black adolescents, 12% showed *Overall High*, 39% showed *Overall Low*, 32% showed *Not Who I Am*, and 18% showed the *Not Science Maybe Math* pattern. Among Latina/o adolescents, 9% showed *Overall High*, 46% showed *Overall Low*, 30% showed *Not Who I Am*, and 15% showed the *Not Science Maybe Math* pattern. Among White adolescents, a little over one in ten (11%) showed the *Overall High* pattern, while one in every two (50%) showed the *Overall Low* pattern. Almost one in every four White adolescents (23%) showed the *Not Who I Am* pattern, and 16% showed the *Not Science Maybe Math* pattern.

11^{th} grade. Figure 2 shows the five patterns of math and science motivational beliefs identified in 11^{th} grade (i.e., data collected in year 2011). The *Overall Low* pattern (dashed line with solid triangle markers) was still, on average, the largest group (44% of all adolescents). Also similar in configuration as identified in 9^{th}, the *Overall High* pattern in 11^{th} grade accounted for, on average, 13% of all adolescents. The pattern shown in dashed line without markers, *STEM is Useful but Not for Me*, was characterized by high utility value in both math and science, yet low interest, expectancy, and attainment values for both subjects. *STEM is Useful but Not for Me* accounted for about 11-16% of adolescents across race/ethnicity. The pattern shown in the solid line with hollow triangle marker, *Not Math Maybe Science* (10-19% across racial/ethnic groups), was characterized by mostly low math motivational beliefs but high or mixed science motivational beliefs. Lastly, *Not Science Maybe Math* (14-25% across racial/ethnic groups) shown in the solid line with hollow square marker, like identified in 9th grade, was characterized by low level for all four science motivational beliefs, while motivational beliefs toward math were mixed.

Figure 2.

Math and science motivational belief patterns in 11th grade



Pattern name	*Graphic*	*Proportion*				
		Across race/ethnicity	*within Asian*	*within Black*	*within Latina/o*	*within White*
Overall High		13%	25%	11%	10%	15%
STEM is Useful but Not for Me		12%	13%	13%	15%	11%
Not Math Maybe Science		14%	11%	16%	11%	15%
Not Science Maybe Math		16%	15%	27%	17%	14%
Overall Low		44%	36%	33%	48%	45%

SOURCE: U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, High School Longitudinal Study of 2009 (HSLS:09), Base Year and First Follow-Up.

The prevalence of the five patterns identified in 11th grade was also estimated within each race/ethnicity. One in four Asian adolescents showed *Overall High*, 13% showed *STEM is Useful but Not for Me*, 11% showed *Not Math Maybe Science*, 15% showed *Not Science Maybe Math*, and 36% showed the *Overall Low* pattern. Among Black adolescents, 11% showed

Overall High, 13% showed *STEM is Useful but Not for Me*, 16% showed *Not Math Maybe Science*, 27% showed *Not Science Maybe Math*, and 33% showed the *Overall Low* pattern. Among Latina/o adolescents, 10% showed *Overall High*, 15% showed *STEM is Useful but Not for Me*, 11% showed *Not Math Maybe Science*, 17% showed *Not Science Maybe Math*, and 48% showed the *Overall Low* pattern. Lastly, 15% of White adolescents showed *Overall High*, 11% showed *STEM is Useful but Not for Me*, 15% showed *Not Math Maybe Science*, 14% showed *Not Science Maybe Math*, and 45% showed the *Overall Low* pattern.

Changes in Patterns of STEM Motivational Beliefs across Race/Ethnicity

All of the changes across patterns are described in Table 3 and the two most prevalent paths across patterns are depicted in Figure 3 for simplicity. For patterns that emerged in both 9th and 11th grade, namely *Overall High*, *Overall Low*, and *Not Science Maybe Math*, stability (i.e., staying in the same pattern) was the most common developmental pattern between the two time points, accounting for 47% - 67% of participants. The pattern *Not Who I Am* emerged in 9th but not 11th grade; adolescents in this pattern were most likely to transition into the following patterns in 11th grade: *STEM is Useful but Not For Me* (28%), *Not Math Maybe Science* (28%), and *Overall Low* (29%). As would be expected, some of the least frequent transitions were switching to opposite patterns, such as between *Overall High* and *Overall Low* (i.e., from *Overall High* to *Overall Low*, 10%, and from *Overall Low* to *Overall High*, 3%) and from *Not Science Maybe Math* at 9th to *Not Math Maybe Science* at 11th (3%). Table 3 also shows that examining adolescents' overall masks substantial heterogeneous patterns within each racial/ethnic group. I next describe some of the changes in patterns of math and science motivational beliefs within each race/ethnicity; please see Table 3 for full details.

Table 3
Change in math and science motivational belief patterns from 9th to 11th grade with greater shade denoting higher proportion

(a) Across race/ethnicity

11th grade patterns / 9th grade patterns	Overall High (13%)	STEM is Useful but Not for Me (12%)	Not Math Maybe Science (14%)	Not Science Maybe Math (16%)	Overall Low (44%)
Overall High (11%)	61%	5%	8%	17%	10%
Not Who I Am (26%)	11%	25%	28%	8%	29%
Not Science Maybe Math (16%)	16%	8%	3%	47%	25%
Overall Low (47%)	3%	8%	11%	11%	67%

(b) Asian

11th grade patterns / 9th grade patterns	Overall High (25%)	STEM is Useful but Not for Me (13%)	Not Math Maybe Science (11%)	Not Science Maybe Math (15%)	Overall Low (36%)
Overall High (19%)	69%	3%	7%	20%	1%
Not Who I Am (28%)	19%	22%	27%	7%	25%
Not Science Maybe Math (17%)	13%	0%	0%	46%	40%
Overall Low (36%)	12%	17%	5%	5%	60%

(c) Black

11th grade patterns / 9th grade patterns	Overall High (11%)	STEM is Useful but Not for Me (13%)	Not Math Maybe Science (16%)	Not Science Maybe Math (27%)	Overall Low (33%)
Overall High (12%)	47%	0%	20%	25%	9%
Not Who I Am (32%)	10%	29%	32%	10%	18%
Not Science Maybe Math (18%)	6%	12%	1%	64%	18%
Overall Low (39%)	3%	4%	8%	25%	61%

(d) Latina/o

11th grade patterns / 9th grade patterns	Overall High (10%)	STEM is Useful but Not for Me (15%)	Not Math Maybe Science (11%)	Not Science Maybe Math (17%)	Overall Low (48%)
Overall High (9%)	55%	0%	3%	18%	24%
Not Who I Am (30%)	6%	28%	24%	11%	32%
Not Science Maybe Math (15%)	18%	22%	3%	39%	18%
Overall Low (46%)	0%	8%	6%	13%	72%

(d) White

11th grade patterns / 9th grade patterns	Overall High (15%)	STEM is Useful but Not for Me (11%)	Not Math Maybe Science (15%)	Not Science Maybe Math (14%)	Overall Low (45%)
Overall High (11%)	64%	7%	7%	14%	8%
Not Who I Am (23%)	13%	23%	29%	5%	30%
Not Science Maybe Math (16%)	18%	3%	5%	45%	29%
Overall Low (50%)	3%	9%	14%	8%	67%

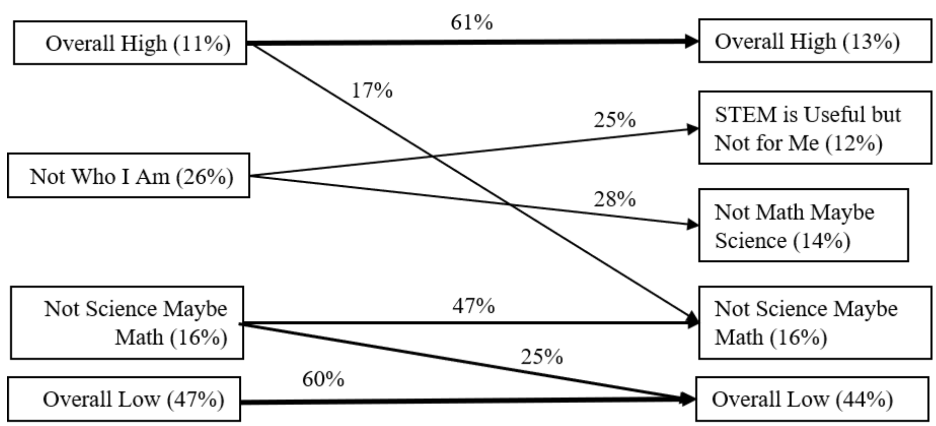
Note. (a) model for adolescents across race/ethnicity, (b) Asian, (c) Black, (d) Latina/o, and (e) White adolescents.
SOURCE: U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, High School Longitudinal Study of 2009 (HSLS:09), Base Year and First Follow-Up.

Figure 3

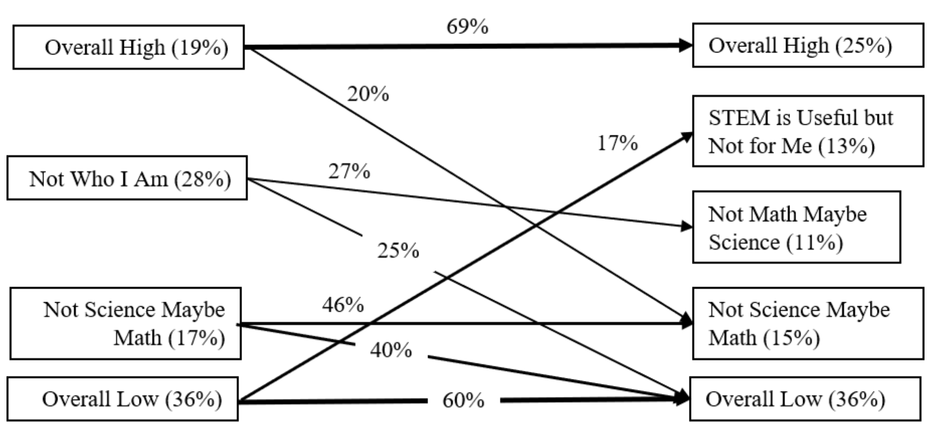
Most prevalent two paths of change in math and science motivational belief patterns from 9th to 11th grade, among (a) adolescent across race/ethnicity, (b) Asian, (c) Black, (d) Latina/o, and (e) White adolescents.

Note. Only one path is presented if the next prevalent path was exhibited by less than 15% of the adolescents.

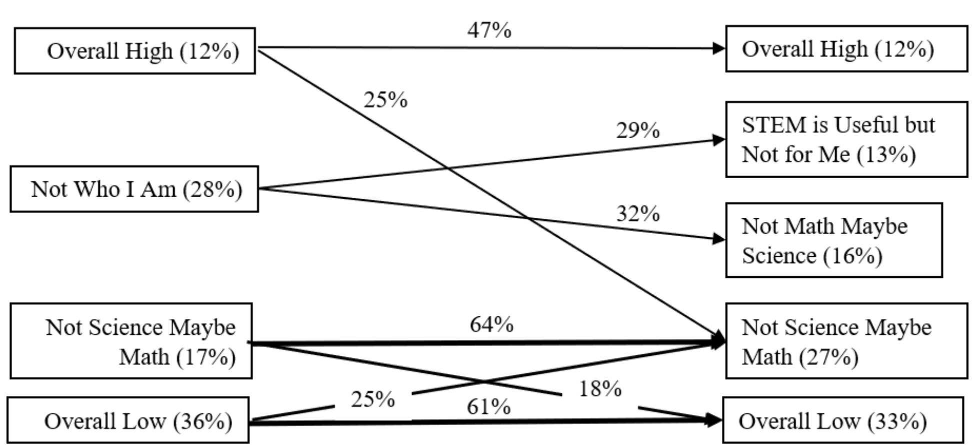
(a) Across race/ethnicity



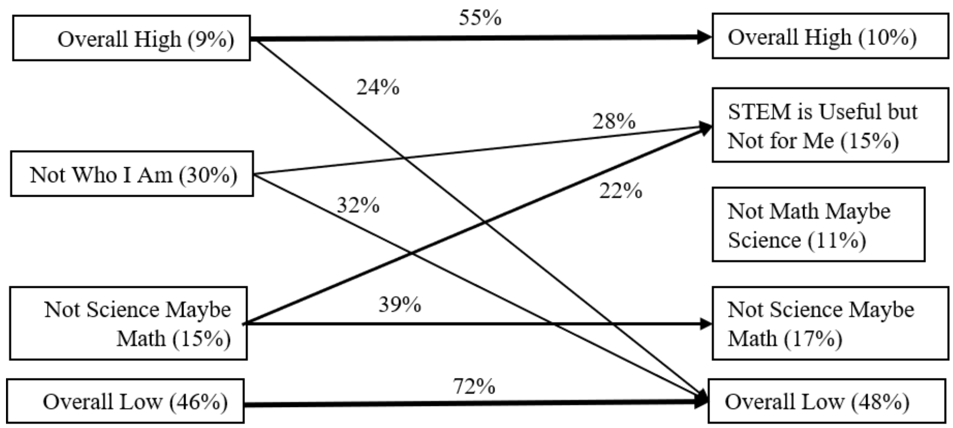
(b) Asian



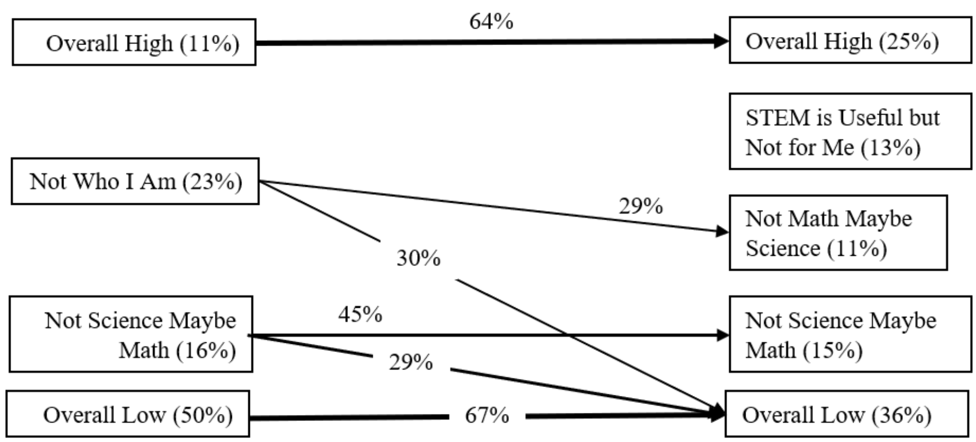
(c) Black



(d) Latina/o



(e) White



SOURCE: U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, High School Longitudinal Study of 2009 (HSLS:09), Base Year and First Follow-Up.

A major finding among Asian adolescents is that the proportion reporting *Overall High* increased from 19% in 9th grade to 25% in 11th grade. Firstly, almost 70% of those with *Overall High* in 9th grade remained the same pattern in 11th grade. Additionally, 12-19% of those with other patterns in 9th grade changed into reporting *Overall High* in 11th grade. On another note, almost half of the Asian adolescents who reported *Not Science Maybe Math* in 9th grade remained in that pattern in 11th grade, but almost as many of them (40%) changed into *Overall Low* in 11th grade. Lastly, although it was most common for Asian adolescents who showed *Overall Low* in 9th grade to remain in the *Overall Low* pattern in 11th grade, there were also the

17% who changed into *STEM is Useful but Not For Me* and the 12% who made the unexpected change into *Overall High.*

Among Black adolescents, the changes into domain-specific patterns stood out. For example, only less than half of those who showed *Overall High* in 9th grade remained in the pattern, whereas 25% changed into *Not Science Maybe Math* and another 20% changed into *Not Math Maybe Science* in 11th grade. Additionally, 10% of those who showed *Not Who I Am* in 9th grade and 25% of *Overall Low* also changed into *Not Science Maybe Math*. Combining the aforementioned changes into *Not Science Maybe Math* with the more than 60% of those who remained in the pattern from 9th to 11th grade, more than one in every four Black adolescents reported *Not Science Maybe Math* at 11th grade.

A major finding among Latina/o adolescents was the changes into *Overall Low* in 11th grade. Firstly, although 55% of the Latina/o adolescents who showed *Overall High* in 9th grade remained so in 11th grade, almost 25% of them shifted into *Overall Low* in 11th grade. Furthermore, around one-third of Latina/o adolescents who showed *Not Who I Am* in 9th grade also changed into *Overall Low* in 11th grade. In addition to the 18% of those with *Not Science Maybe Math* in 9th grade who changed into *Overall Low* in 11th grade, 72% of the *Overall Low* in 9th grade remained so, resulting in almost one in every two Latina/o adolescents in 11th grade showing the *Overall Low* pattern. Another finding to note is that not only did around one in four Latina/o adolescents who reported *Not Who I Am* in 9th grade shifted to *STEM is Useful but Not for Me* in 11th grade, around the same proportion of those who reported *Not Science Maybe Math* in 9th grade made the same shift.

Stability in pattern was prevalent among White adolescents, for example, as observed for 64% of those who reported *Overall High*, 45% of *Not Science Maybe Math*, and 67% of *Overall*

Low in 9th grade. The resulting 11th grade patterns of math and science motivational beliefs were 45% reporting *Overall Low* and the rest of White adolescents about evenly split among the other four patterns.

Adolescents' 11th Grade Motivational Beliefs and Their STEM GPA and Career Aspirations across Race/Ethnicity

As shown in Table 4, the math and science motivational belief patterns at 11th grade (i.e., final time point in the current study) were associated with statistically different levels of STEM GPA and career aspirations. Among Asian adolescents, the range of average STEM GPA across the five patterns of math and science motivational beliefs were relatively high to start with (range = 2.81 – 3.18). Within this relatively high range of STEM GPA among Asian adolescents, those with the *Overall High* pattern had higher STEM GPAs (M = 3.18) than those with the *Overall Low* pattern (M = 2.81). The STEM GPAs of Asian adolescents with the other three patterns (*STEM is Useful but Not for Me* (M = 2.87), *Not Math Maybe Science* (M = 3.02), *Not Science Maybe Math* (M = 3.01) were in between that of the *Overall High* and *Overall Low* patterns and did not differ from each other. In terms of STEM career aspirations (Table 4), 72% of Asian adolescents in the *Overall High* pattern reported aspiring for a STEM-related job for age 30, which was higher than 43% and 41% for the *STEM is Useful but Not for Me* and *Not Science Maybe Math* patterns. Asian adolescents with the *Overall Low* pattern had the lowest STEM career aspirations, with only 17% aspiring for a STEM-related job. The STEM career aspirations of Asian adolescents who reported the *Not Math Maybe Science* pattern was not statistically different from the other patterns, possibly due to its large variance.

Table 4

Association between 11th grade STEM motivational beliefs patterns and high school STEM GPA, by race/ethnicity

Motivation patterns	STEM GPA	STEM career aspirations

	M	(SE)	M	(SE)
Among Asian				
Overall High	3.18[ab]	(.08)	.72[ab]	(.07)
STEM is Useful but Not for Me	2.87[bc]	(.12)	.43[c]	(.08)
Not Math Maybe Science	3.02[bc]	(.14)	.44[bcd]	(.20)
Not Science Maybe Math	3.01[bc]	(.15)	.41[c]	(.11)
Overall low	2.81[c]	(.06)	.17[d]	(.03)
Among Black				
Overall High	2.83[a]	(.12)	.72[a]	(.11)
STEM is Useful but Not for Me	2.11[b]	(.14)	.47[ab]	(.12)
Not Math Maybe Science	1.99[b]	(.19)	.49[ab]	(.11)
Not Science Maybe Math	2.58[a]	(.31)	.31[b]	(.08)
Overall low	1.89[b]	(.11)	.31[b]	(.05)
Among Latina/o				
Overall High	2.92[a]	(.10)	.72[a]	(.07)
STEM is Useful but Not for Me	2.27[bc]	(.13)	.65[ab]	(.11)
Not Math Maybe Science	2.10[c]	(.12)	.51[bc]	(.16)
Not Science Maybe Math	2.61[b]	(.10)	.23[c]	(.04)
Overall low	2.03[c]	(.07)	.25[c]	(.03)
Among White				
Overall High	3.31[a]	(.03)	.70[a]	(.03)
STEM is Useful but Not for Me	2.70[c]	(.06)	.52[b]	(.05)
Not Math Maybe Science	2.51[d]	(.06)	.36[c]	(.04)
Not Science Maybe Math	3.03[b]	(.05)	.31[cd]	(.03)
Overall low	2.53[d]	(.02)	.25[d]	(.01)

Note. SE = Standard Error. Sampling weight incorporated. [abcde]Different letters denote statistical difference within column at $p<.05$ with Bonferroni correction.
SOURCE: U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, High School Longitudinal Study of 2009 (HSLS:09), Base Year and First Follow-Up.

Among Black adolescents, those with the *Overall High* (M = 2.83) and *Not Science Maybe Math* (M = 2.58) patterns had higher STEM GPAs than those with the other three patterns, namely *STEM is Useful but not for Me* (M = 2.11), *Not Math Maybe Science* (M = 1.99), and *Overall Low* (M = 1.89). In terms of STEM career aspirations, 72% of Black adolescents with the *Overall High* pattern reported STEM career aspirations, which was twice as large as those with the *Not Science Maybe Math* and *Overall Low* patterns (31%). STEM career aspirations associated with the *STEM is Useful but not for Me* (47%) and *Not Math Maybe Science* (49%) patterns were in the middle and did not differ from other patterns.

Among Latina/o adolescents, those showing the *Overall High* pattern of motivation had the highest STEM GPA (*M* = 2.92), followed by those with the *STEM is Useful but not for Me* (*M* = 2.27) and *Not Science Maybe Math* (*M* = 2.61) patterns, then by those with the *Not Math Maybe Science* (*M* = 2.10) and *Overall Low* (*M* = 2.03) patterns. Among Latina/o adolescents who reported the *Overall High* pattern, 72% indicated STEM career aspirations, which was similar to 65% of those with the *STEM is Useful but not for Me* pattern, but higher than 51% of those with the *Not Math Maybe Science* pattern. Only around one in four Latina/o adolescents with the *Not Science Maybe Math* and *Overall Low* patterns reported STEM career aspirations.

Among White adolescents, those showing *Overall High* had the highest STEM GPA (*M* = 3.11), followed by those with *Not Science Maybe Math* (*M* = 3.03), then by *STEM is Useful but Not for Me* (*M* = 2.70), and finally, the patterns associated with the lowest STEM GPA were *Not Math Maybe Science* (*M* = 2.51) and *Overall Low* (*M* = 2.53). Among White adolescents, 70% of those with the *Overall High* pattern aspired for a STEM job, which was higher than the 52% of those reporting the *STEM is Useful but Not for Me* pattern. Among White adolescents reporting *Not Math Maybe Science*, 36% had STEM career aspirations, which was higher than the 25% of *Overall Low* but not statistically different from the 31% of *Not Science Maybe Math*.

Discussion

Math and science have become increasingly critical for societal advancement and our daily lives; however, stark racial/ethnic disparities in STEM remain. As a result, it is crucial to understand the development of math and science motivational beliefs among adolescents from different racial/ethnic groups. However, there is a disconnection between theory and empirical analysis such that the examination of motivational belief patterns (as opposed to each motivational belief as independent variables) is called for. To this end, I found four and five patterns of math and science motivational beliefs among U.S. adolescents in 9^{th} and 11^{th} grade, respectively (with data from year 2009 and 2011). I also charted the stability and changes in those patterns from 9^{th} to 11^{th} grade, as well as examined the extent to which patterns at 11^{th} grade were associated with adolescents' STEM performance and career aspirations.

The patterns of adolescents' math and science motivational beliefs supported theories in some regards but also provided additional nuances to consider. Firstly, the two patterns characterized by homogenous high and low motivational beliefs (i.e., *Overall High* and *Overall Low*) aligned with the posited positive correlations among expectancy and value beliefs, which simultaneously support situated expectancy-value and dimensional comparison theories (Denissen et al., 2007; Eccles, 2009; Eccles & Wigfield, 2020). Nonetheless, *Overall High* and *Overall Low* actually only accounted for at most 60% of the adolescents within each racial/ethnic group, meaning that 40% or more of adolescents reported a pattern where their math and science motivational beliefs varied. For example, I found a pattern (*Not Who I Am*) where the level of math and science attainment value differed meaningfully compared to the other motivational beliefs, which aligns with the situated expectancy-value theory and studies that highlighted the importance of domain identity beliefs during this developmental period (Archer et al., 2010; Eccles, 2009; McGee, 2013). In contrast to dimensional comparison theory, I found patterns characterized by domain differentiation (i.e., *Not Math Maybe Science* and *Not Science Maybe Math*), which together accounted for 26-43% of the adolescents across racial/ethnic groups. The presence of these domain-specific patterns and overall high/low patterns helps explain the mixed correlations between math and science motivational beliefs in a recent meta-analysis (Möller et al., 2020). In sum, although the various motivational beliefs and domains aligned for some adolescents, there were nuances and differentiation among the various motivational beliefs or domains for a sizeable proportion. Adolescence is a period marked by complex developmental systems and marked by growth in identity and autonomy (National Academies of Science, Engineering, and Medicine, 2019), all of which could contribute to the unique, intricate patterns of motivational beliefs in STEM. Adolescents may make more fine-grained distinctions as they grow as an individual, discover their identity, and are able to think in more complex ways.

Another gap in the literature that my study addressed is documenting the changes in the patterns of adolescents' math and science motivational beliefs from 9th to 11th grade. As expected, I found stability to be common for patterns that emerged in both 9th and 11th grade (i.e., *Overall High*, *Overall Low*, *Not Science Maybe Math*). Nonetheless, stability was only one of several developmental shifts or changes over time. For example, 31-53% of *Overall High* adolescents (depending on race/ethnicity) shifted to a different pattern in 11th grade, with the most common being *Not Science Maybe Math*. That said, switching to an opposing pattern was uncommon though there were two exceptions that varied by race/ethnicity. First, only 1% of Asian adolescents switched from *Overall High* to *Overall Low*, but 12% switched from *Overall Low* to *Overall High*. Second, 24% of Latina/o adolescents switched from *Overall High* to *Overall Low*, but 0% switched from *Overall Low* to *Overall High*. One possibility is that Asian and Latina/o adolescents being pushed in or out of STEM respectively because of the racial/ethnic stereotypes around STEM (Chen & Buell, 2018; McGee, 2016). Uncovering the reasons why a sizeable number of Asian adolescents switched from low to high and Latina/o adolescents switched from high to low will be an important future direction.

The findings also support increased domain-specialization, which might be particularly important during high school as adolescents are exposed to a wider variety of math and science subjects. The *Not Science Maybe Math* pattern emerged in both 9th and 11th grade and an additional domain-specialized pattern emerged in 11th grade, namely *Not Math Maybe Science*. Moreover, the proportion of adolescents moving into *Not Math Maybe Science* from *Not Who I Am* in 9th grade was the highest of all four patterns in 9th grade; a future direction would be to understand the factors contributing to this move. For example, how might an increasingly specialized curriculum in high school relate to the domain-specialized patterns I observe. Another notable finding regarding the domain-specialized patterns is the prevalence of *Not Science Maybe Math* among Black adolescents. Not only did 64% of Black adolescents who showed *Not Science Maybe Math* in 9th grade remained so in 11th grade (compared to 39-46% Asian, Latina/o, and White adolescents who showed such stability), one in four Black adolescents who reported *Overall High* or *Overall Low* in 9th grade switched to *Not Science Maybe Math* in 11th grade. Overall, my findings contributed to the emerging body of literature that uses innovative analytical methods to document the nuanced changes in motivational beliefs beyond average decline (e.g., Gaspard et al., 2020; Ing & Nylund-Gibson, 2017; Lazarides et al., 2020; Wang et al., 2017).

Lastly, I showed that the patterns of STEM motivational beliefs at 11th grade were associated with adolescents' STEM GPA and career aspirations. A notable finding is that the group differences in STEM GPA were not necessarily the same differences in STEM career aspirations. For example, among Black, Latina/o, and White adolescents, I found that the *Not Science Maybe Math* pattern was associated with higher STEM GPAs than the *Not Math Maybe Science* patterns, but these two groups had similar STEM career aspirations. As another example, adolescents (with the exception of Asian adolescents) who reported *STEM is Useful but Not for Me* in 11th grade had the lowest or second-lowest STEM GPAs, yet they reported the second-highest STEM aspirations with more than 45% of the adolescents aspiring for a STEM career. This finding might speak to prior work that shows value beliefs are more strongly related to aspirations, while expectancy beliefs are more related to performance (Rosenzweig et al., 2019). However, more is needed to understand why adolescents who reported a specific pattern of math and science motivational belief arrive their corresponding level of STEM performance and career aspirations.

Throughout my analyses, I estimated race/ethnicity-specific models. I intentionally decided not to compare racial/ethnic groups because I believe presenting the nuances within each race/ethnicity complements the existing knowledge on between-group differences. Moreover, within-group analyses help identify positive processes that can demystify racially-/ethnically-based stereotypes or overgeneralizations, whereas between-group differences can easily lead to deficit-based narratives. My results in fact showed that there was great variation within each race/ethnicity. For example, I showed that more than half of Black adolescents reported either *Overall High* or a domain-specialized pattern in 11th grade; more studies highlighting the strengths and supports of Black adolescents who show positive motivational beliefs are needed in order to counter deficit-based research that focuses on their marginalization (Collins, 2018). As another example, approximately 60% of Asian adolescents were in the *Not Who I Am* or *Overall Low* patterns in 9th grade, which are critical statistics to help demystify the model minority stereotype in STEM (Chen & Buell, 2018). More studies, however, are needed to understand the processes that underlie the patterns that go against racial/ethnic stereotypes.

Limitations and Future Directions

A major contribution of the current study is mapping out the changes in the patterns of adolescents' math and science motivational beliefs between 9th and 11th grade. Though high school is a critical juncture in the STEM pipeline (Maltese & Tai, 2011), it represents only one segment of this 'leaky' pipeline (Jacobs & Simpkins, 2005). Thus, a future direction is to examine changes in the patterns of adolescents' math and science motivational beliefs before and after high school. Moreover, the current study did not examine what predicts those changes in math and science motivational belief patterns. In some cases, a future direction is to understand what supports help adolescents counter the racial/ethnic stereotypes and structural barriers in STEM (e.g., the more than 50% Black adolescents who reported *Overall High* or a domain-specialized pattern in 11th grade). In other cases, a future direction is to examine the structural and systemic factors that fail students. For example, I observed that one in four Latina/o adolescents switched from *Overall High* in 9th grade to *Overall Low* in 11th grade. How might this finding relate to the racial assaults and other hostile dynamics that marginalized students face in STEM (McGee, 2016)? Finally, it will be important to understand what supports help explain when adolescents move away from *Overall Low* to a more positive STEM pattern. For example, prior work has identified multiple sources of support that could be leveraged to promote adolescents' STEM motivational beliefs, including school, families, peers, and out-of-school programs. A future direction is to examine how such contextual supports are related to changes in adolescents' motivational belief patterns (e.g., Rice et al., 2013; Simpkins et al., 2019; Young et al., 2017).

Another strength of the current study was that I examined motivational beliefs in two domains simultaneously. Although I identified two patterns characterized by domain-specialization (*Not Math Maybe Science* and *Not Science Maybe Math*) and examined their prevalence within each racial/ethnic group, many questions remain unanswered. For example, what explains the relatively high rate of Black adolescents moving into *Not Science Maybe Math* in 11th grade? The *Not Science Maybe Math* pattern also opens more questions in relation to STEM outcomes. Among Black adolescents, those who reported the *Not Science Maybe Math* pattern had STEM GPAs as high as those who reported the *Overall High* pattern, but they had STEM career aspirations as low as those who reported the *Overall Low* pattern. To further employ dimensional comparison theory, it is also important to examine more domains that range in nearness with STEM, such as relatively far domains like humanities and relatively near domains like psychology. Relatedly, there are ample nuances to be explored among the multiple domains within science (e.g., Hsieh et al., 2019; Wang et al., 2017). The differentiation within science domains might be increasingly crucial as I observe emerging disparities within STEM. Overall, the increase in breadth and depth of domains might be particularly important to consider during developmental stages such as college when individuals are faced with a greater number of specialized options.

Conclusion

Guided by situated expectancy-value and the dimensional comparison theories, I examined the patterns of math and science motivational beliefs (interest, utility value, attainment value, and expectancy) among Asian, Black, Latina/o, and White adolescents. I identified both patterns with homogenous levels of motivational beliefs (e.g., *Overall High*) and patterns with heterogenous levels of motivational beliefs, including those characterized by domain differences (e.g., *Not Math Maybe Science*), as well as those characterized by differences in motivational beliefs (e.g., *STEM is Useful but Not for Me*). I also examined the changes in STEM motivational belief patterns from 9th to 11th grade, highlighting that stability is a common path, yet far from the complete picture. Lastly, I showed that the patterns of STEM motivational beliefs in 11th grade were associated with varying levels of STEM GPA and career aspirations. Overall, my findings have implications for understanding the development of math and science motivational beliefs during high school for Asian, Black, Latina/o, and White adolescents.

CHAPTER 3

Longitudinal Associations between Parent Degree/Occupation, Parent Support, and Adolescent Motivational Beliefs in STEM

Abstract

Introduction: The U.S. struggles with racial/ethnic disparities in STEM (science, technology, engineering, mathematics) degrees and occupations. According to the situated expectancy-value theory, the experience and knowledge parents gain through STEM degrees and occupations shape the STEM support they provide and relatedly their adolescents' STEM motivational beliefs. **Methods:** I analyzed data from the High School Longitudinal Study (*N* = 14,200; 50% female; *M*age = 14 at grade 9), which is a recent U.S. dataset that surveyed a nationally representative sample of adolescents. **Results & Conclusions:** Results showed that parent STEM support (9^{th} grade) and adolescent STEM motivational beliefs (11^{th} grade) were lower in families where parents did not have a STEM degree/occupation than families where at least one parent had a STEM degree/occupation. However, parents' STEM support was positively related to adolescents' STEM motivational beliefs among families where parents did not have a STEM degree/occupation, but not among those where at least one parent had a STEM degree/occupation. Furthermore, although more Asian and White adolescents' parents held STEM degree/occupation than Latina/o and Black adolescents' parents, the *associations* between parent STEM support and adolescents' STEM motivational beliefs did not vary by race/ethnicity.

Keywords: STEM, race/ethnicity, parent support, motivational beliefs

Longitudinal Associations between Parent Degree/Occupation, Parent Support, and Adolescent Motivational Beliefs in STEM

STEM (science, technology, engineering, mathematics) is increasingly important for our daily lives and economic advances, but the U.S. continues to struggle with substantial racial/ethnic inequities in STEM degrees and occupations (Bøe et al., 2011; Feinstein, 2011; National Mathematics Advisory Panel, 2008; Xue & Larson, 2015). For example, less than 20% of all full-time STEM employees are Latina/o or Black, whereas Whites and Asian Americans comprise more than 80% (NSF, 2019). These current racial/ethnic disparities are the result of historically rooted structural inequities, which include inequitable access to advanced STEM resources and opportunities, racially biased curriculum, as well as discrimination and implicit biases (Beasley & Fischer, 2012; Grossman & Porche, 2014; Museus & Liverman, 2010; Nasir & Vakil, 2017; Taningco et al., 2008; Walls, 2016).

Not only do these racial/ethnic disparities in STEM degrees and occupations have implications for adults in the current workforce (Jones, 2014; NSF, 2019), but they may also map onto disparities among the next generation. According to situated expectancy-value theory, parents' STEM education and occupation shape the STEM support they provide, which has implications for their children's motivational beliefs (Eccles, 2011; Eccles & Wigfield, 2020). Nonetheless, prior studies highlight the resilience of families marginalized in STEM where parents' support still matters and helps promote adolescents' motivational beliefs (e.g., McGee & Spencer, 2015; Plunkett & Bámaca-Gómez, 2003; Soto-Lara & Simpkins, 2020). The current study explores this complexity by examining differences between families in which parents do and do not have a STEM degree/occupation in terms of adolescents' race/ethnicity, parent STEM support, and adolescent STEM motivational beliefs. Additionally, I examined the extent to which parents' STEM support was associated with their adolescents' STEM motivational beliefs separately among families in which parents do and do not have a STEM degree/occupation, as well as whether these relations varied by race/ethnicity.

Parent STEM Support and Adolescents' Motivational Beliefs

A prominent theory to understand family influences and adolescents' STEM motivational beliefs is the situated expectancy-value theory (Eccles, 2011; Jacobs & Simpkins, 2005; Watt, 2005; Wigfield & Eccles, 2000). According to the situated expectancy-value theory, adolescents' motivational beliefs are shaped by contextual influences, with parents being one of the most important contextual influences (Wigfield et al., 2015). This theory argues that parents' STEM support (e.g., helping with science projects, providing encouragement for STEM, providing STEM-related experiences and opportunities) promotes their adolescents' STEM motivational beliefs (Simpkins, Fredricks, & Eccles, 2015). I focus on four central motivational beliefs in the situated expectancy-value theory. First, expectancy belief pertains to how good individuals think they are and will be in an area like STEM. Second, value beliefs include three positive constituents, namely interest (how enjoyable individuals find STEM to be), utility value (how useful individuals find STEM to be), and attainment value (how central being a STEM person is to who the individual is). Because STEM motivational beliefs typically decline during adolescence, it is critical to examine factors that *promote* STEM motivational beliefs, such as parent STEM support, during this developmental period (Alfaro & Umaña-Taylor, 2015; Gottfried et al., 2007; Hsieh et al., 2019; Jacobs et al., 2002; Wang et al., 2017).

Prior research supports the situated expectancy-value theory and shows that parents' supportive behaviors, such as encouragement, coactivity, and provision of materials, positively predict their adolescents' STEM expectancy belief, interest, utility, and attainment value

(Chakraverty et al., 2020; Gann & Carpenter, 2019; Kang et al., 2018). For example, the math and science encouragement that adolescents report receiving from their parents is positively related to adolescents' math and science expectancy and value beliefs (Aschbacher, Li, & Roth, 2010; Gottfried et al., 2009; Stake, 2006; Turner, Steward, & Lapan, 2004). Similarly, parents' co-participation in math and science activities (e.g., looking at science websites with their child) and providing access to math and science materials were associated with higher math and science motivational beliefs (Jacobs & Bleeker, 2004; Mujtaba et al., 2018; Simpkins, Davis-Kean, & Eccles, 2006; Simpkins, Price, & Garcia, 2015). Indicators summarizing multiple aspects of parents' supportive behaviors in math and science also positively predict children's math motivational beliefs (Hsieh et al., 2019; Simpkins, Fredericks, & Eccles, 2015). This prior work, however, largely focuses on average associations. Though information on the average is helpful, there is also great variability around those averages, such that parent support predicts adolescent motivational beliefs for most but not all families. Among which families might parent support be a stronger predictor? I argue that parents' STEM degree/occupation may be a crucial factor.

Parent STEM Degrees and Occupations

The situated expectancy-value theory argues that parents' educational degrees and occupations are two critical aspects of the cultural milieu that shape family processes as well as adolescents' motivational beliefs, achievement, and choices (Eccles, 2011; Eccles & Wigfield, 2020). Aligned with this theory, evidence suggests that having a family member (e.g., parent) who has a science-related occupation positively predicts children's aspirations for a STEM career, even after controlling for children's STEM expectancy belief and participation in STEM activities (Bryant, Zvonkovic, & Reynolds, 2006; Cheng, Kopotic, & Zamarro, 2019; Gilmartin, Li, & Aschbacher, 2006; Shapiro & Sax, 2011).

The parent socialization model of the situated expectancy-value theory argues that parent characteristics such as their education and occupation shape their beliefs and behaviors (Eccles, 2005). Parents with STEM degrees or occupations are expected to provide more STEM support compared with those without STEM degrees/occupations because their STEM-related educational or occupational experiences might better prepare them to provide STEM support to their adolescents (DeWitt et al., 2016; Dika & Singh, 2002; Eccles, 2005). In a retrospective qualitative study, scientists attributed their interest and subsequent enrollment into the STEM fields to their parents and other family members who possessed STEM 'funds of knowledge' (Chakraverty et al., 2020). For example, parents with STEM degree/occupation might engage in more conversations with their adolescents about STEM because more STEM-related instances at work prompted them to start those conversations (Chakraverty & Tai, 2013).

If adolescents in families where at least one parent has a STEM degree/occupation are exposed to more STEM-related contents at home, they might report higher STEM motivational beliefs than those in families where parents did not have a STEM degree/occupation (Adamuti-Trache & Andres, 2008; Gilmartin et al., 2006; Leppel et al., 2001; Simpkins, Davis-Kean, & Eccles, 2006). However, more empirical evidence is needed to examine this proposition because there are also some mixed results. For example, Anaya and colleagues (2017) found that children of parents with science-related occupations had higher math performance but did not report higher math expectancy belief than children of parents with other occupations.

In addition to the mean-level differences discussed above, parent STEM degrees/occupations might relate to process-level differences wherein the relations between parents' STEM support and adolescents' STEM motivational beliefs might vary between families with and without a parent STEM degree/occupation (Eccles, 2005). For example, Hyde and colleagues (2006) showed that mothers with more math knowledge guided their children in solving mathematical problems more effectively compared to their peers. Similarly, parents' STEM degree/occupation might allow them to be more effective in discussing the values of STEM and the various options for STEM careers with their adolescents (Archer et al., 2013). This effect may be more pronounced in high school as the increasing complexity of STEM high school courses might quickly surpass parents' comfort level (O'Sullivan, Chen, & Fish, 2014).

The expectation that parents' STEM support predicts adolescents' STEM motivational beliefs more strongly when parents hold a STEM degree/occupation sounds intuitive, but it may not be the full story as parent support still matters for those who do not have STEM credentials or are otherwise marginalized in STEM (McGee & Spencer, 2015; Plunkett & Bámaca-Gómez, 2003; Soto-Lara & Simpkins, 2020). Furthermore, individuals from less-well-resourced families might be in a better position to reap the benefits of parent support (Domina, 2005). For example, Rozek and colleagues (2015) showed that an intervention promoting parents' STEM utility effectively enhanced adolescent boys' STEM course-taking for those who had *low* prior STEM performance but not those with high prior STEM performance. Taken together, the associations between parents' STEM support and adolescents' STEM motivational beliefs should be modeled separately based on whether parents hold a STEM degree/occupation or not, though for which families the association might be more pronounced is unclear.

Race/Ethnicity Disparities in STEM

Historically rooted, structural inequities in the U.S. have produced substantial racial/ethnic disparities in STEM. In this study, I focus on the inequities in parents' STEM degrees/occupations because they are major markers or recognized qualifications for what are socially agreed-upon as prestigious, and they show profound racial/ethnic disparities (NSF, 2019; U.S. Census Bureau, 2018). Acknowledging this existing racial/ethnic disparities in STEM, I first explicitly examine the differences in racial/ethnic representation between families with and without a parent STEM degree/occupation. I expect Whites and Asian adolescents to be overrepresented in families with a parent STEM degree/occupation, whereas Black and Latina/o adolescents will be overrepresented in families without a parent STEM degree/occupation.

Although I hypothesized racial/ethnic differences in terms of representation, I take a family strength-based perspective and do not expect racial/ethnic differences in the *associations* between parent STEM support and adolescents' STEM motivational beliefs. In a prior study, although Latino/a adolescents reported receiving less parenting support and having lower science motivational beliefs than their White peers, the positive associations between parents' support and adolescents' science motivational beliefs did not vary by ethnicity (Simpkins, Price, & Garcia, 2015). Thus, I expect that the *associations* between parent STEM support and adolescent STEM motivational beliefs will be similar across racial/ethnic groups.

Theoretically Relevant Factors to Control

In order to examine parents' *STEM* support and adolescents' motivational beliefs, I accounted for two central indicators of parents' general educational support, namely their discussion about their adolescents' higher educational plan and their financial preparation for their adolescents' higher education (Eccles & Harold, 1996; Hill & Tyson, 2009; Wilder, 2014). To account for potential selection effects of parents' STEM support, an earlier measure of adolescents' math standardized achievement was included as a covariate. That is, I estimated the relation between parents' STEM support and adolescents' later STEM motivational beliefs for those with similar achievement levels to start with.

The Current Study

The current study tested four hypotheses under two research aims.

Aim 1: Describe families with and without a parent STEM degree/occupation in terms of their differences in adolescent racial/ethnic representation, parent STEM support, and adolescent STEM motivational beliefs.

Hypothesis 1.1: White and Asian adolescents would be overrepresented whereas Latina/o and Black adolescents would be underrepresented in families whose parents had a STEM degree/occupation.

Hypothesis 1.2: Adolescents whose parents held a STEM degree/occupation will receive more parent STEM support in 9^{th} grade and have higher STEM motivational beliefs in 11^{th} grade compared with those whose parents did not have a STEM degree/occupation.

Aim 2: Estimate the association between parent STEM support and adolescents' STEM motivational beliefs for families with and without a parent STEM degree/occupation.

Hypothesis 2.1: Parents' 9^{th} grade STEM support will positively predict adolescents' 11^{th} grade STEM motivational beliefs. Whether the association is significant for both those with and without parent STEM degree/occupation is not set a priori.

Hypothesis 2.2: The association between parents' 9^{th} grade STEM support and adolescents' 11^{th} grade STEM motivational beliefs is not expected to vary by race/ethnicity.

Method

Dataset and Participants

Participants for the current study were from the High School Longitudinal Study (HSLS) collected by the National Center for Educational Statistics (NCES). HSLS is a fitting dataset for the current study because it includes data reported by both adolescents and their parents. For every adolescent, one parent (71% were biological mothers, 21% were biological fathers) reported for themselves and (if applicable) on behalf of their spouse or partner living in the same household. I excluded participants who missed the entire adolescent (*n* = 3,760) or parent (*n* = 5,020) survey in 9th grade, and then those who had missing data on parent STEM degree (*n* = 820). Lastly, I focused on participants whose race/ethnicity was White (*n* = 8,900), Latina/o (*n* = 2,460), Black (*n* = 1,470), or Asian (*n* = 1,160), yielding a total analytical sample of 14,000 adolescents. Sample sizes throughout this article are rounded to the nearest tenth in accordance with the NCES reporting requirements for restricted dataset. The demographics of the analysis sample are shown on Table 1. As shown on Appendix 4, the analysis sample reported statistically higher STEM motivational beliefs and higher proportion of parents with a STEM degree/occupation than the excluded sample, but the two samples did not differ on the level of parent STEM support. The use of HSLS data for the current study was approved by the Institutional Review Board at [blinded university] (IRB protocol number: HS#:2018-4349).

Measures

The primary indicators of this study were parents' STEM degree/occupation and parents' STEM support when their adolescents were in 9th grade, adolescents' 11th grade STEM motivational beliefs (i.e., STEM expectancy belief, interest, utility value, and attainment value), and adolescents' race/ethnicity. The covariates included parents' general educational support, family income, parent education, as well as adolescents' standardized math achievement in 9th grade, gender, 8th grade math course level and grade, and school type (public or private). All measures came from the HSLS surveys (see Ingel et al., 2009).

Parent STEM Degree/Occupation

Parents reported their current/most recent occupation and major of their highest degree at the time of data collection (i.e., when adolescents were in 9th grade) through open-ended questions. Their responses were coded by the HSLS team into STEM versus not based on Standard Occupational Classification and Classification of Instructional Programs codes respectively (Bureau of Labor Statistics, 2012). Some major STEM categories included computer and information sciences, engineering, biomedical sciences, military technologies, and physical sciences. Parents' STEM degree/occupation was coded into a binary variable where 0 means no while 1 means at least one parent had STEM-related occupation *or* degree.

Parent STEM Support

Parents' STEM support was measured when their adolescents were in 9th grade in reference to the last year as a frequency count of seven binary (yes/no) measures: 1) helped child with school science fair, 2) went to science museum with child, 3) used computer with child, 4) helped child with science project, 5) discussed with child about STEM article or program, 6) talked to parent about science courses selection in 9th grade, and 7) talked to parent about math courses selection in 9th grade. The first five items were reported by the parents. The last two items were reported by adolescents. Prior studies have used items similar to the current study and showed that parents utilize a variety of math and science supportive behaviors, hence a scale instead of independent predictors perform better in predicting youth outcomes (Simpkins, Davis-Kean, & Eccles, 2006; Simpkins, Fredericks, & Eccles, 2015).

Adolescent STEM Motivational Beliefs

Measures of four STEM motivational beliefs based on the expectancy-value theory (Wigfield & Eccles, 2000), namely interest, utility, ability self-concept, and attainment value, were examined as outcomes in 11th grade. Original items were asked with specificity in math and science, and then averaged into STEM (Appendix 2). STEM interest was a composite of 6 items ($\alpha = .75$; e.g., "enjoy math classes very much"), and STEM utility was also a composite of 6 items (α = .82; e.g., “science is useful for a future career”). STEM ability self-concept was a composite of 8 items (α = .86; e.g., “certain that you can master math skills” whereas STEM attainment value was a composite of 4 items (α = .74; e.g., “you see yourself as a science person”). All four STEM motivational beliefs were measured at 11^{th} grade using a 4-point (1 = *strongly disagree*, 4 = *strongly agree*) Likert scale. Similar scales have been used in prior studies to measure STEM motivational beliefs (e.g., Chemers et al., 2011; Simpkins, Fredericks, & Eccles, 2015). Confirmatory factor analysis including all four motivational beliefs and their respective items showed acceptable model fit in terms of RMSEA (.07) and SRMR (.04), and close to acceptable standard of CFI (.93).

Adolescent Race/Ethnicity

Adolescents’ race/ethnicity were recoded into dummy variables, namely Asian, Black, Latina/o, or White.

Covariates

Parents’ general (i.e., non-STEM-specific) educational support was included to isolate the correlates of parents’ STEM specific support and measured with two indicators when their adolescents were in 9^{th} grade. Parents reported whether they have talked to (0 = *no*, 1 = *yes*) school administrator about the adolescent’s college-going plans and whether they will (0 = *no*, 1 = *yes*) provide financial support for the adolescent’s higher education. These two indicators have been examined in prior literature as aspects of parents’ educational support (Eccles & Harold, 1996; Fan & Chen, 2001; Jeynes, 2005).

Other covariates included a standardized measure of math achievement assessed in 9^{th} grade using Item Response Theory. Adolescents’ gender (female or male), 8^{th} grade math course level (regular or advanced), and school type (public or private). Additionally, parent-reported family income (13 categories in $20,000 increments; ranged from less than 15,000 to more than 235,000) and whether at least one parent has a bachelor's degree' were also included as covariates.

Missing Data

All analyses were done on the analytic sample (*N* = 14,000) after multiple imputation (20 imputed datasets) for missing data on all variables (Enders, 2008). Auxiliary variables were included to strengthen the imputation process (i.e., variables that help with imputing missing data but are not used in the main analyses). They included percent of students on free or reduced lunch, percent of students who identify as White, percent student who repeated 9th grade in the adolescent's school, single-parent household, number of children in the household, parents' help with adolescents' homework, adolescents' 9th grade GPA, and adolescents' 9th grade STEM motivational beliefs.

Analysis Plan

For Research Aim 1, I expected mean level differences between families with and without parent STEM degree/occupation in terms of racial/ethnic representation, parents' STEM support, and adolescents' STEM motivational beliefs. *T*-tests for continuous variables or chi-square tests for categorical variables, in addition to their corresponding effect sizes, were calculated to statistically test the mean level differences. Descriptive statistics on all variables used in this study were presented separately for families whose parents had a STEM degree/occupation and those without a parent STEM degree/occupation.

Research Aim 2 examined the associations between parent STEM support and adolescents' STEM motivational beliefs with race/ethnicity tested as a moderator, among those whose parents had and those who did not have a STEM degree/occupation. STEM motivational beliefs (expectancy belief, interest, utility value, and attainment value as the outcome in separate models) were regressed on parents' STEM support, race/ethnicity, and the interactions between parent STEM support and race/ethnicity, in addition to my list of covariates. The regressions were done separately for those in families where a parent has a STEM degree/occupation and in families without a parent STEM degree/occupation. All the analyses were adjusted for the complex sampling design of HSLS (i.e., weights, primary sampling unit, strata, and clustered standard error) using Stata version 14 (StataCorp, 2015); see Appendix 5 for bivariate correlations of the main variables.

Results

Differences across Families With versus Without a Parent STEM Degree/Occupation

As expected, adolescents whose parents had a STEM degree/occupation and adolescents whose parents did not have a STEM degree/occupation differed in terms of their race/ethnicity (Table 1). Overall, Asian adolescents, and White adolescents to a lesser extent, were overrepresented in the families *with* a parent STEM degree/occupation. On the other hand, Latina/o adolescents, and to a lesser extent Black adolescents, were overrepresented in the families *without* a parent STEM degree/occupation. Specifically, Asian adolescents comprised 16% of the adolescents whose parents had a STEM degree/occupation, they accounted for only 5% of the adolescents whose parents did not have a STEM degree/occupation; this difference was statistically significant (χ^2 = 437.27, p <.001) and had a small effect size (d =.39). Also overrepresented in the group with a parent STEM degree/occupation, White adolescents made up 67% of the adolescents whose parents had a STEM degree/occupation and 62% of those without (χ^2 = 23.38, p <.001; d =.21). In contrast, Latina/o adolescents only accounted for 10% of the adolescents whose parents had a STEM degree/occupation, but 21% of those without a parent

STEM degree/occupation (χ^2 = 270.97, *p* <.001; *d* =.30). Black adolescents comprised 8% and 12% of those with and without a parent STEM degree/occupation respectively (χ^2 = 36.07, *p* <.001; *d* =.11).

Table 5.

Descriptive statistics for key variables, separately for parent with and without STEM degree/occupation

	Parents who did not have a STEM degree/occupation (*n* = 9,830)		Parents who had a STEM degree/occupation (*n* = 4,160)		*t*-statistics	chi-square	Cohen's *d* effect size
	Mean	*SE*	*Mean*	*SE*			
11th grade STEM motivational beliefs							
Expectancy belief	2.77	.01	2.90	.01	11.51***	-	.21
Interest	2.74	.01	2.82	.01	7.43***	-	.14
Utility value	3.15	.01	3.24	.01	9.55***	-	.18
Attainment value	2.42	.01	2.65	.01	17.79***	-	.33
9th grade parent STEM support	3.68	.02	4.20	.02	16.76***	-	.31
Asian (8% of entire sample)	.05	.00	.16	.01	-	437.27***	.39
Black (10% of entire sample)	.12	.00	.08	.00	-	36.07***	.11
Latina/o (18% of entire sample)	.21	.00	.10	.00	-	270.97***	.30
White (64% of entire sample)	.62	.00	.67	.01	-	23.38***	.09
Covariates							
9th grade parent financial support for college	.77	.00	.86	.01	-	131.20***	.21
9th grade parent communication with school about college	.42	.01	.48	.01	-	37.69***	.11
Parent has a bachelor's degree	.32	.00	.72	.01	-	2216.65***	.87
9th grade math achievement	50.65	.10	56.03	.15	29.89***		.55
8th grade math class is advanced	.36	.00	.54	.01	-	392.59***	.37
Female	.50	.01	.49	.01	-	.80	.02
Family income	4.05	.03	6.18	.05	40.05***		.74
School type: private	.18	.00	.27	.01	-	161.92***	.24

Notes. Conventions for Cohen's d .20 small, .50 medium, .80 large. *SE* = standard error. t-statistics calculated for continuous outcome while chi-squares calculated for binary outcomes; - denotes not applicable. Missing data imputed with multiple imputation.

* *p* < .05 ** *p* < .01 *** *p* < .001

SOURCE: U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, High School Longitudinal Study of 2009 (HSLS:09), Base Year and First Follow-Up.

In addition to differences in racial/ethnic representation, families with and without parent STEM degree/occupation also differed on the STEM indicators of interest in the current study. Parents who had a STEM degree/occupation, as expected, provided more STEM support compared with parents without a STEM degree/occupation (t = 16.76, p <.001; d = .31). Specifically, parents with STEM degree/occupation on average provided about 0.5 more STEM support (out of 7 possible support items) compared with those without a STEM degree/occupation. Also as expected, adolescents whose parent had a STEM degree/occupation reported higher STEM motivational beliefs compared to adolescents whose parents did not have a STEM degree/occupation (t = 7.43-17.79, p <.001; d = .14-.33). Specifically, adolescents whose parents had a STEM degree/occupation on average reported about .2 units (on a 1-4 scale) higher on STEM motivational beliefs compared with adolescents whose parents did not have a STEM degree/occupation.

Lastly, I tested the differences on all covariates and demographic indicators across families with and without a parent STEM degrees/occupation. Parents who had a STEM degree/occupation were much more likely to have a Bachelor's degree (χ^2 = 2216.65, p <.001; d = .76) and report higher family income (t = 40.05, p <.001; d = .74) than parents without a STEM degree/occupation. Relatedly, parents with STEM degree/occupation on average provided more general educational (i.e., non-STEM-specific) support than parents without STEM degree/occupation (χ^2 =131.20, 37.69; p <.001; d = .21, .11 respectively for providing financial support for college and communication with school about adolescents' college plan). Adolescents whose parents had a STEM degree/occupation were much more likely to have higher math achievement in 9th grade (t = 29.89, p <.001; d = .55), take an advanced math class in 8th grade (χ^2 = 378.05, p <.001; d = .33), and attend private schools (χ^2 = 154.27, p <.001; d

= .87) compared with adolescents whose parents did not have a STEM degree/occupation. Adolescents whose parents had a STEM degree/occupation did not differ on gender from those whose parents did not have a STEM degree/occupation (χ^2 = .80, *p* >.05; *d* = .02).

The results so far demonstrate the numerous differences between families with and without a parent STEM degree/occupation, many of which were significantly different at baseline (i.e., 9th grade). These findings support my reasoning to examine these family environments separately instead of in the same model. Thus, I examined the associations between parent STEM support and adolescent STEM motivational beliefs separately for those two groups in the next section.

Associations between Parent STEM Support and Adolescent STEM Motivational Beliefs

Among adolescents whose parents did not have a STEM degree/occupation, parents' 9th grade STEM support positively predicted all four of their STEM motivational beliefs in 11th grade. These relations emerged even after controlling for parents' general educational support, adolescent's prior math achievement, and other demographic indicators (Table 6). Specifically, one additional parent STEM support item corresponded to .03 (on a 4-point scale) higher in adolescents' later STEM expectancy belief, .05 higher in STEM interest, .04 higher in STEM utility value, and .03 higher in adolescents' STEM attainment value. Among adolescents whose parents had a STEM degree/occupation, however, parents' 9th grade STEM support was not statistically predictive of any of their 11th grade STEM motivational beliefs (B = .00-.03). See Figure 1 for visual presentations).

Table 6.
Parents' STEM support predicting adolescent's STEM motivational beliefs, separately for parents without and with STEM degrees/occupations

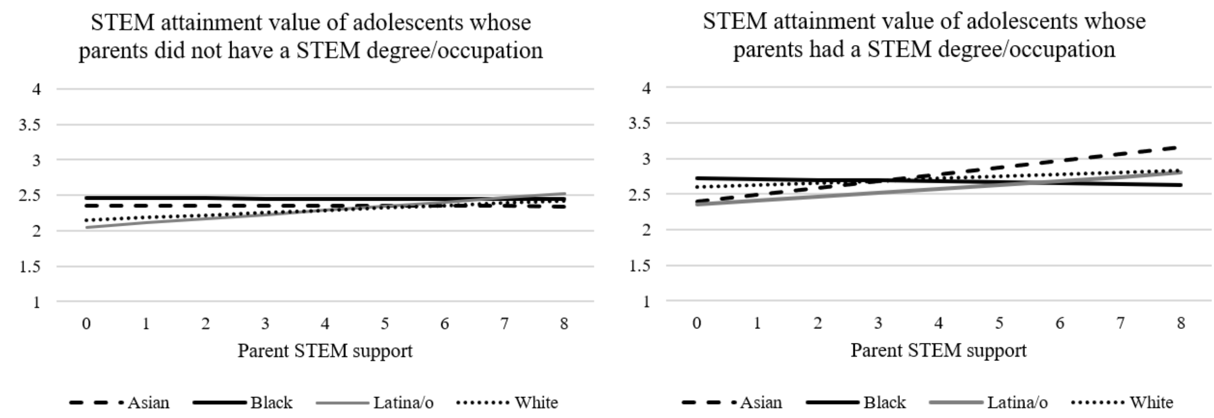
	Parents who did not have a STEM degree/occupation (*n* = 9,830)				Parents who had a STEM degree/occupation (*n* = 4,160)			
	11th grade STEM motivational beliefs							
	Expectancy belief	Interest	Utility value	Attainment value	Expectancy belief	Interest	Utility value	Attainment value
Main predictors								
Grade 9 parent STEM support	.03** (.01)	.05*** (.01)	.04*** (.01)	.03** (.01)	.01 (.01)	.00 (.02)	.02 (.01)	.03 (.02)
Asian	-.06 (.14)	-.04 (.20)	-.01 (.17)	.21 (.15)	-.30 (.23)	-.21 (.24)	.11 (.16)	-.20 (.31)
Black	.48*** (.08)	.32* (.13)	.29** (.09)	.31** (.10)	.22 (.18)	.24 (.16)	.20 (.18)	.13 (.23)
Latina/o	-.06 (.08)	.07 (.08)	-.04 (.07)	-.10 (.09)	.15 (.24)	.21 (.15)	-.14 (.17)	-.24 (.20)
Asian X parent STEM support	.03 (.04)	.04 (.06)	.02 (.05)	-.04 (.04)	.08 (.06)	.06 (.07)	.01 (.04)	.07 (.08)
Black X parent STEM support	-.05* (.02)	-.04 (.03)	-.02 (.02)	-.04 (.02)	-.05 (.05)	-.06 (.04)	-.03 (.03)	-.04 (.05)
Latina/o X parent STEM support	.02 (.02)	-.00 (.02)	.02 (.02)	.02 (.02)	-.06 (.06)	-.06 (.03)	.03 (.04)	.02 (.04)
Covariates								
9th grade parent financial support for college	-.06 (.03)	-.03 (.04)	-.03 (.03)	-.01 (.04)	-.15* (.06)	-.03 (.07)	.03 (.07)	-.23** (.07)
9th grade parent communication with school about college	.03 (.03)	-.02 (.03)	-.01 (.03)	.06* (.03)	.02 (.04)	.04 (.04)	.05 (.03)	.05 (.05)
Parent has a Bachelor's degree	-.09** (.03)	-.10 (.04)	-.05 (.03)	-.07* (.03)	.01 (.05)	-.09 (.05)	-.03 (.05)	.07 (.06)
9th grade math achievement (centered)	.01*** (.00)	.01*** (.00)	.01*** (.00)	.02*** (.00)	.01*** (.00)	.01*** (.00)	.01*** (.00)	.02*** (.00)
8th grade math class is advanced	.07* (.03)	.03 (.03)	-.00 (.03)	.15*** (.04)	.09* (.04)	.08 (.05)	.05 (.04)	.15** (.06)
Female	-.17*** (.03)	-.02 (.03)	-.01 (.02)	-.17*** (.03)	-.20*** (.04)	.04 (.04)	-.02 (.03)	-.10* (.04)
Family income (centered)	.01 (.01)	-.00 (.01)	-.01 (.01)	-.01 (.01)	.01 (.01)	.01 (.01)	-.00 (.01)	.01 (.01)
School type: private	.07 (.04)	.05 (.04)	.02 (.03)	-.02 (.05)	.01 (.05)	-.02 (.05)	-.03 (.04)	-.05 (.05)
Constant	2.74*** (.05)	2.60*** (.05)	3.03*** (.05)	2.32*** (.05)	3.00*** (.09)	2.79*** (.08)	3.11*** (.10)	2.60*** (.10)

Notes. Outcomes were adolescents' STEM motivational beliefs. Coefficients were unstandardized; cluster-adjusted standard error in parenthesis. Weight, primary sampling unit, and strata incorporated. Reference for race/ethnicity is White.
* p < .05 ** p < .01 *** p < .001
SOURCE: U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, High School Longitudinal Study of 2009 (HSLS:09), Base Year and First Follow-Up.

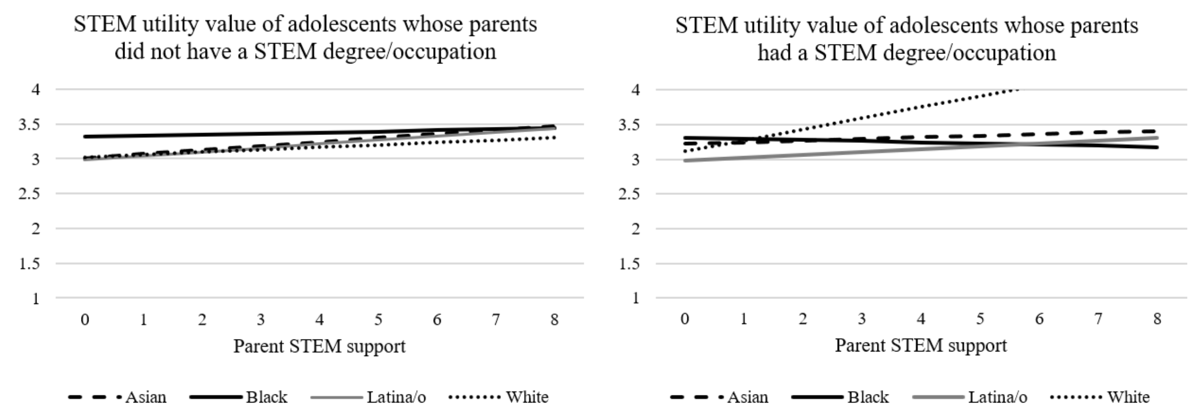
Figure 4.

Separately for parents with and without STEM degrees/occupations, parents' STEM support predicting adolescent's STEM (a) attainment value, (b) utility value, (c) interest, and (d) ability self-concept

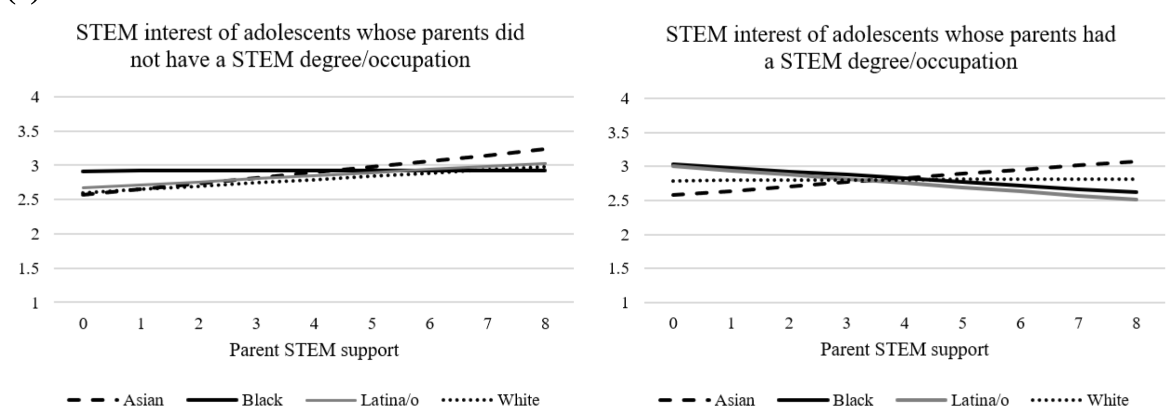
(a) STEM attainment value



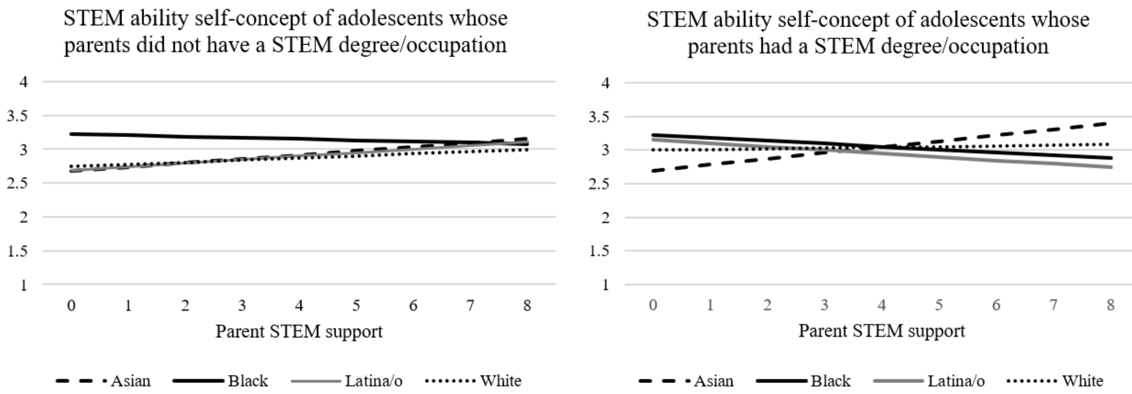
(b) STEM utility value



(c) STEM interest



(d) STEM ability self-concept



Associations between Parent STEM Support and Adolescent STEM Motivational Beliefs Across Racial/Ethnic Groups.

As shown in Table 6, the interactions between parents' STEM support and race/ethnicity were not significantly associated with adolescents' STEM motivational beliefs. For adolescents whose parents did not have a STEM degree/occupation, parent STEM support was positively associated with adolescents' STEM motivational beliefs, and I showed that these positive associations apply for White, Black, Latina/o, and Asian adolescents similarly. For adolescents whose parents held a STEM degree/occupation, parent STEM support was not significantly associated with adolescents' STEM motivational beliefs which was the case for all four racial/ethnic groups that I examined. Taken together, I did not find the *process*, or in other words the *association* between parent STEM support and adolescents' STEM motivational to differ based on race/ethnicity.

Discussion

The U.S. struggles with unequal racial/ethnic representation in STEM, which is even more worrisome as STEM becomes increasingly central to our daily lives and advancements in the economy (Feinstein, 2011; National Science Foundation, 2019; Xue & Larson, 2015). For my first research goals, I examined how the unequal racial/ethnic representation manifested as racial/ethnic disparities in parents' STEM degrees/occupations, which relates to differences in the level of parent STEM support and their adolescents' STEM motivational beliefs. My results align with the persistent, unequal racial/ethnic representation among who obtain STEM degrees and are employed in the STEM fields (NSF, 2019), with disproportionally more Asian and White adolescents, but disproportionally fewer Latina/o and Black adolescents with a parent STEM degree/occupation. Such disproportionate representation seems more pronounced for Asian and Latina/o adolescents. Next, I showed that parents who had a STEM degree/occupation provided more STEM support compared to parents without a STEM degree/occupation, which aligns with the literature on STEM capital (DeWitt et al., 2016). STEM capital (labeled 'science capital' in the original authors' wording) pertains to individuals' knowledge, attitudes, experiences, and social connections to access assets that facilitate their advancements in STEM (DeWitt, Archer, & Mau, 2016; Saw, 2020). Although parent STEM degree and occupation only represent two potential constituents of STEM capital, my findings support the notion that parents with more STEM capital provide more STEM support (DeWitt et al., 2016; Plasman et al., 2020). Lastly, my results further suggested that families with and without a parent STEM degree/occupation differed on their *next generation's* STEM indicators, namely their adolescents' STEM motivational beliefs. This intergenerational link aligns with the situated expectancy-value theory (Eccles, 2011) and supports that some variation in adolescents' STEM motivational beliefs could be accounted for by their parents' STEM educational and occupation experiences.

My second research goal was to examine the associations between parent STEM support and adolescents' STEM motivational beliefs for those whose parents had a STEM degree/occupation and separately those whose parents did not have a STEM degree/occupation. The prior literature on parent support has often controlled for parent education or occupation but not considered if parent support predicted adolescents' motivation for parents with a STEM degree/occupation and those without a STEM degree/occupation. I found that although the association between parent STEM support and adolescent STEM motivational beliefs was not significant for those whose parents had a STEM degree/occupation, parent STEM support positively predicted adolescents' STEM motivational beliefs for those whose without parent STEM degree/occupation even after controlling for a robust list of covariates such as the adolescents' prior math achievement. This could be an encouraging takeaway that align with studies showing how parent support among families marginalized in STEM matters (McGee & Spencer, 2015; Plunkett & Bámaca-Gómez, 2003; Soto-Lara & Simpkins, 2020). Furthermore, this finding could have implications for where to most effectively allocate interventions (e.g., Rozek et al., 2015). Earlier in my first research goal, we showed that adolescents whose parents did not have a STEM degree/occupation on average reported lower STEM motivational beliefs than their peers whose parents held a STEM degree/occupation. Here, we showed that parent STEM support matters and seemed to yield a greater return in terms of adolescents' STEM motivational beliefs for those without a parent STEM degree/occupation.

Lastly, I found that the associations between parents' STEM support and adolescents' STEM motivational beliefs, namely the positive associations among those whose parents did not have a STEM degree/occupation and null associations among those whose parents had a STEM degree/occupation, were similar across racial/ethnic groups. Taken together, my findings suggest that although Latina/o and Black adolescents on average reported lower STEM degree/occupation, support, and motivational beliefs than Asian and White adolescents, Latina/o and Black adolescents would equally experience an increase in adolescent STEM motivational beliefs if I increased parents' STEM support for those without a STEM degree/occupation. That is, I pointed out the existing racial/ethnic disparities in STEM and suggested that interventions promoting parent STEM support might help level the playing field for the next generation. This implication aligns with Harachiewicz and colleagues' (2016) experimental study where intervention that promotes college students' STEM value beliefs was most effective among those who are underrepresented in the fields.

Limitations and Future Directions

This study contributes to the body of literature on the importance of parents, a major social agent that children interact with in their everyday lives, play in shaping their adolescents' STEM motivational beliefs (e.g., Crowley et al., 2001; Harachiewicz et al., 2012; Simpkins, Fredericks, & Eccles, 2015). I focused on the affordances of parents, but other social agents such as teachers, mentors, and peers also provide STEM support to adolescents (Stanton-Salazar, 2011). In fact, parent STEM support might complement support from other sources (Simpkins et al., 2019). On the one hand, parents who had a STEM degree/occupation might have easier and greater access to other social agents who like them have a STEM degree/occupation than parents without a STEM degree/occupation; for examples enrolling their children into classes with more experienced STEM teachers (Eccles, 2005). In this case, the differences in adolescents' STEM motivational beliefs between those with versus without a parent STEM degree/occupation might be even more pronounced when considering STEM support from multiple sources. On the other hand, the gaps between adolescents whose parents had and whose parents did not have a STEM degree/occupation might be reduced once other social agents get involved. Thus, the absence of parent STEM degree/occupation might be remedied if adolescents acquire STEM related support and resources from other social agents. To disentangle this complexity and examine adolescents' exposure to STEM more holistically, future studies could examine how STEM degree/occupation and support from non-parent social agents are associated with adolescents' STEM motivational beliefs.

For the current study I focused on adolescence, which is a critical time for parent STEM support because adolescents' STEM motivational beliefs typically decline during this development stage (e.g., Alfaro & Umaña-Taylor, 2015; Jacobs et al., 2002), but parental influences on STEM are also evident earlier in development (e.g., Crowley et al., 2001; Simpkins, Fredericks, & Eccles, 2015). Hence, an important future direction is to examine the relations between parent STEM support, degree/occupation, and children's STEM motivational beliefs in other development stages. For example, parents' STEM support from those with a STEM degree/occupation might positively predict their children's STEM motivational beliefs earlier in development (e.g., Hyde et al., 2006).

Conclusion

My study effectively demonstrated how parents' STEM degree/occupation and STEM support play a role in the intergenerational transmission of STEM racial/ethnic disparities. I showed that although adolescents whose parents did not have a STEM degree/occupation reported lower STEM support and motivational beliefs than those whose parents held a STEM degree/occupation, parents' STEM support positively predicted adolescents' STEM motivational beliefs for those whose parents did not have a STEM degree/occupation, but not those whose parents had a STEM degree/occupation. I also showed that although there are differences in the racial/ethnic representation of families with versus without a parent STEM degree/occupation, the *process,* or associations, between parent STEM support and adolescent STEM motivational beliefs did not differ by race/ethnicity.

CHAPTER 4

Neighborhood and School STEM Indicators as Correlates of Adolescents' STEM Motivational Beliefs and GPAs

Abstract

Guided by the institutional resource theory, the current study aimed to examine how adolescents' STEM motivational beliefs and GPAs were associated with STEM indicators from two related contexts, neighborhoods and schools. Using the High School Longitudinal Study (N = 14,265; 50% female; *M*age = 14 at Grade 9) in combination with the Occupational Employment Statistics data, I analyzed how the neighborhood STEM jobs and school STEM indicators were associated with Asian, Black, Latina/o, and White adolescents' STEM motivational beliefs and GPAs. Results showed that Asian adolescents reported higher STEM motivational beliefs than Black and White adolescents, who largely reported higher STEM motivational beliefs than Latina/o adolescents. There were also racial/ethnic differences in two of the three school STEM indicators, such that Black adolescents attended schools that offered fewer types of AP STEM course and had math/science teachers with fewer years of experience than the other racial/ethnic groups. In contrast, there were no racial/ethnic differences in the neighborhood STEM jobs or the number of school STEM enrichment programs. Results also suggested that neighborhood STEM jobs and school STEM indicators largely did not directly predict adolescents' STEM motivational beliefs and GPAs. Furthermore, the indirect effects of neighborhood STEM jobs through school STEM indicators on adolescents' STEM motivational beliefs and GPAs were largely insignificant. Potential explanations for the null associations and future directions (e.g., need to examine finer unit of neighborhood) are discussed.

Keywords: neighborhood, school, STEM motivational beliefs, STEM GPAs, race/ethnicity

Neighborhood and school STEM indicators as correlates of adolescents' STEM motivational beliefs and GPAs

According to bioecological perspectives and institutional resource theory, neighborhoods and schools influence students' educational outcomes (Arum, 2000; Bronfenbrenner & Morris, 2006; Leventhal & Brooks-Gunn, 2000). Prior studies, however, have not tested such associations specificity within STEM (science, technology, engineering, mathematics). It is important to test how neighborhood and school STEM indicators predict adolescents' STEM motivational beliefs and performance because STEM is critical to individuals' daily lives, social mobility, and economic well-being; however, the U.S. continues to struggle with recruiting and retaining diverse talents into the STEM (Bøe et al., 2011; Feinstein, 2011; Soergel, 2015; Weiner, 2018; Xue & Larson, 2015). A range of structural issues, including the uneven distribution of resources, has led to stark racial/ethnic disparities in students' STEM outcomes (McGee, 2020; Nasir & Vakil, 2017; Walls, 2016). To address these concerns, the current study first examined how STEM indicators at the neighborhood, school, and individual levels differed by adolescents' race/ethnicity. Then within each racial/ethnic group, I examined how STEM indicators at the neighborhood and school levels predicted adolescents' STEM motivational beliefs and GPAs.

Theoretical Perspectives

According to the situated expectancy value theory, two important STEM indicators in high school are adolescents' motivational beliefs and GPAs, which are positively associated with later STEM choices and performance (Bøe et al., 2011; Eccles & Wigfield, 2020; Else-Quest, Mineo, & Higgins, 2013). STEM motivational beliefs as described in the situated expectancy-value theory (Eccles & Wigfield, 2020) include three promotive STEM value beliefs— STEM interest (how enjoyable do you find STEM to be), STEM utility value (how useful do you find STEM to be), and STEM attainment value (how important is STEM to who you are). Another STEM motivational belief according to the situated expectancy-value theory is STEM expectancies, which pertains to how good you think you are in STEM. The situated aspect of the situated expectancy-value theory further stated that adolescents' STEM performance and motivational beliefs are shaped by the contexts they are situated in.

According to the institutional resource theory, two major contexts that shape educational outcomes are neighborhoods and schools (Leventhal & Brooks-Gunn, 2000). Specifically, neighborhoods and schools are both critical contexts that directly shape adolescents' educational outcomes. Moreover, neighborhood characteristics are theorized to influence the accessibility, affordability, and quality of schools and other learning environments (Leventhal & Brooks-Gunn, 2000). In other words, schools are theorized as a primary institutional mechanism through which neighborhoods affect adolescents' educational outcomes (Rendón, 2014).

Prior research has demonstrated that neighborhood and school indicators are uniquely related to adolescents' STEM outcomes. For example, a study that merged the National Educational Longitudinal Study (NELS) with census data showed that although 19% of the variance in eighth graders' math achievement scores were explained by school indicators, neighborhood indicators explained an additional 6% of the variance (Catsambis & Beveridge, 2001). Although some prior studies suggest that the effects of neighborhoods are partially explained by school indicators (Johnson Jr, 2012), others show only direct effects. For example, an analysis of the National Educational Longitudinal Study showed that neighborhood disadvantage had both direct effects on eighth grade students' math achievement and indirect effects via schools (Catsambis & Beveridge, 2001). However, an analysis of the Panel Study of Income Dynamics dataset suggested that although the direct and total neighborhood effects of neighborhood affluence on adolescents' math performance were significant, the indirect effects through school advantage were not statistically significant (Wodtke & Parbst, 2017). To help address these inconsistent findings, the current study aimed to examine the direct effects of neighborhood and school STEM indicators, as well as the indirect effects of neighborhood STEM jobs through school STEM indicators, on adolescents' STEM motivational beliefs and GPAs.

Neighborhood STEM Jobs as a Critical Indicator

Neighborhood effects are theorized to be more influential during adolescence compared to childhood as adolescents typically spend less time with families and more time in neighborhoods (Bronfenbrenner & Morris, 2006; Urban et al., 2009). General neighborhood characteristics, such as income level and proportion of adults with higher education degrees, are significantly associated with students' math outcomes (Ainsworth, 2002; Catsambis & Beveridge, 2001; Dupéré et al., 2010; Pearman, 2019; Wodtke & Parbst, 2017). No study to my knowledge, however, has examined neighborhood effects on adolescents' STEM outcomes using STEM-specific neighborhood indicators.

Neighborhoods differ in the level of STEM prevalence and resources (e.g., Bustamante et al., 2018; Hassinger-Das et al., 2020). Among the various neighborhood STEM indicators, neighborhood variation in the proportion of jobs related to STEM is critical (Xue & Larson, 2015). Recent statistics show that the proportion of jobs that are related to STEM ranges from 1% in rural Great Plains regions to more than 15% in metropolitan areas with technology centers and research parks (Fayer et al., 2017; Watson, 2014). Such variation in how relatively salient

STEM jobs are compared to non-STEM jobs might have impact individual adolescents' STEM motivational beliefs through modelling effects and transmission of normative (STEM) cultural orientations (Ceballo, McLoyd, & Toyokawa, 2004). For example, growing up in the San Jose area of California, which has a concentration of STEM occupations three-times that of the rest of the U.S. combined likely creates a different environment compared with growing up in neighborhoods where STEM jobs are not major part of in the local workforce. In sum, the proportion of neighborhood STEM employment was expected to positively relate to adolescents' STEM motivational beliefs and GPAs.

Critical School STEM Indicators

According to institutional resource theory, schools are a central context for youth development and one mechanism by which neighborhoods influence development (Leventhal & Brooks-Gunn, 2000). Among the various school-level STEM indicators, the current study examined three indicators that have been previously shown as critical school quality measures: AP (advanced placement) STEM course offerings, number of STEM enrichment programs, and math/science teachers' experience (e.g., Darling-Hammond, 2000; Horn, 2008; Kini & Podolsky, 2016; Sahin, 2013).

Though people intuitively expect that AP STEM courses will raise students' STEM knowledge and interest, as well as give students a head start in college STEM coursework, more empirical evidence is needed (Robinson, 2003; Sadler, 2010; Simzar, Domina, & Tran, 2016). Prior studies show that taking more AP STEM courses positively predicts higher performance and interest in pursuing STEM, though some of the findings are mixed (Burkholder & Wieman, 2019; Kaleva et al., 2019; Miller & Kimmel, 2012; Sadler, Sonnert, Hazari & Tai, 2014). However, to reap the potential benefits of AP STEM courses, adolescents first need to be embedded in a school with such opportunities (Jackson, 2010). American high schools vary substantially in their offerings of advanced math and science courses (Adelman, 2006; Cogan et al., 2001; Duncombe, 2017). For example, a recent analysis of the U.S. Department of Education's Civil Rights Data Collection showed that 55% high schools do not offer AP courses in math or science, limiting millions of high school students' STEM opportunities (ExcelinEd Civil Rights Data Collection Analysis, 2018). Such variation in AP math and science course offerings might have systemic implications for students' STEM outcomes (Horn, 2008); thus, I examined AP STEM course offerings as one of the school STEM indicators.

Another school STEM indicator that also pertains to students' access to STEM opportunities at school is the offerings of STEM enrichment programs, including STEM after-school activities and inter-school competitions/fairs. Participation in STEM after-school programs is positively associated with individuals' STEM aspirations and achievement (Allen et al., 2019; Assouline et al., 2017; Dabney et al., 2012; Krishnamurthi, Ballard, & Noam, 2014). For example, science after-school opportunities such as Science Olympiad can promote adolescents' STEM career aspirations by serving as an inspiring and low-stakes STEM space (Smith, Jaeger, & Thomas, 2019). Notably, a study of a charter school network showed that schools invested in STEM clubs and science fair competitions outperformed the national average in terms of matriculation (Sahin, 2013). As such, I examined the number of STEM enrichment programs as a second school STEM indicator.

The last school STEM indicator was math and science teachers' experience. Prior studies suggest that years of teachers' experience is positively, and often curvilinearly, associated with students' achievement in math and science (Darling-Hammond, 2000; Kini & Podolsky, 2016; Lee & Mamerow, 2019). Specifically, increases in teaching experience was associated with increases in students' achievement in math and science, but the magnitude of the return for every additional year of teaching experience tends to decrease over time (Toropova et al., 2019). Studies differ on when the association tends to plateau, with results ranging from 5 to 20 years of experience (Darling-Hammond, 2000; Kini & Podolsky, 2016; Toropova et al., 2019). In addition, some prior studies found that math/science teachers' experience was not significantly associated with students' math/science outcomes (Buddin & Zamarro, 2009; Friedrichsen et al., 2009; Liu et al., 2010; National Research Council, 2000; Rockoff, 2004). Taken together, I examined how math/science teachers' experience, with it modeled curvilinearly (and alternatively dichotomized at 5 years), was associated with adolescents' STEM motivational beliefs and GPAs.

Racial/Ethnic Disparities in Neighborhood, School, and Adolescent STEM Indicators

The STEM indicators at the neighborhood, school, and adolescent levels that have been discussed are all related to race/ethnicity. Residential neighborhoods and schools remain to a great extent racially/ethnically segregated in the U.S., with Black and Latina/o individuals disproportionally residing in lower-income neighborhoods and attending lower-quality schools (Pong & Hao, 2007). Because STEM jobs are correlated with higher incomes (Fayer et al., 2017), we expect Black and Latina/o adolescents' neighborhoods to have disproportionally fewer STEM jobs than Asian and White adolescents' neighborhoods. The school STEM indicators examined in the current study are also confounded with race/ethnicity (Betts, Rueben, & Danenberg, 2000). For example, data from the National Education Longitudinal Study showed that 61% of Asian adolescents' and 59% of White adolescents' high schools offered calculus in 12^{th} grade, whereas 51% of Black adolescents' and 45% of Latina/o adolescents' high school offered such advanced math courses (Adelman, 2006). Racial/ethnic minority students are also more likely to be taught by novice teachers (Clotfelter et al., 2007; Darling-Hammond, 2000). In sum, we expect racial/ethnic differences in neighborhood and school STEM indicators where Black and Latina/o adolescents on average live in neighborhoods with fewer STEM jobs and attended schools that had fewer AP STEM courses, fewer STEM enrichment programs, and math/science teachers with less teaching experience than their White and Asian peers.

At the adolescent level, the current study examined adolescents' STEM motivational beliefs (i.e., interest, utility value, attainment value, and expectancies) and GPAs as outcomes. Prior studies suggest that there tend to be racial/ethnic differences in adolescents' STEM motivational beliefs such that White and Asian individuals reported stronger STEM motivational beliefs than Black and Latina/o individuals (Andersen & Ward, 2014; Bouchey & Harter, 2005; Brown & Leaper, 2010; Seo et al., 2019; Shanahan, 2009; Nasir & Cobb, 2002; Wenner, 2003). Racial/ethnic disparities are also observed in terms of math and science performance in high school such that more than one in three White and Asian adolescents reached proficiency levels in math and science whereas only around one in ten Black and Latina/o adolescents reached proficiency levels (U.S. Department of Education, 2015, 2019).

In addition to examining racial/ethnic differences in the mean levels of neighborhood, school, and individual adolescents' STEM indicators, a related but distinct question is to ask whether the relations between those STEM indicators emerge in each racial/ethnic group. Whereas the above reviewed racial/ethnic disparities pertain to inequities between race/ethnicity, examining processes for each racial/ethnic group will shed light on how adolescents of the same race/ethnic varied depending on their neighborhood and school STEM resources. For example, underrepresented racial minority adolescents, as reviewed above, are expected to attend high schools with disproportionally fewer STEM opportunities. Nonetheless, Means and colleagues

(2021) showed that underrepresented racial minority adolescents' STEM motivational beliefs and science performance benefited from attending high school that offered more STEM opportunities. Jointly, between-race/ethnicity differences and within-race/ethnicity variations provide a more nuanced understanding to where racial/ethnic inequities were present.

Current Study

The current study examined STEM indicators at the neighborhood, school, and adolescent levels. I first examined how those indicators differed by race/ethnicity, then I examined how neighborhood STEM jobs and school STEM indicators predicted Asian, Black, Latina/o, and White adolescents' STEM motivational beliefs and GPAs. Lastly, I examined to what extent there were indirect effects of neighborhood STEM jobs through school STEM indicators on adolescents' STEM motivational beliefs and GPAs. The specific hypotheses were:

Hypothesis 1: White and Asian adolescents were expected to (a) live in neighborhoods with disproportionally more STEM jobs, (b) attend schools with more AP STEM courses, enrichment programs, and math/science teacher experience, and (c) report higher STEM motivational beliefs and GPAs than Black and Latina/o adolescents.

Hypothesis 2: Neighborhood STEM jobs, as well as school AP STEM course offerings, STEM enrichment program offerings, and math/science teacher experience were expected to positively predict adolescents' STEM motivational beliefs and GPAs.

Hypothesis 3: School STEM indicators were expected to partially explain the associations between neighborhood STEM jobs and adolescents' STEM motivational beliefs and GPAs.

Method

Participants

Adolescents in the current study participated in the High School Longitudinal Study (HSLS) collected by the National Center for Educational Statistics (see Ingels et al., 2014 for more detail about the dataset). The use of HSLS data for the current study was approved by the Institutional Review Board at [blinded university] (IRB protocol number: HS#:2018-4349). HSLS is a fitting dataset because it includes measures about math and science at the individual, teacher, and school levels, as well as can be linked to neighborhood level data. Participants by design were nested within schools; on average, 28 adolescents (range 20-38) from each school were sampled with representativeness in terms of race and ethnicity.

I excluded participants for a few reasons. First, I excluded participants who missed the entire 9th or 11th grade data collection (n = 4,649; 18% of the full HSLS sample). Second, I excluded participants who were home-schooled, dropped out of high school, attended a foreign school, or whose school did not have a NCES school identification number (n = 397; 2%). Third, I excluded participants whose racial/ethnic group was too small (e.g., Native American), heterogeneous (e.g., multiracial), or missing (n = 1,846; 7%). Lastly, I excluded, participants whose school could not be matched with data on neighborhood STEM jobs[3] (n = 4,049; 16%), yielding an analytic sample of 14,265 adolescents. As shown in Appendix 6, the analytic sample was higher on all (nine) variables except STEM utility value than the excluded sample; all of those differences had effect sizes that were small or less than the small criterion.

Measures

The primary predictors of the current study were neighborhood STEM jobs, school AP STEM course offerings, number of STEM enrichment programs, and math/science teachers'

[3] Some schools cannot be matched with data on neighborhood jobs because they did not belong to any core-based statistical area, or their NCES school identification number did not appear in the 2011-12 school year Common Core of Data or the Private School Universe Survey.

experience measured when adolescents were in their 9th or 11th grade. The outcomes were adolescents' STEM motivational beliefs and GPAs when they were in 11th grade. Adolescents' 9th grade math achievement was also included as a covariate.

Neighborhood STEM jobs. Neighborhood STEM jobs was calculated for each core-based statistical area (CBSA), which is a unit that has been used by Bureau of Labor Statistics reports to characterize neighborhoods (e.g., Cover et al., 2011; Watson, 2014). A CBSA is an area (with a population between 10,000 and 50,000 people) consisting of one or more counties that are socioeconomically tied to the urban center by commuting. CBSA is commonly used to analyze labor markets, for example to calculate the local area per capita income or unemployment rates (Bureau of Economic Analysis, 2020). Some examples of CBSA include Los Angeles-Long Beach-Anaheim (CA), Durham-Chapel Hill (NC), Lansing-East Lansing (MI), Madison (WI), and San Jose-Sunnyvale-Santa Clara (CA).

The Occupational Employment Statistics data from 2011, which was the year adolescents in HSLS were in 11th grade, included the number of jobs for each occupational category per 1,000 jobs in each CBSA (Bureau of Labor Statistics, nd). Neighborhood STEM jobs were derived by summing the number of jobs (per 1,000 in the CBSA) that belong to the STEM categories, which according to the U.S. Census Bureau guidelines included the computer and mathematical; architecture and engineering; life, physical, and social sciences; and healthcare practitioners and technical[4] groups (Fayer et al., 2017; Landivar, 2013). Lastly, I divided the measure by 10 to ease interpretation. Thus, neighborhood STEM jobs were defined as the number of STEM related jobs per every 100 job in the CBSA. Neighborhood STEM jobs were merged into HSLS via each participants' school district codes. Which CBSA each school district

[4] Healthcare practitioners and technical jobs are designated as 'STEM-related' (instead of STEM) by the Census Bureau. Thus, the number of jobs in this group were divided by two when summed up to calculate the total number of STEM jobs.

belonged to is documented in the Common Core of Data for public schools and Private School Universe Survey for private schools, both datasets (for year 2011-12) were downloaded from the National Center for Education Statistics. See Appendix 7 for example CBSAs that correspond to different quantiles of neighborhood STEM jobs.

School STEM indicators. The current study included three school STEM indicators that prior studies suggest should be associated with adolescents' STEM outcomes (Adelman, 2006; Darling-Hammond, 2000; Horn, 2008; Kini & Podolsky, 2016; Lee & Mamerow, 2019; Sahin, 2013): AP STEM course offerings, the number of STEM enrichment programs, and math/science teachers' experience. Firstly, AP STEM course offerings were reported when adolescents were in 11^{th} grade by their school counselors regarding whether school offered at least one AP mathematics, AP science, and AP computer science course respectively (0 = *no*, 1 = *yes*). Reports on the three courses were summed to create the breadth of AP STEM course offerings, ranging from 0 to 3.

Secondly, the number of STEM enrichment programs was reported by the school administrators when adolescents were in 9^{th} grade in response to whether the school hosted the following eight opportunities (0 = *no*, 1 = *yes*): (a) a math or science after-school program, (b) math or science fairs/workshops/competitions, (c) partnerships with a college/university that offers a math/science summer program, (d) pairs students with mentors in math or science, (e) brings in guest speakers to talk about math or science, (f) math- or science-relevant field trips, (g) tells students about math/science contests/websites/blogs/other programs, and (h) partners with MESA (Mathematics, Engineering, Science, Achievement advising and academic assistance program) or a similar enrichment-model program. The responses were summed; thus, the number of STEM enrichment programs ranged from 0 to 8.

Lastly, adolescents' 9th grade math and science teachers reported the number of years they have taught high school math/science (e.g., Toropova et al., 2019). The years of teaching experience were averaged between adolescents' math and science teachers, and a squared term was also generated to allow math/science teachers' years of experience to be exponentially related to adolescents' STEM outcomes, which researchers have found in prior studies (Kini & Podolsky, 2016; Lee & Mamerow, 2019). For robustness check purposes, math/science teachers' experience was also dichotomized into under 5 years or not, which aligns with the cutoff for novice teachers used in prior studies (e.g., Kim & Roth, 2011).

Adolescents' STEM motivational beliefs and performance. The outcomes examined in the current study were adolescent STEM motivational beliefs and GPAs. The measures of STEM motivational beliefs were based on the situated expectancy-value theory and have been used in prior studies (e.g., Eccles & Wigfield, 2000; Simpkins, Price, & Garcia, 2015; Snodgrass Rangel et al., 2020); they included STEM interest (6 items; $\alpha = .74$; e.g., "enjoy math/science classes very much"), utility value (6 items; $\alpha = .82$; e.g., "math/science is useful for everyday life"), attainment value (4 items; $\alpha = .74$; e.g., "you see yourself as a math/science person"), and expectancies (8 items; $\alpha = .86$; e.g., "certain that you can master math/science skills"). All four STEM motivational beliefs were measured at 11th grade using a 4-point (1 = *strongly disagree,* 4 = *strongly agree*). The scale scores were then standardized to ease interpretation. The other STEM outcome, adolescents' STEM GPAs (range 0-4) was their cumulative GPA across all of their STEM courses during the four years of high school and collected from participants' transcripts by HSLS one-year after participants' expected time of high school graduation.

Covariate. The covariate for the current study was adolescents' math achievement in 9th grade, which was assessed using 40 computer-based, Item Response Theory questions encompassed six algebraic content domains and four algebraic processes[5]. The math achievement scores were standardized with mean of 50 and standard deviation of 10.

Race/ethnicity. Adolescents who reported their race/ethnicity as Asian, Black, Latina/o, or White were included in the current study.

Analysis Plan

Data cleaning, descriptive statistics and the ANOVAs to test Hypothesis 1 were conducted in Stata version 14 (StataCorp, 2015), whereas the path models to test Hypothesis 2 and 3 were conducted in Mplus version 7.4 (Muthén & Muthén, 2017). All the analyses were conducted with adjustments for the complex sampling design of HSLS incorporated (i.e., sampling weights, primary sampling unit, and strata). Missing data ranged from 1% for STEM interest to 17% for math/science teachers' experience. As shown in Appendix 8, participants with missing data differed from participants with complete data in terms of neighborhood STEM jobs, school STEM indicators, and the covariate math achievement (with small effect sizes), but did not significantly differ in terms of adolescents' STEM motivational beliefs and GPAs. Missing data were imputed using multiple imputation with 20 imputed datasets through predictive mean matching to ensure imputed values fall within reasonable range (Little, 1988; Morris, White, & Royston, 2014). A set of auxiliary variables were included to strengthen the imputation process (Enders, 2008): adolescents' 9th grade STEM motivational beliefs, whether schools met the Adequate Yearly Progress review, whether adolescents' math and science teacher held an alternative teaching credential, whether schools were public or private, school locale (city, suburb, small town, or rural), proportion of students in their school who were on

[5] Algebraic content domains: language of algebra; proportional relationships and change; linear equations, inequalities, and functions; nonlinear equations, inequalities, and functions; systems of equations; sequences and recursive relationships. Algebraic processes: demonstrating algebraic skills; using representations of algebraic ideas; performing algebraic reasoning; solving algebraic problems.

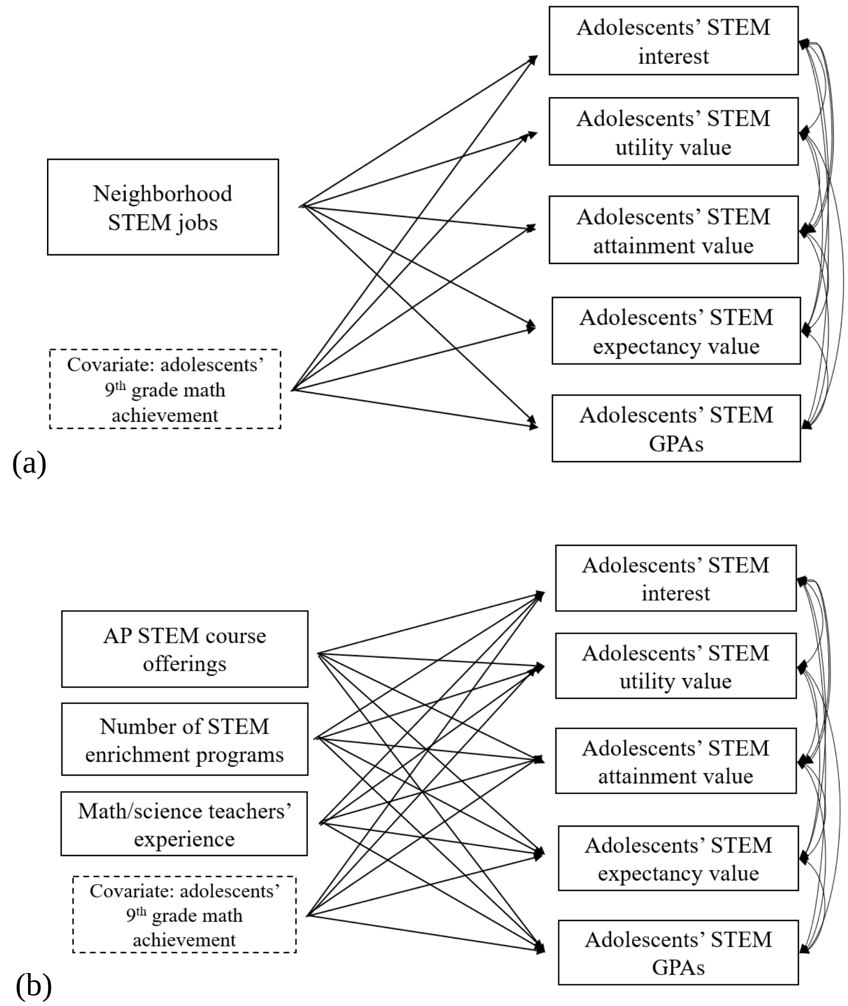
free/reduced lunch, proportion of students in their school who repeated 9th grade, and proportion of students in their school who were White.

For Hypothesis 1, White and Asian adolescents were expected to report higher neighborhood, school, and adolescent-level STEM indicators. Descriptive statistics were calculated for each racial/ethnic group, and ANOVA tests examined whether there were significant racial/ethnic differences on those indicators. Significant differences were followed up with Bonferroni-corrected pairwise post hoc comparison tests.

Path models were tested for Hypothesis 2, in which neighborhood STEM jobs and school STEM indicators were expected to have positive direct effects on adolescents' STEM motivational beliefs and GPAs (see Figure 5). All the variables were inputted as measured variables that were allowed to covary. The first model tested if neighborhood STEM jobs predicted adolescents' STEM motivational beliefs and GPAs (all outcomes in one model), controlling for adolescents' math achievement. The same model was then duplicated for each racial/ethnic group. Hence, five models (with the entire analytic sample, within Asian adolescents, within Black adolescents, within Latina/o adolescents, and within White adolescents) were tested. Then, the second set of models tested if school AP STEM course offerings, number of STEM enrichment programs, math/science teachers' experience, predicted adolescents' STEM motivational beliefs and GPAs, also controlling for adolescents' math achievement. Similarly, the model was estimated with all the adolescents in the analytic sample, as well as separately for each racial/ethnic group. In addition to the paths of interest, model fit indices were examined using the following conventions (Hu & Bentler, 1999): CFI (comparative fit index) ≥ 0.95, RMSEA (root mean squared error of approximation) ≤ 0.05, SRMR (standardized root mean square residual) ≤ 0.05.

Figure 5.

Adolescents' STEM motivational beliefs and GPAs predicted by (a) neighborhood STEM job, and (b) school STEM indicators

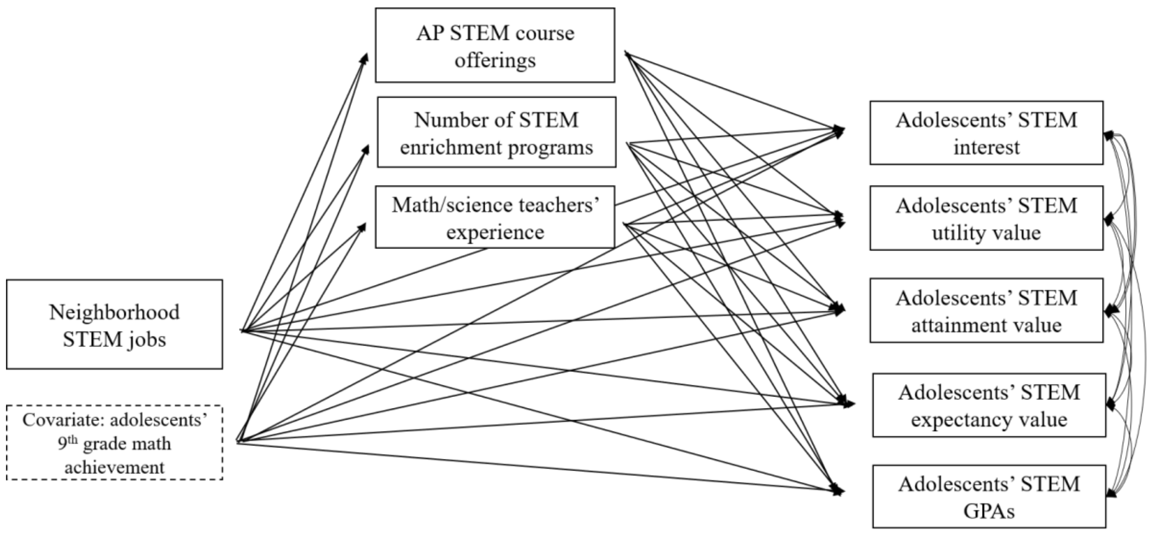


Note. Each model was tested five times: with the entire analytic sample, within Asian adolescents, within Black adolescents, within Latina/o adolescents, and within White adolescent. Hence, ten models in total were tested.

For Hypothesis 3, neighborhood STEM jobs were expected to have indirect effects on adolescents' STEM motivational beliefs and GPAs through the school STEM indicators. To test this hypothesis, the path models from Research Question 2 were combined such that neighborhood STEM jobs and adolescents' math achievement, through the three school STEM indicators, predicted adolescents' STEM motivational beliefs and GPAs (see Figure 6). Again, the model was conducted with all adolescents in the analytic sample, and separately for each racial/ethnic group. The estimates of interest were the indirect effects via school STEM indicators; model fit indices were examined using the same criteria as noted for Hypothesis 2 (Hu & Bentler, 199).

Figure 6.

Indirect effect of neighborhood STEM job, through school STEM indicators, on adolescents' STEM motivational beliefs and GPAs



Note. Each model was tested five times: with the entire analytic sample, within Asian adolescents, within Black adolescents, within Latina/o adolescents, and within White adolescent. Hence, ten models in total were tested.

Results

Descriptive Statistics by Race/ethnicity

The raw bivariate correlations and descriptive statistics of all variables for the full analytic sample were presented in Table 7.

Table 7.
Descriptive statistics and bivariate correlations

Variable	*Mean*	*SD*	*Min*	*Max*	*Skew*	1.	2.	3.	4.	5.	6.	7.	8.	9.
Neighborhood STEM indicator														
1. Neighborhood STEM jobs	8.26	2.37	2.99	19.68	1.74									
School STEM indicators														
2. AP STEM course offerings	1.67	1.00	0.00	3.00	-.54	.12***								
3. Number of STEM enrichment programs	4.00	1.89	1.00	8.00	0.04	.06***	.19***							
4. Math/science teacher experience	10.6	7.08	1.00	47.00	1.28	-.01	.07***	-.01						
Adolescent STEM outcomes														
5. Interest	2.75	0.59	1.00	4.00	-0.21	.01	.00	.02*	.03***					
6. Utility value	3.16	0.52	1.00	4.00	-0.35	.01	-.01	.01	.02**	.48***				
7. Attainment value	2.48	0.70	1.00	4.00	0.03	.04***	.04***	.04***	.07***	.50***	.51***			
8. Expectancies	2.81	0.58	1.00	4.00	-0.21	.03**	.01	.03**	.05***	.55***	.43***	.57***		
9. GPAs	2.52	0.87	0.00	4.00	-0.37	.03***	.16***	.03***	.14***	.23***	.20***	.38***	.28***	
Covariate														
10. Math achievement	52.3	9.75	24.07	82.19	-0.06	.09***	.21***	.09***	.16***	.18***	.18***	.40***	.26***	.61***

Note. SD = Standard deviation.
*$p < .05$. **$p < .01$. ***$p < .001$.
SOURCE: U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, High School Longitudinal Study of 2009 (HSLS:09), Base Year and First Follow-Up.

According to my first hypothesis, the neighborhood, school, and adolescent STEM indicators were expected to be higher for White and Asian adolescents than Black and Latina/o adolescents. I estimated ANOVAs to test such racial/ethnic differences (Table 8). Among the full analytic sample, neighborhood STEM jobs ranged from less than 3 to almost 20 STEM jobs per 100 jobs, with a mean of 8.26 STEM jobs per 100 jobs (Table 7). This variation in the average neighborhood STEM jobs, however, did not differ by race/ethnicity (Table 8). Asian, Black, Latina/o, and White adolescents lived in neighborhoods with average of10.34, 8.12, 8.53 and 8.40 STEM jobs for every 100 jobs respectively.

Table 8.
Weighted descriptive statistics by race/ethnicity

	Asian (n = 1,426)		Black (n = 1,715)		Latina/o (n = 2,576)		White (n = 8,344)				
	Mean	*(SE)*	*Mean*	*(SE)*	*Mean*	*(SE)*	*Mean*	*(SE)*	*F* statistic	*Eta-squared*	Significant post hoc comparisons[a]
Neighborhood STEM indicator											
Neighborhood STEM jobs	10.34	(0.91)	8.12	(0.20)	8.53	(0.26)	8.40	(0.13)	1.99	0.02	
School STEM indicators											
AP STEM course offerings	2.05	(0.12)	1.34	(0.09)	1.70	(0.05)	1.70	(0.04)	7.91***	0.06	A>L,W>B
Number of STEM enrichment programs	4.12	(0.16)	4.21	(0.18)	4.00	(0.16)	4.06	(0.09)	0.45	0.00	
Math/science teacher experience	10.73	(0.48)	8.98	(0.38)	9.08	(0.26)	10.56	(0.22)	10.72***	0.08	A,W>L,B
Adolescent STEM outcomes											
Interest	2.89	(0.04)	2.80	(0.03)	2.75	(0.03)	2.72	(0.01)	8.91***	0.06	A>L,W; B>W
Utility value	3.28	(0.03)	3.26	(0.02)	3.15	(0.02)	3.13	(0.01)	13.47***	0.09	A,B>L,W
Attainment value	2.71	(0.03)	2.42	(0.03)	2.35	(0.03)	2.49	(0.01)	30.45***	0.19	A>W,B,L; W>L
Expectancies	2.86	(0.03)	2.87	(0.03)	2.71	(0.02)	2.80	(0.01)	9.11***	0.06	B,A,W>L
GPA	2.89	(0.05)	2.02	(0.04)	2.10	(0.04)	2.63	(0.02)	127.84***	0.49	A>W>L,B
Covariate											
Math achievement	59.18	(0.60)	45.91	(0.54)	49.25	(0.36)	53.46	(23.00)	142.19***	0.52	A>W>L>B

Note. SE = standard error (with adjustment of complex sampling design: sampling weight, primary sampling unit, and strata). *F* statistics calculated from ANOVA. Conventions for Eta-squared effect size: 0.02 small, 0.13 medium, 0.26 large. [a]Pairwise post hoc comparisons were tested with Bonferroni correction: A = Asian, B = Black, L = Latina/o, W = White.
***p < .001.
SOURCE: U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, High School Longitudinal Study of 2009 (HSLS:09), Base Year and First Follow-Up.

Next, I examined racial/ethnic differences in the school STEM indicators (Table 8). Asian adolescents attended high schools that on average offered 2.05 out of the 3 kinds of Advanced Placement (AP) courses, which was higher compared Latina/o and White adolescents whose schools on average offered 1.7 types of STEM AP courses (B = .34, .35, $p < .05$), which was higher than 1.34 types of STEM AP courses that Black adolescents' high schools offered (B = .36, $p < .01$). There were no racial/ethnic differences in the number of STEM enrichment programs schools offered; on average, 4.00-4.21 enrichment programs were offered. Lastly, Asian and White adolescents' math/science teachers had more experience (10.73 and 10.56 years) than teachers of Latina/o and Black adolescents (9.08 and 8.98 years) (B = 1.47-1.74, $p < .05$).

Lastly regarding the first hypothesis, Table 8 also showed racial/ethnic differences in adolescent STEM indicators, namely adolescents' STEM motivational beliefs and GPAs. Asian adolescents on average reported higher STEM interest than their Latina/o and White peers (B = .14, .17, $p < .001$). Black adolescents also reported higher STEM interest than their White peers (B = .08, $p < .05$). Furthermore, Asian and Black adolescents reported higher STEM utility value than their Latina/o and White peers (B = .11-.15, $p < .01$). In terms of attainment value, Asian adolescents reported higher attainment value than the other three racial/ethnic groups (B = .22-.36, $p < .001$), among whom White adolescents reported higher STEM attainment value than their Latina/o peers (B = .14, $p < .001$). There are also racial/ethnic differences in STEM expectancies such that Latina/o adolescents reported lower STEM expectancies compared with adolescents of the other three racial/ethnic groups (B = .09-.15, $p < .01$). Lastly for STEM GPAs, Asian adolescents had higher STEM GPAs than their White peers (B = .26, $p < .001$), which were higher than their Latina/o and Black peers (B = .52, .62, $p < .001$).

Neighborhood and School STEM Indicators' Relations with Adolescents' STEM Motivational beliefs and GPAs

According to my second hypothesis, neighborhood STEM jobs and school STEM indicators were expected to positively predict adolescents' STEM motivational beliefs and GPAs. The path models testing this hypothesis were just identified, hence showing perfect model fit (Table 9 and 10). As shown in Table 9, the associations between neighborhood STEM jobs and adolescents' STEM motivational beliefs and GPAs were not statistically significant with the full analytic sample. When examined within each racial/ethnic group, the associations between neighborhood STEM jobs and adolescents' STEM motivational beliefs and GPAs were still not significant for Black, Latina/o, and White adolescents. Among Asian adolescents, neighborhood STEM jobs were significantly, but negatively associated with STEM interest, attainment value, and expectancies (β = -.04, -.02, -.03, p < .01). That is, Asian adolescents on averaged reported .04, .02, and .03 standard deviations lower on their STEM interests, attainment value, and expectancies for each additional STEM job per 100 jobs in the neighborhood.

Table 9.
Associations between neighborhood STEM jobs and adolescents' STEM outcomes

	STEM motivational beliefs				
	Interest	Utility value	Attainment value	Expectancies	STEM GPA
	B (SE)	*B (SE)*	*B (SE)*	*B (SE)*	*B (SE)*
Full analytic sample[a]					
Neighborhood STEM jobs	-.01 (.02)	-.00 (.00)	-.01 (.00)	-.00 (.01)	-.01 (.00)
Math achievement	.02*** (.00)	.01*** (.00)	.04*** (.00)	.02*** (.00)	.05*** (.00)
Within Asian adolescents[b]					
Neighborhood STEM jobs	-.04** (.01)	-.01 (.01)	-.02*** (.01)	-.03** (.01)	.00 (.01)
Math achievement	.02** (.01)	.01 (.01)	.04*** (.00)	.02*** (.00)	.04*** (.01)
Within Black adolescents[c]					
Neighborhood STEM jobs	-.00 (.02)	-.01 (.03)	.00 (.02)	.02 (.02)	-.01 (.01)
Math achievement	.01** (.00)	.01 (.00)	.02*** (.00)	.00 (.01)	.04*** (.00)

Within Latina/o adolescents[d]					
Neighborhood STEM jobs	-.02 (.04)	.00 (.01)	-.02 (.01)	-.00 (.01)	-.01 (.01)
Math achievement	.01*** (.00)	.02*** (.00)	.04*** (.00)	.02*** (.00)	.05*** (.00)
Within White adolescents[e]					
Neighborhood STEM jobs	-.01 (.01)	-.01 (.00)	-.01 (.01)	.00 (.01)	-.00 (.01)
Math achievement	.02*** (.00)	.02*** (.00)	.04*** (.00)	.03*** (.00)	.05*** (.00)

Note. Numbers outside parentheses are unstandardized coefficients. Numbers inside parentheses are standard errors (with adjustment of complex sampling design: sampling weight, primary sampling unit, and strata). Covariate was adolescents' 9th grade standardized math achievement. [abcde]All five models were just identified; hence, the model fit indices were CFI (conventional threshold ≥ 0.95) = 1.00, RMSEA (≤ 0.05) = .00, SRMR (≤ 0.05) = .00.
$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.
SOURCE: U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, High School Longitudinal Study of 2009 (HSLS:09), Base Year and First Follow-Up.

Table 10 shows the associations between school STEM indicators and adolescents' STEM motivational beliefs and GPAs. For the full analytic sample, AP STEM course offerings were negatively associated with adolescents' STEM motivational beliefs. Specifically, with every additional category of AP STEM course offered, adolescents on averaged reported .04, .05, .06, and .05 standard deviation lower for their STEM interests, utility value, attainment value, and expectancies. All other associations between school STEM indicators and adolescents' STEM motivational beliefs and GPAs were not statistically significant for the full analytic sample. The analyses within each racial/ethnic group revealed that the negative associations only held for White adolescents but not Asian, Black, or Latina/o adolescents. Among White adolescents, those whose school offered one more category of AP STEM course reported .04, .04, and .05 standard deviation lower for their STEM interest, utility value, and attainment value. Similar to when all adolescents were examined together, neither the number of STEM enrichment programs nor math/science teachers' experience were significantly associated with adolescents' STEM motivational beliefs and GPAs for any of the racial/ethnic groups.

Table 10.
Associations between school STEM indicators and adolescents' STEM outcomes

	STEM motivational beliefs	STEM GPA

	Interest	Utility value	Attainment value	Expectancies	
	B (SE)	*B (SE)*	*B (SE)*	*B (SE)*	*B (SE)*
Full analytic sample[a]					
AP STEM course offerings	-.04* (.02)	-.05** (.02)	-.06*** (.01)	-.05** (.02)	.03 (.01)
Number of STEM enrichment programs	.01 (.01)	-.00 (.01)	-.00 (.01)	.01 (.01)	-.01 (.01)
Math/science teachers' experience	-.00 (.01)	-.01 (.01)	-.01 (.01)	-.01 (.01)	-.00 (.01)
Quadratic of math/science teachers' experience	.00 (.00)	.00 (.00)	.00 (.00)	.00 (.00)	.00 (.00)
Math achievement	.02*** (.00)	.01*** (.00)	.04*** (.00)	.02*** (.00)	.05*** (.00)
Among Asian adolescents[b]					
AP STEM course offerings	-.11 (.07)	-.04 (.05)	-.00 (.04)	-.07 (.04)	.02 (.04)
Number of STEM enrichment programs	.02 (.02)	.00 (.03)	.02 (.02)	-.00 (.02)	-.00 (.02)
Math/science teachers' experience	.03 (.02)	-.02 (.03)	-.01 (.02)	.02 (.02)	-.02 (.01)
Quadratic of math/science teachers' experience	-.00 (.00)	.00 (.00)	.00 (.00)	-.00 (.00)	.00 (.00)
Math achievement	.02** (.01)	.01 (.01)	.03*** (.00)	.02*** (.00)	.04*** (.00)
Among Black adolescents[c]					
AP STEM course offerings	-.06 (.05)	-.02 (.05)	-.07 (.04)	-.06 (.04)	.00 (.04)
Number of STEM enrichment programs	.04 (.02)	-.01 (.03)	-.00 (.02)	.02 (.02)	-.03 (.02)
Math/science teachers' experience	.02 (.02)	-.01 (.02)	-.01 (.02)	.00 (.02)	-.01 (.01)
Quadratic of math/science teachers' experience	-.00 (.00)	.00 (.00)	.00 (.00)	-.00 (.00)	.00 (.00)
Math achievement	.01** (.00)	.01 (.00)	.02*** (.00)	.00 (.01)	.04*** (.00)
Among Latina/o adolescents[d]					
AP STEM course offerings	-.01 (.04)	-.05 (.04)	-.06 (.04)	-.04 (.03)	.05 (.03)
Number of STEM enrichment programs	-.01 (.03)	-.00 (.02)	-.01 (.02)	.01 (.02)	.01 (.02)
Math/science teachers' experience	.01 (.01)	.00 (.02)	.01 (.02)	-.00 (.02)	-.01 (.01)
Quadratic of math/science teachers' experience	-.00 (.00)	-.00 (.00)	-.00 (.00)	-.00 (.00)	.00 (.00)
Math achievement	.01*** (.00)	.02*** (.00)	.04*** (.00)	.02*** (.00)	.05*** (.00)
Among White adolescents[e]					
AP STEM course offerings	-.04* (.02)	-.04** (.02)	-.05** (.02)	-.03 (.02)	.03 (.02)
Number of STEM enrichment programs	.01 (.01)	-.01 (.01)	-.00 (.01)	.00 (.01)	-.00 (.01)
Math/science teachers' experience	-.01 (.01)	-.01 (.01)	-.01 (.01)	-.01* (.01)	.00 (.01)
Quadratic of math/science teachers' experience	.00 (.00)	.00 (.00)	.00 (.01)	.00* (.00)	.00 (.00)
Math achievement	.02*** (.00)	.02*** (.00)	.04*** (.00)	.03*** (.00)	.05*** (.00)

Note. Numbers outside parentheses are unstandardized coefficients. Numbers inside parentheses are standard errors (with adjustment of complex sampling design: sampling weight, primary sampling unit, and strata). Covariate was adolescents' 9th grade standardized math achievement. [abcde]All five models were just identified; hence, the model fit indices were CFI = 1.00, RMSEA = .00, SRMR = .00.

$*p < .05$. $**p < .01$. $***p < .001$.

SOURCE: U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, High School Longitudinal Study of 2009 (HSLS:09), Base Year and First Follow-Up.

According to my third hypothesis, school STEM indicators were expected to partially explain the associations between neighborhood STEM jobs and adolescents' STEM motivational beliefs and GPAs. The path models that tested this hypothesis showed good model fits except for the Black adolescents' model, whose fit was acceptable for one of the three model fit indices (Table 11). As shown in Table 11, for the full analytic sample, the indirect effects of neighborhood STEM jobs through the school indicators were significant, but negative in predicting adolescents' STEM utility value, attainment value, expectancies, and GPAs (*B* = -.003, -.002, -.003, -.002, $p < .05$). The indirect effects were driven by AP STEM course offerings but not the number of STEM enrichment programs or math/science teachers' experience. When examining the racial/ethnic group-specific models, however, none of the indirect effects were statistically significant for Asian, Black, and Latina/o adolescents. For White adolescents, the indirect effects of neighborhood STEM jobs through AP STEM course offerings on their STEM utility and attainment value were significant, but negatively so (*B* = -.003, -.002, $p < .05$).

Table 11.
Direct and *indirect effects of neighborhood STEM jobs and school STEM indicators on adolescents' STEM outcomes*

	STEM motivational beliefs				
	Interest	Utility value	Attainment value	Expectancies	STEM GPA
	B (SE)	*B (SE)*	*B (SE)*	*B (SE)*	*B (SE)*
Full analytic sample (CFI = .987, RMSEA = .035, SRMR = .025)					
Direct effect of neighborhood STEM jobs	-.010 (.016)	-.001 (.004)	-.007 (.005)	.001 (.005)	-.008* (.004)
Total indirect effects	-.002 (.001)	-.002* (.001)	-.002* (.001)	-.002** (.001)	.002* (.001)
Through AP STEM course offerings	-.002* (.001)	-.002* (.001)	-.002** (.001)	-.002* (.001)	.002* (.001)
Through STEM enrichment programs	.000 (.000)	.000 (.000)	.000 (.000)	.000 (.000)	.000 (.000)
Through math/science teachers' experience	.000 (.000)	.000 (.000)	.000 (.000)	.000 (.000)	.000 (.000)
Among Asian adolescents (CFI = 1.000, RMSEA = .000, SRMR = .004)					
Direct effect of neighborhood STEM jobs	-.035** (.011)	-.011 (.008)	-.022** (.007)	-.023** (.009)	-.001 (.007)
Total indirect effects	-.004 (.004)	-.001 (.005)	.001 (.003)	-.002 (.003)	.003 (.004)
Through AP STEM course offerings	-.004 (.004)	-.001 (.003)	.002 (.003)	-.002 (.002)	.002 (.002)
Through STEM enrichment programs	.000 (.002)	.000 (.003)	-.001 (.002)	.001 (.002)	.000 (.002)
Through math/science teachers' experience	.000 (.001)	.000 (.002)	.000 (.001)	-.001 (.001)	.001 (.001)
Among Black adolescents (CFI = .909, RMSEA = .104, SRMR = .041)					
Direct effect of neighborhood STEM jobs	-.004 (.017)	-.006 (.025)	.007 (.018)	.020 (.016)	.000 (.013)
Total indirect effects	.002 (.004)	-.000 (.005)	-.005 (.004)	-.001 (.003)	-.006 (.003)

Through AP STEM course offerings	-.003 (.003)	-.001 (.003)	-.004 (.003)	-.003 (.003)	.000 (.002)
Through STEM enrichment programs	.005 (.004)	-.001 (.004)	-.001 (.003)	.002 (.003)	-.004 (.003)
Through math/science teachers' experience	.000 (.002)	.001 (.002)	.000 (.001)	.000 (.002)	-.002 (.002)
Among Latina/o adolescents (CFI = .986, RMSEA = .036, SRMR = .036)					
Direct effect of neighborhood STEM jobs	-.019 (.039)	.004 (.007)	-.015 (.012)	-.001 (.010)	-.012 (.007)
Total indirect effects	.000 (.003)	-.001 (.003)	-.001 (.003)	-.002 (.003)	.000 (.002)
Through AP STEM course offerings	.000 (.001)	-.000 (.001)	-.001 (.003)	-.001 (.001)	.001 (.001)
Through STEM enrichment programs	.001 (.002)	.000 (.002)	.002 (.002)	-.001 (.002)	.000 (.001)
Through math/science teachers' experience	.000 (.001)	.000 (.001)	-.000 (.001)	.000 (.001)	-.000 (.001)
Among White adolescents (CFI = .990, RMSEA = .041, SRMR = .027)					
Direct effect of neighborhood STEM jobs	-.005 (.005)	-.006 (.005)	-.003 (.006)	.003 (.006)	-.006 (.005)
Total indirect effects	-.002 (.001)	-.002* (.001)	-.002* (.001)	-.001 (.001)	.001 (.001)
Through AP STEM course offerings	-.002 (.001)	-.002* (.001)	-.002* (.001)	-.001 (.001)	.002 (.001)
Through STEM enrichment programs	.000 (.001)	.000 (.001)	.000 (.000)	.000 (.000)	.000 (.000)
Through math/science teachers' experience	.000 (.000)	.000 (.000)	.000 (.000)	.000 (.000)	.000 (.000)

Note. Numbers outside parentheses are unstandardized coefficients. Numbers inside parentheses are standard errors (with adjustment of complex sampling design: sampling weight, primary sampling unit, and strata). Covariate was adolescents' 9th grade math achievement. Conventional threshold for model fit indices: CFI ≥ 0.95, RMSEA ≤ 0.05, SRMR ≤ 0.05.
$^*p < .05$. $^{**}p < .01$.
SOURCE: U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, High School Longitudinal Study of 2009 (HSLS:09), Base Year and First Follow-Up.

Robustness check: Dichotomized measure for math/science teachers' experience. An alternative operationalization of math/science teachers' experience was tested for robustness check purposes, in which it was dichotomized into under 5 years (novice teachers) versus not. With this operationalization, 26% and 23% of Black and Latina/o adolescents respectively were taught by novice math/science teachers, which was higher than 14% of Asian adolescents (*B* = .11, .09, $p < .01$). Not statistically different from those three groups, 19% of White adolescents were taught by novice math/science teachers (*B* = .04-.07, *ns*). As shown in Appendix 9, the results were largely consistent with the main findings presented earlier, such that AP STEM course offerings (but not number of STEM enrichment programs or whether math/science teacher was novice teacher) were negatively associated with adolescents' STEM motivational beliefs (*B* = -.04 - -.06, $p < .05$) and positively with their STEM GPAs (*B* = .03, $p < .05$). When examining those associations among adolescents of the same race/ethnicity, however, school STEM indicators were not significantly associated with Asian, Black, or Latina/o adolescents' STEM motivational beliefs and GPAs. Among White adolescents, AP STEM course offerings were negatively associated with their utility and attainment value (B = -.04, $p < .05$). Also similar to when math/science teachers' experience was modeled curvilinearly and continuously, the indirect effects of neighborhood STEM jobs through school STEM indicators were significant only among White adolescents and when all adolescents were examined together regardless of race/ethnicity, but not among Asian, Black, or Latina/o adolescents (Appendix 10).

Discussion

Guided by the institutional resource theory and the situated expectancy-value theory (Eccles & Wigfield, 2020; Leventhal & Brooks-Gunn, 2000), the current study utilized both the High School Longitudinal Study and the Occupational Employment Statistics data to examine how neighborhood and school STEM indicators were associated with Asian, Black, Latina/o, and White adolescents' STEM motivational beliefs and GPAs. Overall, I found racial/ethnic differences in the level of school STEM indicators and adolescents' STEM motivational beliefs and GPAs, but not neighborhood STEM jobs. Furthermore, neighborhood STEM jobs was not related to adolescents' STEM motivational beliefs and GPAs either directly nor indirectly through school STEM indicators.

Neighborhood STEM jobs. First, my results showed that there were racial/ethnic differences in most of the STEM indicators, but not in neighborhood STEM jobs. Specifically, although neighborhood STEM employment rates in this study ranged from less than 3 to almost 20 STEM jobs per every 100 jobs in the neigbhorhood, Asian, Black, Latina/o, and White adolescents in the current study lived in neighborhoods that on average had similar proportions of STEM jobs. Relatedly, we mostly found null associations between neighborhood STEM jobs and adolescents' STEM motivational beliefs and GPAs (with some exceptions among Asian adolescents). Core based statistical areas (CBSA) were chosen to define the size of the neighborhood because it is a common unit used to define socioeconomical ties and to calculate indicators including employment rates (Bureau of Economic Analysis, 2020). One possible reason for my null results is that CBSAs are too large and have too much variation within each CBSA in regard to STEM and its relations with adolescents' STEM motivational beliefs and GPAs. In other words, the within-CBSA STEM variations may be greater than between-CBSA variations, thus manifesting, on average, null neighborhood-adolescent associations (Cook et al., 2002). As such, a future direction is to use smaller neighborhood units that represent the space adolescents navigate on a daily basis that may more precisely capture adolescent social processes, such as modeling effects and transmission of STEM orientations, in order to map onto significant variations in individual adolescents' STEM outcomes (Nicotera, 2008).

School STEM indicators. We found racial/ethnic differences in two of the three school STEM indicators that aligned with prior studies in showing how Black and Latina/o adolescents tend to disproportionally attend under-resourced schools. Specifically, we found that Black adolescents were more likely than adolescents of the other racial/ethnic groups to attend schools that offered fewer types of AP STEM courses (e.g., Adelman, 2006; Klopfenstein, 2004), and also were more likely to be taught by math/science teachers who had fewer years of experience teaching high school math/science (e.g., Clotfelter et al., 2007; Darling-Hammond, 2000). Contrary to my expectation, there were no racial/ethnic differences in the number of STEM enrichment programs offered at schools. This finding should not be interpreted as there is no inequity in access to STEM enrichment programs, however, because there might still be within-school selection processes or barriers that systemically hinder underrepresented racial/ethnic minority adolescents from accessing or thriving in those programs (e.g., Godec, Archer, & Dawson, 2021; Snellman et al., 2014). Relatedly, the associations between school STEM indicators and adolescents' STEM motivational beliefs and GPAs were mostly not statistically significant (see Bottia et al., 2017 for similar findings). A possible explanation is that significant variations in STEM resources or access to and utilizing those STEM resources appear more within- than between-schools (Nasir & Vakil, 2017). That is, perhaps the number of opportunities did not significantly correlate with adolescents' STEM motivational beliefs and GPAs, however we know selecting into and participating in these opportunities does (e.g., Afterschool Alliance, 2015, 2021; Betts, Reuben, & Danenberg, 2000; Irizarry, 2021). In that case, STEM motivational beliefs and GPAs might be more different between adolescents who attended the same high school but were tracked into or actively selected different STEM opportunities, than between adolescents whose schools on average offered different levels of STEM opportunities.

Indirect effects of neighborhood STEM jobs through school STEM indicators. In addition to examining the direct effects of neighborhood STEM jobs and school STEM indicators on adolescents' STEM motivational beliefs and GPAs, I also tested their indirect effects through school STEM indicators as hypothesized by the institutional resource theory (Leventhal & Brooks-Gunn, 2000). Contrary to expectations, the majority of the indirect effects were not significant. In fact, the few significant indirect effects emerged in models where the total and direct effects of neighborhood STEM jobs were insignificant. A possible explanation is a suppression effect, in which opposing indirect effects can also explain the association between neighborhood STEM employment rates and adolescents' STEM outcomes but were not included in the models (Rucker et al., 2011). For example, neighborhood STEM employment rates might have null or positive influence on other prominent institutions, which canceled out the negative indirect effects through school STEM indicators, yielding an overall null association between neighborhood STEM jobs and adolescents' STEM outcomes.

Limitations and Future Directions

The aim of the current study was to examine the relations between neighborhood-, school-, and individual-level STEM indicators. This bioecological perspective spoke to the part of the situated expectancy-value theory that emphasized how motivational beliefs are shaped by contextual factors (Bronfenbrenner & Morris, 1998; Eccles & Wigfield, 2020). More specifically, I used institutional resource theory to guide my examination of two contexts--neighborhoods and schools (Leventhal & Brooks-Gunn, 2000). Institutional resource theory, however, only focuses on one of the many possible ways neighborhood and school factors shape adolescents' educational development (Arum, 2000; Johnson Jr, 2012; Pong & Hao, 2007). Institutional resource theory was derived from Jencks and Mayer (1990) who also proposed the collective socialization model where adults (instead of schools) in neighborhoods are theorized as the central mechanism through which neighborhoods influence individuals. Applying the collective socialization model to adolescents' STEM development, studies could also examine how outreach initiatives, internships, or shadowing programs facilitate the interactions between STEM professionals and adolescents in their neighborhood. The frequency and quality of such interactions might positively influence adolescents' motivational beliefs toward and performance in STEM. In sum, a future direction is to examine other prominent mechanisms through which neighborhood STEM characteristics might shape adolescents' STEM motivational beliefs and performance.

Another limitation that should be noted in regard to neighborhood effects is that people vary in their susceptibility and vulnerability to neighborhood effects, which might lead to within-neighborhood heterogeneity or mixed results (Harding et al., 2011). For example, relatively more advantaged families in a neighborhood with few STEM jobs might have greater resources to alternatively expose adolescents to STEM (e.g., afford STEM summer programs far away) than less-advantaged families in the same neighborhood. In that case, the more-advantaged families would be less susceptible to the effects of low neighborhood STEM jobs because they can more easily compensate by other means. Such variation in the susceptibility to neighborhood effects might be a particularly crucial limitation for the current study because the unit of neighborhood (i.e., core-based statistical areas) was large. Thus, a needed future direction is to examine how adolescents in the same neighborhoods vary in other contextual influences, such as family STEM resources and characteristics of friends, which might interact with neighborhood and school characteristics to differentially shape adolescents' development (Cook et al, 2002; Witherspoon et al., 2009).

Lastly, although adolescents are embedded in their neighborhoods, they are also active agents in their contexts rather than just being passively influenced by neighborhoods (Lerner, 1991). For example, given the advances in technology, adolescents in neighborhoods with few STEM jobs can still access information about STEM careers online. In other words, the hypothesized positive effects of neighborhood STEM jobs on adolescents' STEM motivational beliefs and GPAs might not have emerged because adolescents are able to effectively expand their neighborhood beyond physical boundaries through online interactions. A future direction, hence, is to examine adolescents' agency in how they actively seek out STEM resources, which then reciprocally shape their STEM motivational beliefs and GPAs.

Conclusion

Guided by the institutional resource theory and the situated expectancy-value theory, I employed the High School Longitudinal Study and the Occupational Employment Statistics data to examine how neighborhood STEM jobs and school STEM indicators were associated with Asian, Black, Latina/o, and White adolescents' STEM motivational beliefs and GPAs. First, results suggest that there were racial/ethnic differences in adolescents' STEM motivational beliefs and GPAs, as well as two out of the three school STEM indicators (AP STEM course offerings and math/science teachers' experience), but not for neighborhood STEM jobs or the number of STEM enrichment programs at school. The direct effects of neighborhood STEM jobs on adolescents' STEM outcomes were not significant, except for a few negative associations among Asian adolescents. Results also suggested no direct effects from the number of STEM enrichment programs and math/science teachers' experience to adolescents' STEM outcomes. AP STEM course offerings were negatively associated with adolescents' STEM motivational beliefs, but race/ethnicity-specific models revealed that such negative associations only held for White adolescents, but not Asian, Black, or Latina/o adolescents. Overall, the current study showed racial/ethnic differences in the level of school STEM indicators and adolescents' STEM motivational beliefs and GPAs, but found the direct and indirect effects of neighborhood and school STEM indicators on adolescents' STEM motivational beliefs and GPAs to be mostly not significant.

CHAPTER 5

Overarching Discussion

Although the three studies in this dissertation were written to be published independently, there were muliple overarching key points that emerged across the three studies. Rather than reiterating the discussion points from each of the three studies, below I elaborate on three key points derived collectively from the three papers. These points also echo some themes raised in the overarching introduction.

The promise of adolescence[6]. Since G. Stanley Hall described adolescence in the early 1900s as a period of 'storm and stress' when adolescents are unmotivated, rebellious, and at-risk. This notion often still prevails to this day. This dissertation pushes back on this negative narrative by addressing the possibilities that adolescence holds. For example, whereas most of the literature talks about declines in math/science motivation being the most typical trend during adolescence, my findings from Study 1 move away from a deficit-orientation and towards a focus on potential for growth/change and diverse possibilities. For example, there were configurally different patterns between 9th and 11th grade (e.g., *Not Math Maybe Science* emerged in 11th but not 9th grade), suggesting that some adolescents developed new constellations of math/science motivational beliefs at 11th grade. Furthermore, even for patterns that appeared at both timepoints, the proportion of adolescents who reported the same patterns ranged from 39% to 75%, suggesting that many adolescents' math/science motivational beliefs were still changing rather than just reporting stagnation or declines. For example, although around one in three Black adolescents reported the *Overall Low* pattern in 9th grade, 40% of them

[6] This is an intentional wording in reference to *Promise of Adolescence: Realizing Opportunity for All Youth* (The National Academies Press, 2019), which is a Consensus Study Report that focused on providing research evidence on the rich opportunity for positive, flourishing developments during adolescence.

did not stay and instead changed to a less unfavorable combination of math/science motivational beliefs in 11^{th} grade. Documenting such variation and potential for change is fundamental to moving away from the simplistic notion of adolescence as period characterized by motivational declines.

Findings from Study 1 also spoke to two fundamental features of human development that highlighted the complexity and various possibilities of adolescence— equifinality and multifinality (see Bergman, Andershed, & Andershed, 2009 for theoretical discussion on equifinality and multifinality applied to a different content area). On the one hand, equifinality pertains to when different antecedents or influences are associated with the same outcome. On the other hand, multifinality pertains to when the same antecedent is associated with different outcomes across individuals. An example of equifinality in Study 1 is when adolescents who held configurally different patterns of math/science motivational beliefs (e.g., *STEM is Useful but Not for Me* and *Not Math Maybe Science*) nonetheless had similar STEM GPAs and career aspirations two years later. For an example of multifinality, take the adolescents who reported the *Overall Low* pattern in 9^{th} grade in Study 1; they were more similar to each other than to everyone else at that particular timepoint because most of them disagreed with all motivational beliefs (interest, utility value, attainment value, expectancy) across the two domains. Just two years later, however, around one in every three adolescents in the *Overall Low* pattern changed into a configurally different pattern, even including 3%-12% of them (depending on race/ethnicity) who made the drastic change into the *Overall High* pattern. Jointly, equifinality and multifinality exemplified the complexity of educational psychology studies. A group of students who looked similar in one snapshot can come from very different histories (equifinality), as well as develop into varying future paths (multifinality).

Contextual correlates. The second overarching key point that emerged across my three studies pertained to contextual correlates. The malleability and complex development of adolescents' math/science motivational beliefs point to the importance of examining contextual factors that could be leveraged to promote those motivational beliefs. As introduced at the beginning of this dissertation, my examination of contextual correlates was guided by the bioecological systems theory (Bronfenbrenner & Morris, 1998, 2006), which emphasized that individuals are simultaneously embedded in multiple, nested contexts. To that end, I identified positive leverage points in the family context (STEM support from parents without a STEM degree/occupation) but mostly found null results in the school and neighborhood context. Such mixed findings might be attributed to how some indicators were more close/proximal to adolescents. The school and neighborhood STEM indicators may not have been strong correlates of adolescents' STEM motivation and performance because the measures focused on structural opportunities and lacked information on proximal processes, engagement, and exposure (Nicotera, 2008). In fact, the bioecological systems theory stated that for proximal processes to effectively shape development, they should happen "on a fairly regular basis, over an extended period of time" (Bronfenbrenner & Morris, 1998; Merçon-Vargas et al., 2020). In other words, I might have failed to capture the salient proximal processes or meaningful mechanisms through which school and neighborhood-level variations in STEM influence adolescents. With that, the null associations I found in Study 3 should not be interpreted as variations in school and neighborhood do not matter; instead, it should serve as a call for more nuanced and robust measurements, such as a more well-grounded measures of math/science teacher quality or teacher-student interactions instead of just years of teaching experience.

Racial/ethnic differences. The last overarching key point that that came out of this dissertation is the evolution of my understanding of how to conceptualize, test, and discuss racial/ethnic disparities in STEM. The evolution manifested statistically as the shift from between- to within- (racial/ethnic) group analyses, but it is the product of a humble journey of learning the critical race literature (e.g., Bullock, 2017; Chen & Buell, 2018; McGee, 2020; Walls, 2016), realizing how research on race/ethnicity can both be empowering and harmful, and adjusting my positionality as Asian in a research field that still largely centers White voices. I realized that without challenging the status quo of who gets to be studied and what research questions are regarded as important, research could often perpetuate a deficit narrative (e.g., Held, 2020, Syed et al., 2018). For example, merely using racial/ethnic under-representation and the achievement gap in STEM to establish the needs for study might unintentionally convey the assumption that marginalized groups only deserve to be understood when they are problematized or used in a comparative framework. I tried to counter this savior mentality in my dissertation studies by complementing between-group analysis with examining within-group processes.

My findings showed that while there are substantial existing racial/ethnic disparities in STEM, there are also abundant nuances within each racial/ethnic group (see Causadias, Korous, & Cahill, 2018 for a discussion on how psychology researchers tend to overestimate between-group differences and under-study within-group variations). Through the race- and ethnicity-specific latent transition models in Study 1, various traditionally understudied trends became apparent. For instance, the unfavorable patterns of math/science motivation among Asian adolescents and change among Black adolescents to more favorable math/science patterns might have gone undetected if not for the race/ethnicity-specific models approach. This within-group instead of between-group approach is one promising direction to overcome the invisibility of racial/ethnic minorities in developmental science and challenges the heuristic that racial/ethnic groups are often perceived to be more different than they actually are (Syed et al., 2018).

My findings also showed that it is important to distinguish between racial/ethnic differences at the mean level versus process level. In Studies 2 and 3, I found significant racial/ethnic differences in the *means* of family, school, and adolescent STEM indicators, but not in the processes or associations between those contextual correlates and adolescents' STEM motivational beliefs. Specifically, Black and Latina/o adolescents were disproportionally underrepresented in families with parent STEM capital as well as schools with AP STEM courses and experienced math/science teachers in addition to reporting lower STEM motivational beliefs than Asian and White adolescents. Nonetheless, results also showed that parent STEM support was a promotive factor across all racial/ethnic groups in shaping adolescents' STEM motivational beliefs among those whose parents did not have a STEM degree/occupation. Similarly, the nonsignificant associations between school STEM indicators and adolescents' STEM motivational beliefs and performance held for most of the racial/ethnic groups. The findings of process-level racial/ethnic similarities align with calls to combat cultural (mis)attribution bias, which is the erroneous tendency to expect (often hierarchical) differences between racial/ethnic minorities and Whites solely due to race/ethnicity or other cultural factors (Causadias, Vitriol, & Atkin, 2018; Held, 2020). Findings regarding the racial/ethnic differences at the mean level versus process level also speak to sources of inequities and offer implications for interventions. Mean-level racial/ethnic differences pertain to the existing disparities at a particular point in time that accumulated over their lifetime to position adolescents at different levels, whereas process-level racial/ethnic similarities pertain to the promising potential or room for mobility that adolescents have. Taken together, my findings suggest that racial/ethnic differences lay more in the level of STEM resources afforded to each group, but racial/ethnic minorities would benefit equally if they had access to promotive experiences that support their STEM motivational beliefs and performance (e.g., see Simpkins, Price, & Garcia, 2015 for a similar finding regarding mean-level but not process-level differences between Latina/o and White adolescents).

Limitations and Future Directions

While the three studies in my dissertation contributed to the literature in several regards, they should be understood in light of some limitations. Below, I elaborate on the limitations and offered four major themes of future directions.

A lifespan perspective. Adolescence is an important period to study the development and contextual correlates of STEM motivation. Adolescence, however, is not the only critical period for STEM motivation and learning. For example, the Motivational Theory of Life-Span Development (Heckhausen, Wrosch, & Schulz, 2010) and the chronosystem of the bioecological theory (Bronfenbrenner & Morris, 1998) both argue that the opportunities and priorities at different periods of life directly influence our development, including the motivations beliefs we develop. The term “STEM pipeline” highlights the developmental aspect of individuals’ motivation toward STEM, where influencing factors start in early childhood and continue through adulthood (e.g., Morgan, Farkas, Hillemeier, & Maczuga, 2016). During early developmental periods prior to adolescence, even the choice of toys can have a significant impact on the development of STEM interests (e.g., Coyle & Liben, 2020; McClure et al., 2017). Developmental periods after adolescence are also critical; for example, the experiences and decisions made during college have implications for one’s STEM enrollment and motivation (e.g., Chen, 2013; Leaper & Starr, 2019). In sum, the development of STEM motivational beliefs is a life-long process; hence, the examination of STEM motivational beliefs at any developmental period should be positioned within the broader lifespan perspective and warrant limitations accordingly. Regarding contextual factors, it is important to not only examine how their associations with STEM motivational beliefs manifest during different developmental periods, but also fundamentally question what contextual factors are central to STEM motivation development at the different developmental periods.

Contextual correlates. Although Studies 2 and 3 speak to several significant social contexts—family, school, neighborhood—there are many more contexts that warrant consideration. For example, through projects outside of this dissertation, I studied organized out-of-school time activities such as afterschool programs as promising contexts to support adolescents' STEM motivation and achievement (Yu et al., 2020). Organized out-of-school time activities are unique contexts to remediate, solidify, and enrich STEM learning because they often have greater flexibility than in-class instruction for math and science to be authentic, collaborative, and fun (Braund & Reiss, 2006; McCombs, Whitaker, & Yoo, 2017; National Research Council, 2015; Vandell et al., 2015). A foreseeable future direction is to better integrate my work on out-of-school time with STEM motivation.

Out of the many other contextual factors that I have not yet explore in my studies, a critical one for adolescents is peers (e.g., Melton, Brehm, & Deutsch, 2021; Ryan, 2003). Adolescents are susceptible to peer influence; for example, their STEM motivation tends to change in accordance to how they perceive other students in the classroom like or were engaged with STEM (Fredricks et al., 2018; Raabe, Boda, & Stadtfeld, 2019). Furthermore, peers and especially friends can influence the likelihood that adolescents join STEM-related activities (e.g., Calabrese Barton, Tan, & Greenberg, 2017; Simpkins et al., 2012). Relatedly, peers are theorized as one of the important ‘cultural conduits’ through which neighborhood effects trickle down to shape individuals’ educational outcomes (Harding et al., 2011). Thus, examining how adolescents are influenced by their peers regarding their engagement with neighborhood and school STEM resources is a promising future direction for Study 3. Related to Study 2, prior studies have shown that peers are a promising source of support to promote adolescents’ STEM motivation (Bouchey & Harter, 2005; Fredricks et al., 2018; Leaper, Farkas, & Brown, 2012). Thus, a future direction is to examine how STEM support from peers, parents, and other significant social agents influence adolescents’ STEM motivation (e.g., Simpkins et al., 2019). Overall, peer influences on adolesecents’ STEM motivation is an important future direction as peer influences tend to be particularly salient during adolescence, and prior studies have suggested multiple avenues through which peers can shape adolescents’ STEM motivation (Fredricks et al., 2018; Ryan, 2003).

Another context that I have not yet explore but expect to be particularly critical for adolescents is (social) media. On the one hand, social media can enrich diversity in STEM, for example by facilitating adolescents to connect to each other and with role models whom they otherwise would not have access to (Gregg et al., 2016; Pinkard et al., 2017). On the other hand, media can insidiously intensify divides in STEM, for example by perpetuating discrimitory stereotypes (Long et al., 2010). Overall, how social media can be leveraged to promote adolescents’ STEM motivation is an important future direction especially considering the increasing amount of time adolescents spend online (Evans, Won, & Drape, 2014). My expectation that (social) media will play an increasingly significant role in understanding adolescents’ STEM motivation speaks to the chronosystem in the ecological systems theory, which stated that the socio-historical environment that individuals are embedded in can shape their development. That is, it will be critical to continuously adapt my research to understand the significant contextual correlates that each new generation of adolescents faces. This includes examining new trends such as the increasing consumption of (social) media, as discussed above. It would also include examining new momentous events that have implications for adolescents' STEM development, such as a global pandemic that changed the format of instruction and highlighted the importance of science literacy (e.g., Lee & Campbell, 2020; Perets et al., 2020).

Race/ethnicity. As discussed throughout, race/ethnicity was a focus for all three of my dissertation studies. Based on what the dataset offers, I examined racial/ethnic categories. Racial/ethnic categories, however, do not translate to racial/ethnic identities , which are constantly evolving and in-negotiation with various social interactions (Tan et al., 2013). In reality, people with the same race/ethnicity vary widely in their racial/ethnic identities, and prior studies have showed how racial/ethnic identities are related with STEM motivational beliefs and performance (McGee, 2016). That is, although racial/ethnic groups are convenient grouping categories, racial/ethnic identities can speak to the more nuanced lived experiences that shape one's STEM motivational beliefs. Thus, a future direction is to move from broad racial/ethnic categories to the nuances of individuals' racial/ethnic identities, which would allow adolescents' social positions to be examined as a continuous and elaborate construct instead of a single-dimensional category.

Another limitation regarding race/ethnicity that should not be left unsaid is how I only studied the four numerically largest groups, namely Asian, Black, Latina/o, and White adolescents. The omission of smaller groups is a limitation to my studies and should not be interpreted as if they are too small to deserve to be studied. For example, a group of adolescents I excluded under this criterium were those who reported belonging to more than one racial/ethnic group. The theories and empirical data about multiracial/ethnic adolescents in STEM are not as developed as those for the mono-racial/ethnic groups (Charmaraman et al., 2014; Harris, 2016), although they can offer theoretical implications (Dunham & Olson, 2016; Nishina & Witkow, 2020).

Lastly, it should be noted that another major axis of disparity in addition to race/ethnicity in STEM is gender. Although gender differences in math achievement are typically small and mostly observed only at the extremes, STEM fields continue to struggle with recruiting and retaining female talent (Lindberg et al., 2010; Wang & Degol, 2017), thus highlighting the complexity and importance of gender differences in STEM motivation. I chose not to focus on gender in this dissertation because gender disparities in STEM are most salient in math-intensive fields (e.g., more pronounced in physical than biological sciences), but my measure of science in the dataset does not delineate such subfield nuances. An important future direction for me is to bring gender back to my studies. In a study leading up to this dissertation, I showed that the intersection of gender and race/ethnicity afforded more nuanced understanding than what we learned from race/ethnicity or gender alone (Hsieh, Simpkins, & Eccles, under review). In another study outside this dissertation, I showed that the gender differences in adolescents' motivational beliefs varied across specific STEM subjects (Hsieh, Liu, & Simpkins, 2019). Taken together, one future direction is to collect data that would be able to address the interrelatedness of race/ethnicity with gender across specific STEM subjects.

Qualitative research. I firmly believe that quantitative, qualitative, and mixed-method research designs complement rather than compete with each other. The fact that all three of my dissertation studies are quantitative, hence, does not in any way imply that I think adolescents' STEM motivational belief development are best understood quantitatively. In fact, I believe my findings nicely set up many future directions that better lend themselves to qualitatively inquiry. For example, there is no study to my knowledge that interviews adolescents with different patterns of math/science motivational beliefs, even though that would be a fruitful direction to more holistically understand the antecedents, consequences, and lived experiences of adolescents with different STEM motivation patterns. A follow-up of Study 2 could be to qualitatively examine parent STEM support and adolescents' STEM motivational beleifs for those with versus without parent STEM degree/occupation. For example, Archer and colleagues (2006) utilized interview data to exmaine STEM aspirations of UK adolescents whose families possessed minimal science resources and connections (including parent STEM degree/occupation). Building on that and related studies, a future direction is to qualitatively examine parent STEM support for parents with and without STEM degree/occupations, and specifically how different practices shape different adolescent STEM motivational belief patterns. Study 3 also led to many qualitative future directions, including leveraging interview data to center adolescents' voices in understanding how they perceive their neighborhood influence (or did not influence) their STEM motivational beliefs (e.g., see Niceotera, 2008 for a youth-centered qualitative definitions of neighborhood; see McWilliams, 2017 for an ethnographic example of how youth perceived their neighborhood shaped their school choice and educational outlook).

Conclusion

My dissertation examined Asian, Black, Latina/o, and White adolescents' STEM motivational beliefs, which not only have implications for individual adolescent's upward mobility but also plays a role in understanding the persistent inequities in STEM. Study 1 employed a person-centered approach to examine the interrelatedness of multiple math and science motivational beliefs, in addition to changes in those patterns and their association with

STEM performance and aspirations. Findings from Study 2 showed that parents' STEM support could be leveraged to promote adolescents' STEM motivational beliefs, with the most pronounced benefit observed among parents without a STEM degree/occupation. Study 3 suggested that the direct and indirect effects of neighborhood STEM jobs and school STEM indicators on adolescents' STEM motivational beliefs and performance were mostly nonsignificant. Across Studies 2 and 3, findings suggested several racial/ethnic differences in the mean levels of family, school, and adolescent STEM indicators, but mostly suggested racial/ethnic similarities regarding the associations between contextual factors and adolescents' STEM motivational beliefs, aspirations, and performances. Overall, the three studies in this dissertation contributed to understanding the development and contextual correlates of Asian, Black, Latina/o, and White adolescents' STEM motivational beliefs.

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APPENDICES

Appendix 1.
Analysis versus excluded sample (for Study 1)

	Analysis sample (N = 10,320)		Excluded sample (N = 14,890)		Chi-square	Effect size phi φ
	Mean	SD	Mean	SD		
9th grade motivational beliefs						
Math interest	.35	.48	.30	.46	48.79***	.04
Math utility value	.46	.50	.44	.50	5.73*	.02
Math expectancy	.34	.47	.27	.44	104.42***	.06
Math attainment value	.21	.41	.16	.36	89.63***	.06
Science interest	.34	.48	.30	.46	38.96***	.04
Science utility value	.31	.46	.29	.45	12.89***	.02
Science expectancy	.26	.44	.22	.42	31.04***	.04
Science attainment value	.17	.38	.11	.32	132.12***	.07
11th grade motivational beliefs						
Math interest	.25	.43	.22	.42	24.86***	.03
Math utility value	.27	.44	.22	.41	76.72***	.06
Math expectancy	.51	.50	.47	.50	26.51***	.03
Math attainment value	.20	.40	.14	.35	121.99***	.07
Science interest	.34	.47	.30	.46	41.34***	.04
Science utility value	.38	.49	.32	.47	97.94***	.06
Science expectancy	.27	.44	.23	.42	48.87***	.04
Science attainment value	.19	.39	.14	.34	89.57***	.06
STEM GPA	2.68	.82	2.21	.96	38.31***[t]	.52
STEM career aspirations	.39	.49	.32	.47	84.43***	.06
Ethnicity						
Asian	.10	.30	.07	.26	80.03***	.06
Black	.10	.30	.11	.31	11.78**	.02
Latina/o	.16	.37	.16	.36	.79	.01
White	.64	.48	.38	.49	1649.69***	.26

Notes. Conventions for phi φ .1 small, .3 medium, .5 large. SD = standard deviation. [t] t-statistic (as opposed to chi-square) and Cohen's *d* effect size were calculated for STEM GPA because it is a continuous variable.
* $p < .05$ ** $p < .01$ *** $p < .001$
SOURCE: U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, High School Longitudinal Study of 2009 (HSLS:09), Base Year and First Follow-Up.

Appendix 2.
Items for scales used in this dissertation

STEM/math/science interest
- You enjoy math classes very much.
- You enjoy science classes very much.
- You think math classes are a waste of your time.
- You think science classes are a waste of your time.
- You think math classes are boring.
- You think science classes are boring.

STEM/math/science utility
- Math is useful for everyday life.
- Science is useful for everyday life.
- Math is useful for college.
- Science is useful for college.
- Math is useful for a future career.
- Science is useful for a future career.

STEM/math/science ability self-concept
- You are confident that you can do an excellent occupation on math tests.
- You are confident that you can do an excellent occupation on science tests.
- You are certain that you can master math skills.
- You are certain that you can master science skills.
- You are confident that you can do an excellent occupation on math assignments.
- You are confident that you can do an excellent occupation on science assignments.
- You are certain that you can understand the most difficult material presented in math textbooks.
- You are certain that you can understand the most difficult material presented in science textbooks.

STEM/math/science attainment value
- You see yourself as a math person.
- You see yourself as a science person.
- Others see you as a math person.
- Others see you as a science person.

Appendix 3

Model fit indices of the random half samples

Number of patterns	AIC		saBIC		AWR		RI		cmP		Smallest class size	
	Sub-sample: (1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
9th grade												
1	59114.081	59340.754	59151.163	59377.835	59328.40	59555.07	1.00	1.00	<.001	<.001	100%	100%
2	53826.236	53724.765	53903.770	53802.299	54274.36	54172.89	0.18	0.15	<.001	<.001	35%	31%
3	52922.295	52852.107	53040.281	52970.093	53604.22	53534.03	0.11	0.11	<.001	<.001	20%	20%
4	52358.583	52279.122	52517.022	52437.560	53274.32	53194.85	0.05	0.05	<.001	<.001	10%	11%
5	52144.402	52017.440	52343.292	52216.331	53293.94	53166.98	0.04	0.04	<.001	<.001	9%	10%
6	51942.781	51794.661	52182.124	52034.003	53326.12	53178.00	0.04	0.03	<.001	<.001	8%	7%
7	51781.757	51625.102	52061.552	51904.898	53398.90	53242.25			1	1	4%	6%
11th grade												
1	58586.101	58146.278	58623.182	58183.359	58800.42	58360.60	1.00	1.000	<.001	<.001	100%	100%
2	53211.237	52974.849	53288.771	53052.382	53659.36	53422.97	0.15	0.19	<.001	<.001	43%	40%
3	52443.311	52029.346	52561.297	52147.332	53125.24	52711.27	0.12	0.11	<.001	<.001	23%	16%
4	51813.879	51478.901	51972.317	51637.340	52729.61	52394.63	0.10	0.07	<.001	<.001	11%	11%
5	51303.553	51129.470	51502.443	51328.360	52453.09	52279.01	0.04	0.03	<.001	<.001	9%	11%
6	51092.178	50983.480	51331.521	51222.823	52475.52	52366.82	0.04	0.03	<.001	<.001	7%	2%
7	50890.801	50829.302	51170.596	51109.097	52507.95	52446.45			1	1	8%	2%

Note. Ideal AIC (Akaike Information Criterion), saBIC (sample size-adjusted Bayesian Information Criterion) and AWR (Approximate Weight of Evidence Criterion) have the lowest marginal reduction. Ideal RI (relative improvement) has the smallest marginal reduction. The size of the smallest class is recommended to be no smaller than 2%. The greater cmP (correct model probability), the more ideal.
SOURCE: U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, High School Longitudinal Study of 2009 (HSLS:09), Base Year and First Follow-Up.

Appendix 4.

Analysis versus excluded sample (for Study 2)

	Analysis sample (n = 14,200)		Excluded sample (n = 11,010)		*t*-statistics	chi-square	Cohen's *d* effect size
	Mean	*SD*	*Mean*	*SD*			
11th grade STEM motivational beliefs							
Expectancy belief	2.81	.58	2.76	.59	6.08***	-	.09
Interest	2.76	.59	2.72	.59	4.81***	-	.07
Utility value	3.18	.52	3.15	.53	3.49***	-	.05
Attainment value	2.49	.70	2.40	.68	9.38***	-	.14
Parent STEM degree/occupation	0.31	0.46	0.06	0.23	-	2538.52***	.64
Asian	0.08	0.28	0.08	0.28		0.11	.00
Black	0.11	0.31	0.10	0.31		0.00	.00
Latina/o	0.17	0.38	0.14	0.35		59.52***	.10
White	0.64	0.48	0.29	0.45	-	3339.55***	.73
Covariates							
9th grade parent science support	3.85	1.63	3.78	1.63	1.67	-	.04
9th grade parent financial support for college	0.81	0.39	0.78	0.41	-	7.69**	.04
9th grade parent communication with school about college	0.44	0.50	0.43	0.49	-	1.48	.02
Parent has a bachelor’s degree	0.44	0.50	0.10	0.29	-	4048.92***	.81
9th grade math achievement	52.28	10.02	48.82	9.80	24.08***	-	.35
8th grade math class is advanced	0.42	0.49	0.32	0.46	-	212.63***	.19
Female	0.50	0.50	0.47	0.50	-	13.52***	.05
Family income	4.71	3.09	4.22	2.80	7.69***	-	.16
School type: private	0.20	0.40	0.15	0.36	-	117.89***	.14

Notes. Conventions for Cohen’s *d* .20 small, .50 medium, .80 large. *SD* = standard deviation. t-statistics calculated for continuous outcome while chi-squares calculated for binary outcomes; - denotes not applicable.
* $p < .05$ ** $p < .01$ *** $p < .001$
SOURCE: U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, High School Longitudinal Study of 2009 (HSLS:09), Base Year and First Follow-Up.

Appendix 5.

Bivariate correlations of main variables among families with parent STEM degree/occupation (above the diagonal) and among families without parent STEM degree/occupation (below the diagonal)

		1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
1.	11th grade STEM interest	1	.48***	.51***	.55***	.12***	.09***	-.03	-.00	-.05**	.21***
2.	11th grade STEM utility value	.48***	1	.55***	.44***	.09***	.12***	-.01	-.02	-.08***	.21***
3.	11th grade STEM attainment value	.50***	.50***	1	.59***	.15***	.16***	-.07***	-.07***	-.04*	.42***
4.	11th grade STEM expectancy belief	.55***	.43***	.57***	1	.10***	.08***	.00	-.06***	-.03	.29***
5.	9th grade parent STEM support	.10***	.11***	.13***	.11***	1	-.00	.01	-.02	.01	.16***
6.	Asian	.06***	.08***	.08***	.04***	-.04***	1	-.12***	-.14***	-.62***	.28*
7.	Latina/o	.04***	.07***	-.01	.05***	.01***	-.08***	1	-.09**	-.46***	-.10*
8.	Black	.04***	.00	-.04***	-.02*	-.07***	-.11***	-.16***	1	-.41***	-.17***
9.	White	-.08***	-.08***	.00	-.03**	.07***	-.32***	-.68***	-.45***	1	-.06***
10.	9th grade math achievement	.15***	.15***	.37***	.24***	.16***	.13***	-.13***	-.25***	.17***	1

Notes. Families with parent STEM degree/occupation (n = 4,160) are above the diagonal, families without parent STEM degree/occupation (n = 9,830) are below the diagonal. Missing data imputed with multiple imputation.

* $p < .05$ ** $p < .01$ *** $p < .001$

SOURCE: U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, High School Longitudinal Study of 2009 (HSLS:09), Base Year and First Follow-Up.

Appendix 6.

Analytic versus excluded sample (of Study 3)

	Analytical sample (n = 14,265)		Excluded sample (n = 10,941)			
	Mean	*(SD)*	*Mean*	*(SD)*	t-statistic	*Cohen's d*
Neighborhood STEM jobs	8.26	(2.37)	8.53	(2.60)	8.59***	.11
AP STEM course offerings	1.67	(1.00)	1.24	(1.07)	32.65***	.41
Number of STEM enrichment programs	4.00	(1.89)	3.84	(1.83)	6.65***	.08
Math/science teacher experience	10.60	(7.08)	10.14	(6.73)	5.15***	.07
STEM interest	2.75	(0.59)	2.72	(0.47)	4.32***	.06
STEM utility value	3.16	(0.52)	3.15	(0.41)	1.89	.02
STEM attainment value	2.48	(0.70)	2.39	(0.56)	10.41***	.13
STEM expectancies	2.81	(0.58)	2.75	(0.47)	8.98***	.12
STEM GPA	2.52	(0.87)	2.27	(0.89)	22.97***	.29
Math achievement	52.30	(9.75)	49.60	(9.15)	22.38***	.29

Note. SD = standard deviation. Conventions for Cohen's d effect size: 0.2 small, 0.5 medium, 0.8 large.
***p < .001.
SOURCE: U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, High School Longitudinal Study of 2009 (HSLS:09), Base Year and First Follow-Up.

Appendix 7.

Example CBSAs (core-based statistical area) in each quantile of neighborhood STEM jobs

Neighborhood STEM jobs quantile		Example CBSAs
1	2.99-5.38 STEM jobs per every hundred jobs	• Anderson, IN (4.91) • Visalia-Porterville, CA (4.33) • Sioux City, IA-NE-SD (4.58)
2	5.41-6.56 STEM jobs per every hundred jobs	• Appleton, WI (6.20) • Spartanburg, SC (5.76) • Greensboro-High Point, NC (6.27)
3	6.57-7.91 STEM jobs per every hundred jobs	• Ashville, NC (6.72) • Tyler, TX (6.81) • Chicago-Naperville-Joliet, IL-IN-WI (7.76)
4	7.91-19.68 STEM jobs per every hundred jobs	• Ann Arbor, MI (10.77) • Tucson, AZ (9.90) • Houston-Sugar Land-Baytown, TX (9.40)

Appendix 8

Participants with imputed data versus participants with full data

	Participants with imputed data (n = 10,678)		Participants with full data (n = 3,587)			
	Mean	*(SD)*	*Mean*	*(SD)*	*t*-statistic	*Cohen' d*
Neighborhood STEM jobs	8.21	(2.35)	8.39	(2.44)	3.95***	.08
AP STEM course offerings	1.64	(1.06)	1.81	(1.00)	8.39***	.17
Number of STEM enrichment programs	3.93	(2.00)	4.18	(2.06)	6.14***	.12
Math/science teacher experience	10.83	(8.26)	10.35	(6.09)	3.12**	.07
STEM interest	2.75	(0.59)	2.76	(0.59)	1.14	.02
STEM utility value	3.16	(0.53)	3.17	(0.51)	1.06	.02
STEM attainment value	2.47	(0.70)	2.49	(0.70)	1.27	.02
STEM expectancies	2.81	(0.59)	2.81	(0.58)	.52	.01
STEM GPA	2.54	(0.88)	2.51	(0.89)	1.64	.03
Math achievement	52.22	(10.03)	52.86	(9.99)	3.25**	.06

Note. SD = standard deviation. Conventions for Cohen's d effect size: 0.2 small, 0.5 medium, 0.8 large.
**$p < .01$. ***$p < .001$.
SOURCE: U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, High School Longitudinal Study of 2009 (HSLS:09), Base Year and First Follow-Up.

Appendix 9.

Associations between school STEM indicators and adolescents' STEM outcomes: math/science teachers' teaching experience operationalized as novice teachers versus not

	STEM motivational beliefs				
	Interest	Utility value	Attainment value	Expectancies	STEM GPA
	B (SE)	*B (SE)*	*B (SE)*	*B (SE)*	*B (SE)*
Full analytic sample[a]					
AP STEM course offerings	-.04* (.02)	-.05** (.02)	-.06*** (.01)	-.05** (.02)	.03* (.01)
Number of STEM enrichment programs	.01 (.01)	-.00 (.01)	-.00 (.01)	.01 (.01)	-.01 (.01)
Math/science teachers under 5 years	-.06 (.04)	.02 (.04)	.02 (.04)	.01 (.04)	-.00 (.03)
Math achievement	.02*** (.00)	.01*** (.00)	.04*** (.00)	.02*** (.00)	.05*** (.00)
Within Asian adolescents[b]					
AP STEM course offerings	-.11 (.07)	-.04 (.05)	-.00 (.04)	-.07 (.04)	.03 (.04)
Number of STEM enrichment programs	.03 (.02)	.01 (.03)	.02 (.02)	.00 (.02)	-.00 (.02)
Math/science teachers under 5 years	-.19 (.10)	-.09 (.16)	.01 (.19)	-.19 (.14)	.08 (.07)
Math achievement	.01** (.01)	.01 (.01)	.04*** (.00)	.02*** (.00)	.04*** (.00)
Within Black adolescents[c]					
AP STEM course offerings	-.06 (.05)	-.02 (.05)	-.07 (.04)	-.06 (.04)	-.00 (.04)
Number of STEM enrichment programs	.04 (.02)	-.00 (.03)	-.00 (.02)	.02 (.02)	-.03 (.02)
Math/science teachers under 5 years	-.16 (.10)	.06 (.09)	.11 (.12)	-.04 (.12)	-.02 (.08)
Math achievement	.01** (.00)	.01 (.00)	.02*** (.00)	.00 (.01)	.04*** (.00)
Within Latina/o adolescents[d]					
AP STEM course offerings	-.02 (.04)	-.05 (.04)	-.06 (.04)	-.04 (.03)	.05 (.03)
Number of STEM enrichment programs	-.00 (.03)	-.00 (.02)	-.01 (.02)	.01 (.02)	.01 (.02)
Math/science teachers under 5 years	-.04 (.09)	-.01 (.09)	-.01 (.10)	.05 (.09)	.13* (.06)
Math achievement	.01*** (.00)	.02*** (.00)	.04*** (.00)	.02*** (.00)	.05*** (.00)
Within White adolescents[e]					
AP STEM course offerings	-.04 (.02)	-.04* (.02)	-.04** (.02)	-.02 (.02)	.03 (.02)
Number of STEM enrichment programs	.01 (.01)	-.01 (.01)	-.00 (.01)	.00 (.01)	-.00 (.01)
Math/science teachers under 5 years	-.04 (.04)	.00 (.04)	.01 (.04)	.02 (.04)	-.05 (.03)
Math achievement	.02*** (.00)	.02*** (.00)	.04*** (.00)	.03*** (.00)	.05*** (.00)

Note. Numbers outside parentheses are unstandardized coefficients. Numbers inside parentheses are standard errors (with adjustment of complex sampling design: sampling weight, primary sampling unit, and strata). Covariate was adolescents' 9th grade standardized math achievement. [abcde]All five models were just identified, hence the model fit indices were CFI (conventional threshold ≥ 0.95) = 1.00, RMSEA (≤ 0.05) = .00, SRMR (≤ 0.05) = .00.

*p < .05. **p < .01. ***p < .001.

SOURCE: U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, High School Longitudinal Study of 2009 (HSLS:09), Base Year and First Follow-Up.

Appendix 10.

Direct and indirect effects of neighborhood STEM employment rates and school STEM indicators on adolescents' STEM outcomes: math/science teachers' teaching experience operationalized as novice teachers versus not

	STEM motivational beliefs				
	Interest	Utility value	Attainment value	Expectancies	STEM GPA
	B (SE)	*B (SE)*	*B (SE)*	*B (SE)*	*B (SE)*
Full analytic sample (CFI = .989, RMSEA = .033, SRMR = .025)					
Direct effect of neighborhood STEM jobs	-.010 (.016)	-.001 (.004)	-.007 (.005)	.001 (.006)	-.008* (.004)
Total indirect effects	-.002 (.001)	-.002* (.001)	-.003* (.001)	-.003** (.001)	.002* (.001)
Through AP STEM course offerings	-.002* (.001)	-.002* (.001)	-.002** (.001)	-.002* (.001)	.001 (.001)
Through STEM enrichment programs	.000 (.000)	.000 (.000)	.000 (.000)	.000 (.000)	.000 (.000)
Through novice math/science teachers	.000 (.000)	.000 (.000)	.000 (.000)	.000 (.000)	.000 (.000)
Among Asian adolescents (CFI = 1.000, RMSEA = .000, SRMR = .007)					
Direct effect of neighborhood STEM jobs	-.036** (.011)	-.012 (.008)	-.022** (.007)	-.025** (.008)	.000 (.007)
Total indirect effects	-.003 (.004)	-.001 (.004)	.001 (.002)	-.000 (.003)	.001 (.003)
Through AP STEM course offerings	-.004 (.004)	-.001 (.003)	.002 (.003)	-.002 (.002)	.002 (.002)
Through STEM enrichment programs	-.001 (.002)	.000 (.003)	-.001 (.002)	.001 (.002)	.000 (.002)
Through novice math/science teachers	.001 (.001)	.001 (.001)	.000 (.001)	.001 (.001)	-.001 (.001)
Among Black adolescents (CFI = .947, RMSEA = .076, SRMR = .037)					
Direct effect of neighborhood STEM jobs	-.005 (.016)	-.005 (.026)	.008 (.017)	.020 (.016)	-.001 (.013)
Total indirect effects	.003 (.004)	-.002 (.004)	-.006 (.004)	-.001 (.003)	-.004 (.003)
Through AP STEM course offerings	-.003 (.003)	-.001 (.003)	-.004 (.003)	-.003 (.003)	.000 (.002)
Through STEM enrichment programs	.005 (.004)	.000 (.004)	-.001 (.003)	.002 (.003)	-.004 (.003)
Through novice math/science teachers	.002 (.002)	-.001 (.001)	-.001 (.002)	.000 (.001)	.000 (.001)
Among Latina/o adolescents (CFI = .990, RMSEA = .031, SRMR = .020)					
Direct effect of neighborhood STEM jobs	-.019 (.040)	.004 (.007)	-.017 (.012)	-.001 (.010)	-.013 (.008)
Total indirect effects	.001 (.002)	-.001 (.003)	-.000 (.002)	-.002 (.002)	.001 (.002)
Through AP STEM course offerings	.000 (.001)	-.000 (.001)	-.001 (.001)	-.001 (.001)	.001 (.001)
Through STEM enrichment programs	.001 (.002)	.000 (.002)	.001 (.002)	-.001 (.002)	.000 (.001)
Through novice math/science teachers	.000 (.000)	.000 (.000)	.000 (.000)	.000 (.000)	.000 (.001)
Among White adolescents (CFI = .990, RMSEA = .042, SRMR = .027)					
Direct effect of neighborhood STEM jobs	-.006 (.005)	-.006 (.005)	-.003 (.006)	.003 (.006)	-.007 (.005)
Total indirect effects	-.001 (.001)	-.002* (.001)	-.002* (.001)	-.001 (.001)	.002 (.001)
Through AP STEM course offerings	-.002 (.001)	-.002* (.001)	-.002* (.001)	-.001 (.001)	.002 (.001)
Through STEM enrichment programs	.000 (.001)	.000 (.001)	.000 (.000)	.000 (.000)	.000 (.000)
Through novice math/science teachers	.000 (.000)	.000 (.000)	.000 (.000)	.000 (.000)	.000 (.000)

Note. Numbers outside parentheses are unstandardized coefficients. Numbers inside parentheses are standard errors (with adjustment of complex sampling design: sampling weight, primary sampling unit, and strata). Covariate was adolescents' 9th grade math achievement. Conventional threshold for model fit indices: CFI ≥ 0.95, RMSEA ≤ 0.05, SRMR ≤ 0.05.

*$p < .05$. **$p < .01$.

SOURCE: U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, High School Longitudinal Study of 2009 (HSLS:09), Base Year and First Follow-Up.