The Relationship of Science Motivation with Science Achievement: Evidence from the NAEP 2015 Science Assessment

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Executive Summary

The AIR ESSIN Task 14 NAEP research team has conducted motivation research studies in reading and mathematics using National Assessment of Educational Progress (NAEP) data to investigate whether subject specific motivation (reading and mathematics) is associated with achievement in the corresponding subject area. Both studies' results indicated that subject-specific motivation plays a significant role in explaining student achievement even after controlling for student demographic (and school-related) background variables.

In order to cover an even fuller spectrum of motivation research as it relates to NAEP achievement, the current study focuses on science. This study aims to understand the role that science motivation plays in middle school science achievement by analyzing the 2015 grade 8 NAEP science data. The study focused on identifying the unique contributions of student-level science motivation and aggregated school-level mean science motivation on science achievement. Hierarchical linear modeling (HLM) was used to partition variability in student science achievement into within- and between-school components after student- and school-level demographic variables had been taken into account. In addition, the study investigated whether the identified unique contributions of science motivation to science achievement varied by gender, race/ethnicity, socioeconomic status groups (SES), and other demographic variables.

A series of HLM models revealed the following:

Both science self-efficacy and science interest as measures of science motivation were significant positive predictors of science achievement after controlling for student background and other variables with self-efficacy having the larger effect of the two. After taking all demographics and other interaction variables into consideration, a one-unit difference in student science self-efficacy (rated on a 4-point scale) is associated with an estimated 10.67-point difference in science achievement, which is approximately one third of the science assessment's standard deviation. A one-unit increase in student interest (rated on a 4-point scale) is also associated with an estimated 3.27-point increase in science achievement. Overall, the addition of the two student motivation variables accounts for 19 percent of the within-school variance. This finding is consistent with results from other motivation studies conducted by the AIR ESSIN NAEP Research team using the NAEP mathematics and reading data in that student subject specific motivation explains approximately one third of variance in NAEP performance.

The relationship between science interest and science achievement varies by gender, student SES, and individualized education program (IEP) status. The model results indicate that the science interest coefficient for female students is estimated to be -1.98 points lower than for male students after controlling for all other variables. That is to say, the effect of science interest on science achievement is larger for male students compared to female students. Similarly, the science interest coefficient for students who are enrolled in an IEP program is estimated to be 2.62 points higher than for those who are not after controlling for all other variables. Finally, the relationship of science interest to science achievement is larger for students with a higher SES background compared to those from a lower SES background.

The study also found significantly random effects of science interest and self-efficacy on science achievement across schools. That is to say, the relationships between science interest and self-efficacy and science achievement are different across schools. For example, the positive relationship between science interest and science achievement would be larger in some schools than other schools. By adding a random slope model to understand factors that are associated with the varied effects of students' sense of science interest on NAEP science achievement across schools, we found that the positive association between students' science interest and NAEP science achievement was stronger for schools providing more advanced teaching and learning supplies for science instruction, although the size of the effect is not substantial.

School-level mean science self-efficacy was statistically significant in moderating the association of student science self-efficacy with student science achievement. The relationship of student self-efficacy with student science achievement was higher for schools with a higher level of mean science self-efficacy. This finding supports other research which indicates that school climate is associated with student academic learning and growth (Maslowski, 2001; Hoy et al., 2006). The major levers seen as important for improving school climate are principals' leadership, teachers' expectations, and inter-personal relationships within and around schools (Ertem, 2021; MacNeil, Prater & Bush, 2009). School leaders are gateway custodians for values, ideas, and practices that cultivate the positive school climate for science education. Meanwhile school leaders are responsible of setting school priorities and acquiring and allocating school resources for various school practices. School leaders valuing science education would be more likely to support spending limited funds on science equipment acquisition.

Model results also indicated that school-level mean science self-efficacy was statistically associated with school-level science achievement after taking into consideration the school demographic variables. A one-unit difference in school-level mean self-efficacy was associated with an estimated 12.63-point difference in school-level mean science achievement, which is approximately 40 percent of the NAEP science assessment's standard deviation.

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Introduction

The effects of motivation on achievement are central issues in educational psychology. Research has shown that students' motivation impacts students learning and achievement taking into consideration cognitive ability and other demographic and social characteristics. The AIR ESSIN Task 14 NAEP research team has conducted motivation research studies in reading and mathematics using National Assessment of Educational Progress (NAEP) data to investigate whether subject-specific motivation (reading and mathematics) is associated with achievement in the corresponding subject area. In order to more fully cover the spectrum of motivation research as it relates to NAEP achievement, the current study focuses on science motivation. This study uses the national 2015 NAEP data to explore the relationship between grade 8 students' science motivation, and science achievement. In addition, it investigates how school-level motivation and other school-level demographic variables are related to school-level variations in science achievement.

Similar to achievement status overall, the majority of US students' performance in science is below the NAEP proficiency level. The NAEP science assessment measures students' knowledge and abilities in the areas of Earth and space science, physical science, and life science at grades 4, 8, and 12 in both public and private schools periodically for the nation.[1] NAEP achievement levels define what students should know and be able to do: *NAEP Basic* indicates partial mastery of fundamental skills, and *NAEP Proficient* indicates demonstrated competency over challenging subject matter. In 2015, roughly two-thirds of 4th and 8th grade students performed below the *NAEP Proficient* achievement level (63 percent and 66 percent, respectively). The performance of the nation's 12th grade students was even worse given that 78 percent performed below the *NAEP Proficient* level. Moreover, 24 percent of 4th grade students, 32 percent of 8th grade students, and 40 percent of grade 12th students performed below the *NAEP Basic* level, indicating that many of the nation's students are struggling to master even fundamental science skills.

This discouraging trajectory in science achievement from elementary to secondary school is a great concern given the significance of mastering science and technology skills in school in preparation for the 21st century workplace. The demand in the science, technology, engineering, and mathematics (STEM) sector of the workforce has been increasing rapidly in today's information and technology era. The number of jobs in the STEM sector is predicted to grow two times faster than that for non-STEM jobs between 2019 to 2029 (The U.S. Bureau of Labor Statistics, 2021). Therefore, the public educational system needs to prepare, maintain, and attract students to fill these STEM job. The US needs to tighten the joints in the education pipeline from elementary to middle school to high school and increase the flow of students who are prepared for a STEM major in college and for eventually choosing a STEM occupation. Middle school is a critical joint along the pipeline for students' psychological development and

[1] NAEP is the largest nationally representative assessment of U.S. students' performance in a variety of academic subjects, including reading, mathematics, science, and social studies. Please see details on NAEP science assessment content at https://nces.ed.gov/nationsreportcard/science/.

academic achievement. The middle school years are a critical transitional period for students' mathematics and science achievement at high school or college. Early interest and success in science in the middle grades plays a significant role in students' decisions to take advanced STEM courses in high school, which inevitably impacts access to postsecondary and occupational opportunities (Singh, Granville & Dika, 2002). However, few research studies have investigated the role of science motivation for science achievement using middle school students. Additionally, most studies have had small samples which makes generalization difficult. The current study aims to add national data evidence to understand the relationship between science motivation and science achievement for middle school students and to provide suggestions for school practices, which may better elicit and keep students' interests in science during the middle school years.

Multiple research studies have identified sets of factors that influence academic achievement including students' socioeconomics background, students' motivation, students' academic discipline and behavior. In addition, school-level factors, such as school socioeconomic status, school educational resources e.g., science education instructional materials, lab equipment, teachers' quality, have also been found to be associated with students' achievement. School educational resources could potentially mitigate the effect of student individual socioeconomic factors on academic achievement by providing equal opportunities and access to learn for all students. Regarding the focus of this study—science—hands-on learning experiences are critical for motivating students to learn and master scientific concepts.

In short, this study aims to understand the role that science motivation plays in middle school science achievement by analyzing the 2015 grade 8 NAEP science data. The study focuses on identifying the unique contributions of student-level science motivation and aggregated school-level mean science motivation on science achievement. Hierarchical linear modeling is used to partition variability in student science achievement into within- and between-school components after student- and school-level demographic variables have been taken into account. In addition, the study investigates whether the identified unique contributions of science motivation to science achievement vary by gender, race/ethnicity, socioeconomic status groups (SES), and other demographic variables. To achieve these aims this study addresses the following six research questions:

1. Is science motivation significantly associated with NAEP science achievement?

2. Does the association between motivation and achievement persist even after student socio-demographic characteristics are taken into account?

3. Does the association investigated in research question 2 between motivation and achievement vary by gender and race/ethnicity, socioeconomic status, English learner (EL) and individualized education program (IEP) status?

4. Does the association between science motivation and science achievement vary across schools? If yes, are school-level characteristics related to the association between student science motivation and NAEP science achievement?

5. Is school-level mean science motivation related to school-level variations in student science achievement across schools?

6. Are school-level characteristics (socio-demographics) related to school-level variations in student science achievement across schools?

Theoretical Background[2]

Motivation can be thought of as the driver or energy expended in pursuit of a goal (science achievement in this study). It can either be extrinsic (based on actual or perceived rewards or punishments) or intrinsic (based on internalized beliefs and values about the importance of achieving the goal) (Deci, 1975). More generally, motivation has been defined as “the process whereby goal-directed activity is instigated and sustained” (Pintrich and Schunk, 2002, p. 5). Because one cannot directly observe this internal, latent process, a theoretical framework is necessary for measuring motivational beliefs. And as noted by Lameva and Choneteva (2013): “Due to the latency of psychological constructs, the construct motivation can be conceptualized in different ways, with different theories focusing on different psychological processes.” (p. 4). In this study, a socio cognitive theoretical perspective is used. The social cognitive perspective focuses on understanding students’ cognitive process, specifically on whether they choose to engage in learning tasks and how persistent they are while working on those tasks. Central motivational beliefs include individuals’ competence-related beliefs such as self-efficacy, interest, and subjective values (Eccles and Wigfield, 2002). Competence-related beliefs refer to beliefs about individuals’ current and future perceptions of the confidence they have of how well they can or will perform different tasks and activities currently or in the future; values refer to incentives or reasons for undertaking the task or activity. Specifically, motivational theories address two questions: (1) Can I do the task? and (2) Why am I doing the task? For example, in the domain of science, competence-related beliefs address individuals’ beliefs on whether they can do well in science. Values explain why individuals want to take more challenging science courses such as Physics or to participate in other science activities such as science fairs or science Olympiad. For the current study, the focus of science motivation is on self-efficacy and interest.

Science self-efficacy

Bandura (1994) defined self-efficacy as:

> [P]eople’s beliefs about their capabilities to produce designated levels of performance that exercise influence over events that affect their lives. Self-efficacy beliefs determine how people feel, think, motivate themselves, and behave. Such beliefs produce these diverse effects through four major processes. They include cognitive, motivational, affective, and selection processes. (p. 71)

[2] Part of the content from the section of the theoretical background is extracted from mathematics and reading motivational studies conducted by the AIR ESSIN research team.

Zimmerman (2000) summarized that (1) Self-efficacy measures focus on performance capabilities rather than personal qualities, such as physical or psychological capabilities; (2) Self-efficacy beliefs are multidimensional and differ on the basis of the domain of functioning. For example, self-efficacy beliefs about performing on a science test may differ from beliefs about performance on a reading test; (3) Self-efficacy beliefs depend on a mastery criterion of performance rather than on normative or other criteria. For example, students evaluate how well they are at solving a science problem, not how well they expect to do on the problem compared with other students; (4) Self-efficacy beliefs specifically refer to future performance and are assessed before students perform the relevant activities.

In Eccles's expectancy-value theory, self-efficacy beliefs are referred to as competence-related beliefs and these are of two types: ability beliefs and expectancy beliefs (Eccles et al.,1983). *Ability beliefs* are defined as individuals' perceptions of their *current* competence, particularly in a specific domain such as mathematics or science. These beliefs reflect evaluations not only of their own ability, but how their ability compares to others. *Expectancy beliefs* refer to how one thinks he or she will do on *future* tasks, either in the immediate or longer-term future. Thus, self-efficacy beliefs are of two types, one of which refers to present competence (ability beliefs) and the other to future performance (expectancy beliefs) (Wigfield & Eccles, 2000). Expectancy-value theorists hypothesize that expectancies for future performance are influenced by ability beliefs, the perceived difficulty of different tasks, individual goals, and previous experiences. For example, individuals' beliefs about their mathematics ability comes from many years of experiences with mathematics and reflect their own evaluation of their current skills in mathematics. Individuals' expectancies refer to how they think they will do in the future on a science-related activity (e.g., in an upcoming science course) will be based primarily on their beliefs about their ability in science. As important as these two constructs are theoretically, research has shown that they cannot easily be distinguished from each other empirically (Eccles & Wigfield, 1995; Eccles, Wigfield, Harold & Blumenfeld, 1993). Eccles and Wigfield (2002) concluded that, "[a]pparently, even though these constructs can be theoretically distinguished from each other, in real-world achievement situations they are highly related and empirically indistinguishable" (p. 119).

The formulation of self-efficacy by expectancy-value, with its emphasis on ability and expectancy beliefs, fits comfortably with Bandura's self-efficacy theory, given its emphasis on persons' beliefs about their capabilities to generate performances that have influence over events that impact their lives.

Extensive research has indicated that students with lower science self-efficacy perform less well on science tests, science tasks and activities, compared to students with higher science self-efficacy (Bassi et al., 2007; Britner, 2008; Bircan and Sungur, 2016; Kaya & Bozdag, 2016; Larry and Wendt, 2021; Lofgran, Smith & Whiting, 2015). For example, Bircan and Sungur (2016) investigated 861 seventh grade students and found that motivational beliefs (i.e., self-efficacy and task value) positively and significantly related to students' science achievement and self-efficacy was the best predictor of science achievement. Similarly, Yerdelen-Damar and Pesman (2013) focused on examining how self-efficacy relates to physic achievement for high school students and found that self-efficacy was the strongest predictor of physics achievement. Kaya and Bozdag (2016) conducted a study with a total of 698 students in sixth, seventh and eighth grade level of a state secondary school. They found that high self-efficacy has proven to be a crucial characteristic among students with high science assessment scores because it represents one's competence to deal with a possible situation, one's judgement for their learning and achievement skills, one's capacity to manage and resist against difficulties in their duties. Finally, students with high perceived self-efficacy in science are more likely to select more science courses and participate in science extracurricular activities clubs (Kupermintz, 2002; Lodewyk &Winne, 2005) than students with low science self-efficacy.

Science interest

Having an interest in science (hereafter referred to as "science interest") is also an important motivational construct. Hidi and Renninger (2006) define interest as a learners' predisposition to engage and reengage specific disciplinary content (e.g., mathematics, science) over time as well as the psychological state that accompanies this engagement. Under the framework of the expectancy-value theory, science interest emphasizes the enjoyment of science; in this regard, the construct is similar to intrinsic motivation in self-determination theory (Ryan & Deci, 2000). When students intrinsically like science, they are more likely to deeply engage in science activities and be more resilient in the face of difficulty while working on science assignments. However, the effects of interest on science performance are inconclusive from the literature. Schiefele, Krapp and Winteler (1992) conducted a meta-analysis of the relationship between subject matter interest and academic achievement. They summarized that the domain-specific interest in physics, science and mathematics had a relatively stronger relationship with students' academic achievement compared to other subjects. Chang and Cheng (2008) found that a combined scale with science self-efficacy and interest is significantly associated with student's science achievement. However, Areepattamannil, Freeman & Klinger (2011) conducted HLM analysis with 13,985 15-year-old students from 431 schools across Canada and found that student's general interest in science was negatively associated with their science achievement by taking into consideration of other motivation variables (i.e., self-efficacy and self-concept) and student- and school-level demographic characteristics. Zhang, et. al. (2021) found similar results for the effects of mathematics interest on mathematics achievement. After mathematics identity and self-efficacy and other contextual factors were taken into consideration in the model, mathematics interest was not significantly associated with mathematics performance.

Singh, Granville, and Dika (2002) used the 1988 National Education Longitudinal Study to investigate how mathematics and science achievement are affected by interest, and academic engagement. They found that students who had a higher level of science interest are more likely to spend more time on science homework and watch less TV on the weekdays. They also found that science interest is influenced by science self-efficacy. Theoretical work shows important connections between self-efficacy and interest. According to Eccles's expectancy-value theory and Bandura's self-efficacy theory, self-efficacy beliefs should influence interest beliefs. Wigfield (1994) proposed a developmental view on the relationship between self-efficacy beliefs and interest beliefs. He thought that young children are likely to view self-efficacy and interest beliefs as being independent of each other. Over time, particularly in the achievement domain, children begin to attach more value to activities in which they do well. Eventually, self-efficacy beliefs and interest become positively related to one another.

Gender, race/ethnicity, science motivation and science achievement

Gender plays a significant role in shaping students' types of achievement motivation and thus influences achievement behaviors (e.g., participating in science fair) and related achievement outcomes (e.g, science performance test). Although the gender gaps in science achievement have narrowed, the gender difference in attitudes toward science and science self-efficacy persist. A large body of research on gender difference in interest in science shows that male students are more likely than females to view science positively and to be more interested in science and math as a career. (Feist, 2006; Catsambis, 1995). For example, Baram-Tsabari and Yarden (2011) found that the gender gap widened in a stereotypical manner with an increase in age with girls being increasingly interested in biology and boys more interested in physics and technology.

The gender difference in self-efficacy toward science is also well-documented and the findings are not consistent but suggest that females on average show score higher on science self-efficacy than males. Chumbley, Haynes and Stofer (2015) used a modified version of the Science Motivation Questionnaire II (SMQ II) to investigate how the secondary agriculture students conceptualize their motivation to learn agriscience. They found no significant correlations between gender and motivation to learn science. Also, they found that compared to male students, female students experienced a higher motivation from factors like intrinsic motivation, self-efficacy, self-determination, and grade motivation. However, males are more motivated by career than female students. In other studies investigating the gender difference in self-efficacy and their relationship with science achievement, researchers also found that girls reported stronger science self-efficacy than boys (Britner, 2008; Britner & Pajares, 2006). Interestingly, Lee (2016) investigated the gender difference among South Korean high schools' students in science and technology learning and found an opposite relationship. Male students were highly motivated to do well in science as measured by intrinsic motivation and relevance, and self-determination compared to females.

Lee (2016) also examined gender difference for the various fields in science for grade 11 students. In Earth Science classes, female students earned higher grades and reported stronger self-efficacy than male students while in life science classes, female students earned higher grades than male students but did not report stronger self-efficacy. In Physics, no gender difference in grades and self-efficacy were reported (Britner & Pajares, 2006).

Students' science achievement varies by their race/ethnicity status. Black and Hispanic students tend to achieve at lower levels and participate less in STEM degree programs and occupations than White students (Anderson & Kim, 2006; Herrera & Hurtado, 2011; Quinn & Cooc, 2015; Schultz et al., 2011). Scholars have offered a number of possible answers, pointing to factors ranging from inequalities in students' social class backgrounds, to differences in cultural orientations toward schooling, to various inequalities between and within schools themselves

(Aschbacher, Li & Roth, 2009; Downey, 2008; Rothstein, 2004). For example, Cridage and Cridage (2015) found that Asian families believe that science has a greater long-term impact, so the children get a lot of support for their science studies. Riegle-Crumb, Moore, and Wada (2011) used a national representative data of 8th graders and found that white students have generally higher levels of parental education and report more books in home.

Motivation is another important factor in interpreting the differences in academic behaviors and achievement when comparing White and minority students. Research has shown that there are differences in the level of science self-efficacy across different race/ethnicity groups. For example, Lofgran, Smith, and Whiting (2015) found that Hispanic students' level of science self-efficacy was significantly lower than that of White students for the 6th, 7th, 8th, and 9th grades.

Social contexts, motivation, and achievement

Students' motivational beliefs develop under the influence of various social contexts, including family and school. Therefore, a better understanding of students' motivational beliefs as they relate to science performance requires having knowledge of family and school contexts as well.

Family environment is integral of students' academic success. Parents with higher levels of education and higher earnings are able to provide greater learning opportunities and a more academic environment at home than parents with lower levels of education and lower earnings. Parental support is an important factor in influencing the development of students' science motivational beliefs (e.g., Archer, DeWitt & Willis, 2010; Aschbacher et al., 2010; Navarro, Flores & Worthington, 2007;). In addition, students' science motivation and achievement are also related to the quality of parent-child science interactions. Parents positivity, valuing STEM achievement, and school-focused behaviors are associated with students' science motivation beliefs (Simpkins, Price & Garcis, 2015). Overall, family income and parents' education have been shown to relate to students' motivation and achievement.

School context is also an important factor in understanding student achievement. Freiberg (1999) argued that school influences student achievement through student attachment, commitment, involvement, and, most importantly, through schools' resources and academic climate. Perry and McConney (2010) found that school SES was significantly associated with students' academic achievement. The relationship was similar for all students regardless of their level of SES. Rumberger and Parlardy (2005) used the National Education Longitudinal Survey of 1988 (NELS:88) to examine individual and school effects on achievement growth between grade 8 and grade 12 in mathematics, science, reading, and history. They found that school-level SES had as much impact on students' achievement as the students' individual-level SES did, after controlling for other background factors.

Modern motivation theories not only consider motivation as an individual characteristic, but also acknowledge the important impacts of social context and interpersonal relations on motivation. The current study uses a modern motivational framework to conceptualize reading motivation and its impacts on reading achievement. Intrinsic and extrinsic reading motivation beliefs are the major components investigated in this study. Student family and school background variables are included to capture the social context so as to better understand the relationships between science motivation and achievement.

Methods

Data

This study uses 2015 National Assessment of Educational Progress (NAEP) grade 8 science assessment data, based on a nationally representative sample of 110,900 students from 6,050 schools. Because the current study's focus is on public school students, students from private schools, Bureau of Indian Education schools, and Department of Defense schools were excluded from the sample. In addition, around 24 percent of students had missing demographics or science motivation information needed for the hierarchical linear model (HLM) analysis, so were also excluded from the final analytic sample. As a result, the final analytic sample contained roughly 81,470 students from 4,423 schools. Table 1 shows the distribution of the final analytic sample by sex, race/ethnicity, and other socio-demographic variables.

Table 1. Descriptive statistics for final analytic sample

Student demographic characteristics	Final analytic sample: Unweighted number of students	Unweighted percentage	Weighted percentage[1]: Percentage	Standard error
Total	81470	100.0	100.0	†
Gender				
Male	40570	49.79	50.36	0.17
Female	40910	50.21	49.64	0.17
Race/ethnicity				
White	50440	61.91	53.84	0.48
Black	10260	12.59	13.84	0.36
Hispanic	10260	12.59	23.70	0.48
Asian/Pacific Islander	4050	4.97	5.23	0.24
Other	3740	4.59	3.88	0.12
NSLP eligibility				
Eligible	38830	47.66	50.00	0.57
Not eligible	42020	51.58	48.96	0.58
Information not shown	42020	51.58	1.04	0.20
English language learner				
Yes	3350	4.11	5.63	0.17
No	78130	95.89	94.37	0.17
Missing	0	0.00	0.00	0.00
Individualized Education Program				
Yes	9850	12.09	11.97	0.14
No	71620	87.91	88.03	0.14
Missing	0	0.00	0.00	0.00

† Not applicable.

[1] Weighted using grade 8 NAEP survey weights.

NOTE: NSLP=National School Lunch Program. Values may not sum to totals because of rounding. Numbers are rounded to the nearest 100 or 10 based on the NCES technical standards.

SOURCE: U.S. Department of Education, National Center for Education Statistics, National Assessment of Educational Progress, 2015 Grade 8 Science Assessment.

Tables 2 and 3 display the comparison of the final analytic sample to the original NAEP public school sample. The results show that these two samples are very similar in terms of basic demographic characteristics. Compared to the NAEP public school sample, the final analytic sample has a slightly higher percentage of White students. The percentage of students who were eligible for the National School Lunch Program (NSLP), were English learners (ELs), or had an Individualized Education Program (IEP) in the analytic sample were very similar to the NAEP public school sample with a less than 1 percentage point difference for each variable (except for NSLP with around a 1.5 percentage point difference). In addition, NAEP science performance in the final analytic sample was very similar to that of the original NAEP public school sample (154 versus 153 when rounded). As expected, the standard errors of the final analytic sample were slightly larger in all cases than those in the NAEP public school sample since the analytic sample is smaller. Overall, no indication that missing data biased the study's results was detected from the various analyses conducted to examine this issue[3].

Table 2. Comparison of the final analytic sample with the 2015 grade 8 public school sample, by student subgroups

Student demographic characteristics	Final analytic sample		NAEP public school sample	
	Percentage	Standard error	Percentage	Standard error
Total	100.0	†	100.0	†
Gender				
Male	50.36	0.17	50.89	0.13
Female	49.64	0.17	49.11	0.13
Race/ethnicity				
White	53.84	0.48	50.88	0.42
Black	13.84	0.36	15.24	0.29
Hispanic	23.70	0.48	24.85	0.40
Asian/Pacific Islander	5.23	0.24	5.56	0.22
Other	3.88	0.12	3.48	0.11
NSLP eligibility				
Eligible	50.00	0.57	51.47	0.46
Not eligible	48.96	0.58	47.08	0.50
Information not shown	1.04	0.20	1.45	0.26
English language learner				
Yes	5.63	0.17	6.15	0.14
No	94.37	0.17	93.81	0.14
Missing	0.00	0.00	0.04	0.01
Individualized Education Program				
Yes	11.97	0.14	12.27	0.11
No	88.03	0.14	87.70	0.11
Missing	0.00	0.00	0.03	0.01

† Not applicable.
NOTE: NSLP=National School Lunch Program. Detail may not sum to totals because of rounding. Numbers are rounded to the nearest 100 or 10 based on the NCES technical standards.
SOURCE: U.S. Department of Education, National Center for Education Statistics, National Assessment of Educational Progress, 2015 Grade 8 Science Assessment.

[3] The analyses included student-level and school-level demographics comparisons between the analytic sample and the full NAEP sample. In addition, NAEP science performance was compared between the analytic sample and the full NAEP sample.

Table 3. Science achievement comparison of the final analytic sample with the NAEP public school sample on the 2015 NAEP grade 8 assessment, by operational population student subgroups

Student demographic characteristics	Final analytic sample		NAEP public school sample	
	Average composite scale score (weighted)	Standard error	Average composite scale score (weighted)	Standard error
Overall score	154.41	0.24	152.89	0.20
Gender				
Male	156.13	0.39	154.34	0.33
Female	152.67	0.42	151.40	0.37
Race/ethnicity				
White	164.94	0.33	165.02	0.28
Black	132.59	0.59	131.11	0.47
Hispanic	141.25	0.68	139.17	0.55
Asian/Pacific Islander	163.35	0.98	163.09	0.99
Other	155.97	1.31	154.13	1.10
NSLP eligibility				
Eligible	141.66	0.42	139.82	0.35
Not eligible	167.49	0.36	167.04	0.33
Information not shown	151.88	2.75	157.70	2.86
English language learner				
Yes	111.53	1.39	109.52	1.13
No	156.97	0.29	155.75	0.27
Missing	0.00	0.00	117.35	0.00
Individualized Education Program				
Yes	125.24	0.72	123.81	0.61
No	158.38	0.32	156.98	0.31
Missing	0.00	0.00	0.00	0.00

† Not applicable.
NOTE: NSLP=National School Lunch Program. Detail may not sum to totals because of rounding. Numbers are rounded to the nearest 100 or 10 based on the NCES technical standards.
SOURCE: U.S. Department of Education, National Center for Education Statistics, National Assessment of Educational Progress, 2015 Grade 8 Science Assessment.

Because the HLM analysis includes the school-level, the representativeness of schools in the final analytic sample is also important for the generalization of the study findings to the full NAEP public school sample. Table 4 compares school demographic characteristics between the final analytic sample and the original NAEP public school sample. The results show that the final analytic sample was also very similar to the original NAEP public sample in terms of school-level basic demographic characteristics. The distributions of school key demographic variables included in the study were almost the same between the final analytic sample and the NAEP public school sample. For example, 14.5 percent of schools had 0–25 percent of students eligible for NSLP in the final analytic sample, and the percentage for the NAEP public school sample was 14.6. Similar patterns were observed for other variables.

Table 4. Comparison of the final analytic sample with the 2015 grade 8 public school population, by school characteristics

School characteristics	Final analytic sample		NAEP public school population[1]	
	Percentage	Standard error	Percentage	Standard error
Percent of students eligible for NSLP				
0–25 percent	14.49	0.67	14.57	0.67
26–50 percent	28.53	0.83	28.51	0.82
51–75 percent	28.17	1.20	27.56	1.18
76–100 percent	28.81	0.96	29.35	0.99
Percent enrollment identified as English learner				
0–25 percent	92.52	0.71	92.51	0.66
26–50 percent	5.07	0.60	5.03	0.54
51–75 percent	2.01	0.52	1.86	0.45
76–100 percent	0.40	0.12	0.59	0.12
Percent of students in special education				
0–25 percent	91.71	0.62	91.51	0.56
26–50 percent	7.19	0.64	7.03	0.57
51–75 percent	0.27	0.07	0.34	0.08
76–100 percent	0.83	0.25	1.12	0.28
Percent of students absent on average day				
0–5 percent	81.10	0.82	80.92	0.74
More than 5 percent	18.90	0.82	19.08	0.74
School percent of Black students (mean)	15.16	0.49	16.27	0.39
School percent of Hispanic students (mean)	19.49	0.47	19.78	0.34

[1] Statistics for the NAEP public school population exclude schools with missing data.

NOTE: NSLP=National School Lunch Program. Detail may not sum to totals because of rounding.

SOURCE: U.S. Department of Education, National Center for Education Statistics, National Assessment of Educational Progress (NAEP), 2015 Grade 8 Science Assessment.

Overall, student and school characteristics between the final analytic sample and NAEP public school sample were very similar. For the purposes of this study, the final analytic sample can be taken as representative of the entire NAEP public school sample.

Variables used in the HLM analysis

The selection of variables used in the HLM models was based on the theoretical background discussed in the previous section, variables which demonstrated an important relationship between them and science achievement.

Student-level variables

Demographic Background Variables. Student background variables included gender, race/ethnicity, socioeconomic status (SES), ELL status, and IEP status. Gender and race/ethnicity were dummy coded variables. Female students were coded as 1 and the reference group was male students who were coded as 0. Race/ethnicity categories were coded as dummy variables for Black, Hispanic, Asian/Pacific Islander, and Other[4], with White as the reference group. SES was coded using a composite developed in previous research by Xie and Broer (2016). The resulting index, which incorporates NSLP eligibility, parental education, and other items from the NAEP contextual questionnaire, takes integer values ranging from 0 to 16 (see Appendix A for details). Student EL and IEP status were also dummy coded variables—students who were EL or had IEPs were both coded as 1, those not, 0.

Science Motivation Variables. The current study includes six items drawn from the NAEP student questionnaire related to science motivation. The selection of these six items was based on the theories of science motivation discussed in the previous section. These six items were: “I like science” (interest); “Science is one of my favorite activities” (interest); “I take science only because I have to” (interest); “How often do you feel you can understand what the teacher talks about in science class?” (efficacy); “How often do you feel you can do a good job on your science assignments?” (efficacy); “How often do you feel you can do a good job on your science tests?“(efficacy). The first three items were a 4-point Likert scale consisting of “strongly disagree,” “disagree,” “agree,” and “strongly agree.” The fourth to sixth items also contain four response categories: “never,”” hardly ever,” “always,” and “almost always.” A value of 0 was assigned to the least positive response, and a value of 3 was assigned to the most positive response.

Exploratory and confirmatory factor analyses for science motivation

To examine the underlying structure of the six student-reported variables related to science motivation, both exploratory and confirmatory factory analyses (EFA[5] and CFA) were conducted. EFA results suggested that a two-factor model fit the data best, which was confirmed by the CFA results. Model fit indices from the CFA indicated that the hypothesized two-factor model fit the data well (Hu & Bentler, 1999): the Root Mean Square Error of Approximation (RMSEA) was 0.06, the Comparative Fit Index (CFI) and the Tucker-Lewis Index (TLI) were 0.99 and 0.98, as seen in Table 5. Based on the CFA results, two science motivation indices (labeled “science efficacy” and “science interest”) were constructed by averaging item scores for each index. Both indices show acceptable values for internal consistency reliability (Cronbach, 1951) 0.83.

[4] Other includes Native American/Alaska Natives and students who are unclassified.

[5] Results from exploratory factor analysis (EFA) with two-factors solution are not reported in the table as they are same as the confirmatory factor analysis model reported in Table 5. EFA results with other numbers of factors were not reported as the models did not converge.

Table 5. Confirmatory factor analysis of NAEP science motivation items

Mode fit indices		Model fit summary
RMSEA		0.06
CFI		0.99
TLI		0.98
Factor	**Item**	**Standardized factor loading**
Interest	I like science.[1]	0.89
	Science is one of my favorite subjects.[1]	0.87
	I take science only because I have to. (reverse coding)[1]	0.63
Efficacy	Can understand what teacher talks about in science[2]	0.75
	Can do a good job on my science tests[2]	0.82
	Can do a good job on my science assignments[2]	0.78

[1] Four response categories ranging from strongly disagree with the statement to strongly agree.
[2] Four response categories ranging from never or hardly ever to always or almost always.
NOTE: All variables were recoded from 0 to 3. The estimates of Cronbach's alpha are .83 and .83 for Interest and Efficacy factors, respectively.
SOURCE: U.S. Department of Education, National Center for Education Statistics, National Assessment of Educational Progress (NAEP), 2015 Grade 8 Science Assessment.

School-level variables

School Demographic Characteristics. School characteristics included the following variables: percentage of students eligible for the NSLP; percentage of students identified as EL; percentage of students with IEPs; percentage of Black students; and percentage of Hispanic students. For percentage of students eligible for the NSLP and percentage of students identified as IEP, the original categories were: 0 percent, 1–5 percent, 6–10 percent, 11–25 percent, 26–50 percent, 51–75 percent, 76–90 percent, and 91–100 percent. To create equal intervals for facilitating the interpretation of HLM results, these two variables were recoded into quartile categories. Percentage of Black students and percentage of Hispanic students were continuous variables with a theoretical range of 0 to 100 percent.

School Academic Environment. In addition to the school-level demographic variables listed above, the study also accounted for the school-level academic environment as captured by the following three variables: student-level aggregates of (1) science interest, and (2) self-efficacy as well as (3) the percentage of students absent on an average day. The percentage of students absent on an average day is a categorical variable[6] with two categories: 0–5 percent and more than 5 percent.

School Supplies for Science Instruction Science is a subject that needs to be taught through hands-on learning experiences by providing students access to practical instructional supplies. The NAEP school questionnaire collected data on school supplies provided to science teachers. Both exploratory and confirmatory factory analyses (EFA and CFA) were conducted for the school supplies items. EFA results suggested that a two-factor model fit the data best, which

[6] The original categories for this variable were 0–2 percent, 3–5 percent, 6–10 percent, and more than 10 percent. It was impossible to create an equal interval variable; therefore, two categories were used.

was confirmed by the CFA results. Model fit indices from the CFA indicated that the hypothesized two-factor model fit the data well (Hu & Bentler, 1999): the Root Mean Square Error of Approximation (RMSEA) was 0.06, the Comparative Fit Index (CFI) and the Tucker-Lewis Index (TLI) were 0.99 and 0.91, as seen in Table 6. Based on the CFA results, two indices were constructed (Labeled "Basic teaching and learning supplies for science" and "Advanced teaching and learning supplies for science") by averaging item scores for each index. The factor scores of basic teaching and learning supplies for science ranged from 0.50 to 0.62. And the factor scores of advanced teaching and learning supplies for science was from 0.53 to 0.69. Both indices show acceptable values for internal consistency reliability (Cronbach, 1951), with values of 0.73 and 0.89.

Table 6. Confirmatory factor analysis of NAEP school supplies items

Mode fit indices		Model fit summary
RMSEA		0.06
CFI		0.99
TLI		0.91
Factor	**Item**	**Standardized factor loading**
Basic teaching and learning supplies for science	Science magazines/books (including digital forms, such as online magazines and books)	0.50
	Student access to class computers in class for science instruction	0.54
	Student access to computer labs for science instruction	0.53
	Computerized science labs for classroom use	0.62
	Audiovisual materials for science instruction	0.57
Advanced teaching and learning supplies for science	Supplies-science demonstrations	0.63
	Supplies for science labs	0.69
	Scientific measurement instruments (e.g., telescope, microscopes, thermometers, or weighting scales)	0.53

NOTE: The survey asked, "To what extent are any of the following available to eighth-grade teachers who teach science?". Four response categories ranging from not at all or small extent to moderate extent or large extent. All variables were recoded from 0 to 3. The estimates of Cronbach's alpha are .73 and .89 for Basic and Advanced factors, respectively.
SOURCE: U.S. Department of Education, National Center for Education Statistics, National Assessment of Educational Progress (NAEP), 2015 Grade 8 Science Assessment.

Outcome variables

2015 Science Grade 8 NAEP Assessment scores

NAEP reports an overall score for science which is a composite of three subscales: Physical Science, Life Science, and Earth and Space Sciences. The overall score of the 2015 grade 8 NAEP science performance (scale scores) was the outcome variable used in the current study. NAEP scale individual level scores are reported as "plausible values" because by design, students are administered only a small subset of the total pool of assessment items, not the entire assessment[7]. Multiple imputation procedures are used to produce a set of twenty "plausible values" (e.g., plausible scores) for each student taking the reading assessment. In generating the plausible values, NAEP uses a "conditioning model" that includes all the variables from the various contextual questionnaires NAEP collects along with the responses of students to the particular portion of the assessment items that they are assigned to.

Analysis

A series of hierarchical linear models (HLM) were developed to address the research questions starting from the null model to a set of contextual models at both the individual and school levels. Mplus Version 8.1 was used for the HLM analysis, which implemented procedures to handle multiply imputed data as well as adjusting student sample weights. First, a null model without any predictors at both levels was estimated to determine how much of the variance in the dependent variable (NAEP grade 8 science scores) could be accounted for by school-level differences. Substantial variance between schools justified the need to use HLM analysis. Sufficient variance has been interpreted as 10 percent or more (Ma, 2001). Then, twelve sequential HLM models were conducted to address the seven research questions delineated in the previous section. Table 7 presents the HLM results.

Model 1, the HLM null model, provides a baseline for the decomposition of variance. The total variance is the sum of the two displayed components: 262.37 (school-level) + 837.55 (student-level) = 1099.92 (total). The intraclass correlation (ICC), or the proportion of variance in student science achievement between schools is defined as: between-school variance (τ) /total variance ($\tau + \sigma^2$). Therefore, in this study ICC = 262.37/ (262.37 + 837.55) = 0.24, which means that 24 percent of the total variance in 8th grade science achievement is attributable to between-school heterogeneity and 76 percent is attributable to within-school heterogeneity. This substantial variation across schools justified the need to use HLM for further analysis. This model also indicates that the grand mean science achievement for all schools was 152.35 points which is very similar to the national public sample mean shown in Table 3 above.

Results

The subsequent section presents the HLM results to address the six research questions.

Research question 1: Is science motivation significantly associated with NAEP science achievement?

Model 2, which adds the student science motivation variables (i.e., interest and self-efficacy), indicates that students' interest and self-efficacy in the science subject are significantly associated with science achievement. Without controlling for any demographic or other related variables, a one-unit difference in student self-efficacy (rated on a 4-point scale) is associated with an estimated 15.19-point difference in science achievement - roughly half of the assessment's standard deviation (32)[7]. A one-unit increase in student interest (rated on a 4-point scale) is associated with an estimated 4.26-point increase in science achievement—

[7] This is the standard deviation for the final analytic sample. The standard deviation for grade 8 science by all students from national public schools is 32 points.

about 1/8th of the assessment's standard deviation. Overall, the addition of two student motivation variables accounts for 19 percent of the within- school variance.

Research question 2: Does the association between motivation and achievement persist even after student social demographic characteristics are taken into account?

Model 3 added student-level demographic variables, including seven dummy variables (Female, Black, Hispanic, Asian, Other,[8] ELL, and IEP) and the composite score for students' socioeconomic status (SES). When differences in students' social demographic backgrounds were accounted for, the relationships between student science motivation and science achievement remained statistically significant but were reduced in size for the self-efficacy variable. Specifically, when controlling for all student-level demographic variables (i.e., gender, race/ethnicity, ELL, IEP, and SES), each one-unit difference in student self-efficacy is associated with a difference of about 10.45 points in science achievement—just over a third of the assessment's standard deviation; and each one-unit difference in student interest is estimated to result in a difference of about 4.31 points in science achievement—a value that is almost identical to that found in Model 2. All student-level demographic variables were statistically significantly associated with science achievement, except for Asian. Overall, student-level demographics explained an additional 20 percent of the variance within schools (39 percent explained in Model 3 compared to 19 percent explained in Model 2).

Research question 3: Does the association investigated in research question 2 between science motivation and science achievement vary by gender, race/ethnicity, socioeconomic status, English language learner status, and/or individualized education program status?

Model 4 added sixteen interaction terms between student science motivation (i.e., interest and self-efficacy) and student-level demographic variables to examine whether the association between science motivation and achievement varied by student demographic characteristics. The addition of the interaction terms alters the interpretation of the main effects of motivation on achievement. In Model 2, the coefficient is interpretable as the mean within-school relationship between motivation and achievement across all students. While in Model 3, it is interpretable as the mean relationship for the "average" student in each school (i.e., students whose background characteristics are set to zero, after background characteristics have been centered about their school-level means). The interaction effects are then estimates of the difference in the slopes of the motivation variables associated with an increment of 1 point in the interacted variable. There were three statistically significant interaction effects-all associated with science interest. First, it was the interaction of SES with science interest. The coefficient of 0.19 associated with the $SES \times Interest$ interaction indicates that for students with a given level of science interest, an increase in SES of one point is associated with a 0.19 increase in the science interest slope. all else being equal. For dummy-coded indicator variables, this is interpretable as the difference in motivation slopes between the indicated group and the reference group. Thus, the coefficient of -1.73 for $Female \times Interest$ implies

[8] A combination of the American Indian/Alaska Native and Other racial/ethnic categories. White was the omitted (reference) variable for the race/ethnicity set of dummy variables.

that the slope associated with science interest is estimated to be -1.73 points lower for female than for male students. The third and final interaction was between having an IEP and science interest where the 2.95 value means that the slope for science interest is estimated to be 2.95 points higher for those students without an IEP compared to those with one, when other variables in the model held constant.

Given there were no interaction effects between science self-efficacy and student's social demographic background Model 5 contains only the interactions with the science interest variable plus the student level demographic variables. In this "trimmed" model, the SES × Interaction effect is unchanged (0.19) and the science interest coefficient for female students is estimated to be -2.08 points lower than for male students—just slightly larger than the -1.73 found in Model 4. The IEP × interest interaction effect is only slightly smaller in the trimmed model—2.58 versus 2.95. Interestingly, the Hispanic × interest interaction which was not significant in Model 4 was statistically significant in Model 5. The effect of science interest on science achievement is 1.52 points greater for Hispanic students compared to White students.

Research question 4: Does the association between science motivation and science achievement vary across schools? If any variations, do school-level characteristics help explain the association between student science motivation and NAEP science achievement?

Model 6 allowed random slopes for the two science motivation variables to investigate whether the association between motivation and achievement varies across schools. The estimated variance of the slopes for science interest and science efficacy were 1.86 and 11.86, both of which were statistically significant. Based on this result, we infer that the associations between the two science motivation variables and science achievement varied significantly across schools. Therefore, science interest and self-efficacy were treated as random effect variables in the subsequent models.

To address the second part of research question 4, models 7, 8, and 9 added a series of school-level variables (mean school-level science motivation, school basic and advanced teaching and learning supplies for science, and proportion of students having free and reduced lunch) to identify school characteristics that might be playing a role in the varying relationships between science motivation and achievement across schools. Model 8 results indicated that schools that provided advanced teaching and learning supplies for science instruction had a statistically significant moderating effect of science interest on science achievement, with a coefficient of 0.88. That indicated that a one-unit increase in the measure of whether school providing advanced learning and teaching supplies was associated with an estimated 0.88-point increase in the slope of student science self-interest on the science assessment score, all else being equal. The positive association between student science interest and NAEP science achievement was stronger for schools providing more advanced teaching and learning supplies for science instruction. The significant effect was not observed for science self-efficacy. However, the results did indicate that school-level mean science self-efficacy was a statistically significant moderator of the effect of student science self-efficacy on science achievement.

A one-unit increase in school mean self-efficacy was associated with an estimated 5.52-point increase in the slope of student science self-efficacy on the science assessment score, all else being equal.

Research question 5: Does school-level mean science motivation explain school-level variations in student science achievement across schools?

Model 10, which added the school mean motivation variables, indicates that school mean science self-efficacy is highly associated with school mean science achievement net of student level science self-efficacy and student background variables. The estimated coefficient for school mean science self-efficacy suggests that for each unit difference in school mean science self-efficacy, there is an estimated 23.29-point difference in school mean science achievement, which is 73 percent of the science assessment's standard deviation. The inclusion of the school mean motivation variables explained 20 percent of the variance between schools, using Model 9 as the baseline.[9] This suggests that, in addition to student-level motivation and students' own backgrounds, motivation at the school-level is substantially related to science achievement.

Research question 6: Do school-level characteristics (social demographics) explain school-level variations in student science achievement across schools?

Models 11 and 12 added school social demographics to identify school-level characteristics that might explain school-level variations in student science achievement across schools. The model results indicate that school demographics (i.e., race/ethnicity distribution, school proportion of NSLP, EL, and IEP) were significantly associated with school-level science achievement. In addition, the results indicate that the coefficient for schools with more than 5 percent students absent on an average day is estimated to be -2.20 points lower than for schools with 5 percent or less students absent on an average day. Finally, there is an estimated 1.39-point difference in school mean science achievement associated with each one-point increase on the Likert scale associated with whether schools provide advanced teaching and learning supplies.

Summary of Results

Model 13 is our final model with random slope models and random intercept. Overall, the model results indicate:

1. Both students' science self-efficacy and interest factors are significant positive predictors of science achievement after controlling student background and other variables, although self-efficacy has a larger effect. After taking into consideration of all demographics and other interaction variables, a one-unit difference in student self-

[9] According to Raudenbush and Bryk (2002), "Technically speaking, the variance explained in a level-2 parameter, such as [the random intercept], is conditional on a fixed level-1 specification. As a result, the proportion reduction in variance statistics at level 2 are interpretable only for the same level-1 model. Consequently, we recommend that researchers develop their level-1 model first, and then proceed to enter level-2 predictors into the analysis" (p. 150).

efficacy (rated on a 4-point scale) would result in an estimated 10.67-point difference in science achievement, which is approximately one third of the standard deviation. A one-unit increase in student interest (rated on a 4-point scale) would also result in an estimated 3.27-point increase in science achievement. This finding is in consistent with results from other motivation studies conducted by the AIR Research team using the NAEP mathematics and reading data.

2. The relationship between science interest and science achievement vary by gender, race/ethnicity, individualized education program status. No interaction effects were observed for science self-efficacy. The mode results indicate that the science interest coefficient for female students is estimated to be -1.98 points lower than for male students after controlling all other variables. That is to say, the role of science interest on science achievement is larger for male students compared to female students. Similarly, the science interest coefficient for students who enrolled in IEP program is estimated to be -2.62 points lower than for those who did not after controlling for all other variables. Also, the role of science interest on science achievement is larger for students with a higher SES background compared to those from a lower SES background. However, no interaction effects were observed for science self-efficacy.

3. The data showed that the associations between science interest and self-efficacy and achievement vary significantly across schools. The positive association between student science interest and NAEP science achievement was stronger for schools providing more advanced teaching and learning supplies for science instruction, although the size of the effect is not substantial. In addition, model results found that school-level mean science self-efficacy is statistically significant moderating the role of science self-efficacy on science achievement. The effects of self-efficacy on science achievement were higher for schools with a higher level of science self-efficacy.

4. Model results also indicated that school-level mean science self-efficacy was statistically associated with school mean science achievement after taking into consideration of other school demographic variables, a one-unit difference in school-level mean self-efficacy would result in an estimated 12.63-point difference in school-level mean science achievement, which is approximately 40 percent of the standard deviation.

Table 7. Summary of HLM Results.

Variable	Model 1: Null Model		Model 2: Motivation Only		Model 3: Motivation and Demographic Variables		Model 4: Interactions	
	Est.	SE	Est.	SE	Est.	SE	Est.	SE
Fixed Effects								
Intercept: school mean achievement	152.35***	0.49	152.29***	0.49	152.33***	0.50	152.33***	0.50
Interest			4.26***	0.25	4.31***	0.22	2.46**	0.85
Self-efficacy			15.19***	0.32	10.45***	0.29	10.78***	0.93
Female					-3.78***	0.32	0.72	0.96
Black					-17.50***	0.67	-17.14***	1.66
Hispanic					-4.11***	0.63	-7.79***	1.63
Asian					0.81	0.84	-3.60	2.50
Other Race					-3.15***	1.28	-6.19*	2.41
ELL					-26.02***	1.17	-26.39***	3.50
IEP					-23.86***	0.61	-26.94***	1.54
SES					1.68***	0.05	1.35***	0.13
Female*Interest							-1.73***	0.46
Female*Self-efficacy							-0.78	0.50
Black*Interest							1.35*	0.63
Black*Self-efficacy							-1.40	0.77
Hispanic*Interest							1.23	0.84
Hispanic*Self-efficacy							0.81	0.77
Asian*Interest							0.21	0.99
Asian*Self-efficacy							1.86	1.07
Other Race*Interest							-0.09	0.95
Other Race*Self-efficacy							1.55	1.25
ELL*Interest							-1.02	1.82
ELL*Self-efficacy							1.39	1.80
IEP*Interest							2.95***	0.73
IEP*Self-efficacy							-0.88	0.84
SES*Interest							0.19**	0.06
SES*Self-efficacy							0.01	0.07
Random Effects								
Intercept (variance between schools)	262.37***	16.20	277.62***	16.66	294.45***	17.16	294.69***	17.17

See notes at the end of the table.

Variable	Model 5: Interactions (reduced)		Model 6: Random Slopes		Model 7: Random Slopes (Mean mot as predictors)		Model 8: Random Slopes (school supply as predictors)	
	Est.	SE	Est.	SE	Est.	SE	Est.	SE
Level-1 (variance within schools)	837.55	28.94	674.59	25.97	509.53	22.57	507.49	22.53
Fixed Effects								
Intercept: school mean achievement	152.33***	0.50	152.32***	0.50	152.33***	0.50	152.33***	0.50
Interest (slope)	2.55***	0.76	2.50**	0.75	2.68***	0.75	2.76***	0.75
Mean Interest					-0.55	1.23	-0.71	1.23
Mean Self-efficacy					0.44	1.06	0.50	1.06
Basic Supply							-0.18	0.43
Advanced Supply							0.88*	0.44
Self-Efficacy (slope)	10.51***	0.29	10.54***	0.30	10.72***	0.29	10.71***	0.29
Mean Interest					2.16	1.28	2.22	1.27
Mean Self-efficacy					5.54***	1.33	5.52***	1.33
Basic Supply							-0.15	0.52
Advanced Supply							0.01	0.55
Female	-0.26	0.72	-0.30	0.71	-0.41	0.71	-0.42	0.71
Black	-18.93***	1.21	-18.68***	1.21	-18.41***	1.20	-18.39***	1.20
Hispanic	-6.67***	1.38	-6.47***	1.35	-6.22***	1.35	-6.12***	1.33
Asian	-0.87	1.80	-0.83	1.81	-0.65	1.80	-0.51	1.80
Other	-4.30**	1.61	-4.31**	1.60	-4.29**	1.60	-4.29**	1.61
ELL	-25.91***	1.17	-25.85***	1.16	-25.78***	1.15	-25.78***	1.15
IEP	-27.93***	1.22	-27.96***	1.21	-27.95***	1.21	-27.91***	1.21
SES	1.36***	0.11	1.34***	0.11	1.36***	0.11	1.38***	0.11
Female*Interest	-2.08***	0.39	-2.07***	0.39	-2.00***	0.39	-2.00***	0.39
Black*Interest	0.82	0.59	0.67	0.60	0.54	0.59	0.53	0.59
Hispanic*Interest	1.52*	0.70	1.40*	0.68	1.27	0.68	1.22	0.67
Asian*Interest	0.95	0.89	0.93	0.89	0.84	0.89	0.76	0.89
Other Race*Interest	0.62	0.88	0.64	0.88	0.65	0.88	0.65	0.88
IEP*Interest	2.58***	0.64	2.62***	0.64	2.69***	0.63	2.66***	0.63
SES*Interest	0.19***	0.05	0.20***	0.05	0.18***	0.05	0.18**	0.05
Random Effects								
Intercept (variance between schools)	294.62***	17.16	295.33***	17.19	295.41***	17.19	295.43***	17.19

See notes at the end of the table.

Variable	Model 9: Random Slopes (proportion lunch as predictors)		Model 10: Random Intercept (Mean mot as predictors)		Model 11: Random Intercept (school supply as predictors)	
	Est.	SE	Est.	SE	Est.	SE
Interest			1.86***	1.36	1.79***	1.34
Self-efficacy			11.86***	3.44	9.68***	3.11
Level-1 (variance within schools)	507.95	22.54	501.81	22.4	501.53	22.39
Fixed Effects						
Intercept: school mean achievement	152.33***	0.50	152.28***	0.46	152.44***	0.45
Mean Interest			0.24	1.87	-0.34	1.79
Mean Self-efficacy			23.29***	2.14	22.74***	2.01
Basic Supply					0.63	0.83
Advanced Supply					4.55***	0.91
Interest (slope)	2.61***	0.77	2.61***	0.77	2.61***	0.77
Mean Interest	-0.76	1.23	-0.76	1.23	-0.75	1.23
Mean Self-efficacy	0.51	1.07	0.30	1.07	0.30	1.07
Proportion Lunch	0.28	0.26	0.27	0.26	0.27	0.26
Basic Supply	-0.20	0.43	-0.20	0.44	-0.20	0.44
Advanced Supply	0.92*	0.45	0.92*	0.45	0.88	0.46
Self-Efficacy (slope)	10.70***	0.29	10.70***	0.29	10.70***	0.29
Mean Interest	2.16	1.27	2.14	1.28	2.15	1.28
Mean Self-efficacy	5.51***	1.40	5.04***	1.41	5.05***	1.41
Proportion Lunch	0.09	0.32	0.10	0.32	0.10	0.32
Basic Supply	-0.15	0.52	-0.15	0.52	-0.17	0.52
Advanced Supply	0.02	0.56	0.01	0.56	-0.08	0.56
Female	-0.43	0.71	-0.43	0.71	-0.43	0.71
Black	-18.33***	1.21	-18.33***	1.21	-18.33***	1.21
Hispanic	-6.02***	1.35	-6.02***	1.34	-6.02***	1.34
Asian	-0.54	1.80	-0.55	1.80	-0.55	1.80
Other	-4.23	1.60	-4.23**	1.60	-4.23**	1.60
ELL	-25.78***	1.15	-25.78***	1.15	-25.77***	1.15
IEP	-27.97***	1.20	-27.96***	1.20	-27.96***	1.21
SES	1.36***	0.11	1.36***	0.11	1.36***	0.11
Female*Interest	-1.99***	0.39	-1.99***	0.39	-1.99***	0.39
Black*Interest	0.49	0.60	0.49	0.60	0.49	0.60
Hispanic*Interest	1.16	0.68	1.16	0.68	1.16	0.68
Asian*Interest	0.78	0.89	0.78	0.89	0.78	0.89
Other Race*Interest	0.61	0.88	0.61	0.88	0.61	0.88
IEP*Interest	2.70***	0.64	2.69***	0.64	2.69***	0.64

See notes at the end of the table.

Variable	Model 12: Random Intercept (school demo as predictors)		Model 13: Final model	
	Est.	SE	Est.	SE
SES*Interest	0.19***	0.06	0.19***	0.06
Random Effects				
Intercept (variance between schools)	295.40***	17.19	236.10***	15.37
Interest	1.72***	1.31	1.71***	1.31
Self-efficacy	9.51***	3.08	9.44***	3.07
Level-1 (variance within schools)	501.42	22.39	501.69	22.40
Fixed Effects				
Intercept: school mean achievement	153.31***	0.30	153.31***	0.30
Mean Interest	1.69	1.29	1.69	1.28
Mean Efficacy	12.61***	1.38	12.63***	1.38
Proportion Black	-0.27***	0.01	-0.27***	0.01
Proportion Hispanic	-0.12***	0.02	-0.12***	0.02
Proportion NSLP	-5.54***	0.42	-5.54***	0.42
Proportion EL	-5.12***	1.61	-5.12**	1.61
Proportion IEP	-2.15**	0.78	-2.14**	0.78
Proportion Absent	-2.20*	0.87	-2.19*	0.87
Mean Female	-0.62	2.31		
Basic Supply	0.33	0.55	0.34	0.55
Advanced Supply	1.39*	0.65	1.38*	0.66
Interest (slope)	2.58***	0.77	3.27***	0.69
Mean Interest	-0.76	1.23	-0.62	1.23
Mean Self-efficacy	0.38	1.07	0.26	1.06
Proportion Lunch	0.33	0.24	0.44	0.24
Basic Supply	-0.21	0.44	-0.23	0.44
Advanced Supply	0.91*	0.45	0.96*	0.46
Self-efficacy (slope)	10.68***	0.29	10.67***	0.29
Mean Interest	2.13	1.28	2.15	1.28
Mean Self-efficacy	5.21***	1.40	5.22***	1.40
Proportion Lunch	0.31	0.27	0.31	0.27
Basic Supply	-0.16	0.52	-0.16	0.52
Advanced Supply	-0.01	0.55	0.00	0.55
Female	-0.43	0.71	-0.47	0.71
Black	-18.57***	1.19	-17.51***	0.66
Hispanic	-6.14***	1.35	-4.11***	0.62
Asian	-0.63	1.80	0.85	0.81

See notes at the end of the table.

Variable	Model 12: Random Intercept (school demo as predictors)		Model 13: Final model	
	Est.	SE	Est.	SE
Other	-4.27**	1.60	-3.20***	0.83
EL	-25.80***	1.15	-25.82***	1.15
IEP	-27.97***	1.21	-27.85***	1.21
SES	1.36***	0.11	1.41***	0.11
Female*Interest	-1.99***	0.39	-1.98***	0.39
Black*Interest	0.63	0.59		
Hispanic*Interest	1.23	0.68		
Asian*Interest	0.83	0.90		
Other Race*Interest	0.63	0.88		
IEP*Interest	2.69***	0.64	2.62***	0.64
SES*Interest	0.19***	0.06	0.16**	0.05
Random Effects				
Intercept (variance between schools)	86.49***	9.30	86.47***	9.30
Interest	1.89***	1.37	1.64***	1.28
Self-efficacy	9.32***	3.05	9.24***	3.04
Level-1 (variance within schools)	502.33	22.41	502.54	22.42

NOTE: *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$

SOURCE: U.S. Department of Education, National Center for Education Statistics, National Assessment of Educational Progress, 2015 Grade 8 Science Assessment.

Discussion

Student science motivation and school-level mean motivation on science achievement

The primary purposes of the present study were (1) to identify the unique effects of science motivation on science achievement and (2) characterize these relationships by student- and school- level characteristics. The study found that science motivation items used in the study could be seen as representing two constructs (science self-efficacy and science interest). The two factors accounted for 19 percent of the student-level variance in NAEP science scores which is in line with Multon, Brown, and Lent (1991) who reported that students' self-efficacy explained 14 percent of variance in their science performance on standardized tests, classroom-related tests and basic skills. The analyses also indicated that both student science self-efficacy and science interest are statistically associated with student science achievement, even after taking into account student gender, race/ethnicity, and SES, EL, IEP statuses, and interactions of the two motivation constructs with the background items. Each unit difference in student science self-efficacy was associated with a 10.67-point difference in NAEP science scores, which is approximately one third of the science assessments standard deviation. The relationship of science interest with the NAEP science performance was relatively smaller—although it was also statistically significant—a one-unit difference in student science interest was associated with a 3.27-point increase in science scores. The findings from this study comport with the literature on positive effects of science self-efficacy on science achievement (Bircan & Sungur, 2016; Britner, 2008; Chen & Pajares, 2010; Hidi, Ainley, Berndorff & DelFavero, 2006; Lavonen & Laaksonen, 2009). However, the effects of interest on science performance are more mixed in the research literature. For example, Schiefele, Krapp and Winteler (1992) conducted a meta-analysis of the relationship between subject matter interest and academic achievement. They found that domain-specific interests in physics, science and mathematics had a relatively stronger relationship with students' academic achievement compared to other non-science subjects. And Chang and Cheng (2008) found that a combined scale with science self-efficacy and interest was significantly associated with students' science achievement. However, Areepattamannil, Freeman & Klinger (2011) conducted HLM analysis for 13,985 15-year-old students from 431 schools across Canada and found that student's general interest in science was negatively associated with science achievement when taking into consideration of other motivation variables (i.e., self-efficacy and self-concept) as well as student- and school-level demographic characteristics. Zhang, et. al. (2021) and Bohrnstedt et al. (2020) found similar results for the effects of mathematics interest on mathematics achievement. After mathematics identity and self-efficacy and other contextual factors were taken into consideration in the model, mathematics interest was not significantly associated with mathematics performance. Bohrnstedt et al. (2020) speculated that "Interest in an activity requires little engagement. It does not require deep knowledge or understanding of what it takes to accomplish an activity compared to self-efficacy and identity which do require knowledge and understanding. To have the confidence that one *can* accomplish a task (a feeling of efficaciousness) and to believe that one will be *good* at doing requires an understanding of what it takes to accomplish that activity."

Another important finding of the current study is the unique and substantial association of school-level mean self-efficacy with school science achievement in the presence of other school demographic variables—variables such as mean school-level SES, proportion of racial/ethnic minority students, and proportion of IEP students. The estimated coefficient for school mean science self-efficacy suggests that for each unit difference in school mean science self-efficacy, there is a predicted 12.63-point difference in school mean science achievement which is about 40 percent of the science assessment's standard deviation. By contrast, the relationship between school-level mean science interest and science achievement was not statistically significant. School-level mean science motivation also explained 20 percent of the science achievement variance between schools. This substantial positive effect highlights the likely significant role that overall school performance has on individual students' academic performance. While the current study does not shed light on what might account for this strong school effect, many researchers and school reformers have suggested that school climate makes a difference in student academic learning and growth (Maslowski, 2001; Hoy et al., 2006). The major levers seen as important for improving school climate are principals' leadership, teachers' expectations, and inter-personal relationships within and around schools (MacNeil, Prater & Bush, 2009). School leaders are gateway custodians for values, ideas, and practices that cultivate the school climate for science education. Haverson, Feinstein, and Meshoulam (2011) argued that the school leadership is the key to successful science education, which helps teachers and students make better use of the materials of science education, including curriculum materials, lab equipment, and professional training opportunities already in existence.

School science education teaching and learning supplies and science achievement

Teaching and learning supplies are essential for achieving the goals of science education. The Next Generation Science Standards (NGSS) focus on content, scientific and engineering practices, and cross-cutting concepts. The integration of rigorous content and application reflects how science is practiced in the real world, which requires science instruction providing more hands-on opportunities and real-world contexts to understand the scientific content and build the real-world problem-solving skills. Teaching and learning supplies provided by schools have an important role in improving school science education to align with the NGSS. The current study found that whether schools are able to provide advanced teaching and learning supplies including supplies for science demonstrations and science labs and scientific measurement instruments has a direct positive relationship with school-level science achievement after controlling school-level motivation and other demographic variables. This finding highlights the importance of teaching and learning supplies for science education. Science education instructional supplies perform such functions as the extension of the range of experience available to learners, supplement and complement the teacher's verbal instructions thereby making learning experience richer and providing the teacher with interest into a wide variety of learning activities. Also, this finding reiterates the important role that school leadership might play for school science education. School leaders are responsible of setting school priorities, creating a school culture that values science education, and acquiring and allocating school resources for various school practices. School leaders valuing science education would be more likely to support spending in equipment acquisition. In addition, this study finds that the role of science interest on science achievement was moderated by the factor indicating whether a school was able to provide advanced supplies. Students from schools that are more likely to provide advanced supplies tended to have a higher level of science interest which, in turn, is associated with a higher level of science achievement.

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Appendix A

Table A-1. Items in the construction of the SES index and their coding

Items	Value
NSLP eligibility	
No info on NSLP	0
Eligible for NSLP	0
Not eligible for NSLP	4
Parent education	
Missing or unknown pared	0
Did not graduate from HS	1
Graduated from HS	2
Some college after HS	3
Graduated from college	4
Books	
Missing info on books	0
Few books (0–10)	1
Enough to fill one shelf (11–15)	2
Enough to fill one bookcase (26–100)	3
Enough to fill several bookcases (more than 100 books)	4
Household possessions	
Missing info or one HH possession	0
2 HH possessions	0
3 HH possessions	1
4 HH possessions	2
5 HH possessions	3
6 HH possessions	4

NOTE: NSLP=National School Lunch Program.
SOURCE: U.S. Department of Education, National Center for Education Statistics, National Assessment of Educational Progress (NAEP), 2015 Grade 8 Science Assessment.

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