Humanities & Social Sciences Communications

COMMENT

https://doi.org/10.1057/s41599-024-02707-0 OPEN

Parent involvement and student academic motivation towards science in 9th grade

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Parents' beliefs and behavior act as both explicit and implicit ways of communicating the value of science and their confidence that their child can be successful in science-related classes. Using the NCES High School Longitudinal Survey (HSLS:09), we examined how parent beliefs and behaviors regarding their 9th grader's science education predicted the students' motivation in science. Using multiple regression indicates that the combination of parental education, beliefs, and involvement in science-related activities with their child are weak but significant predictors of students' academic motivation in science ($adjR^2 = 0.04$, $F(6, 14{,}933) = 26.32$, $P < 0.001$). In particular, parent education and parent involvement have positive and significant effects on students' science identity and science self-efficacy. These findings suggest that students may have a stronger academic motivation in science with parents who have higher levels of education, more confidence in their ability to help their child in science, and who engage in more science activities with their child.

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Introduction

With increasing concern about student disengagement from science, technology, engineering, and mathematics (STEM), parental engagement is viewed by researchers, educators, and educational administrators as an important factor in the educational success of their children in these disciplines (An et al., 2019; Castro et al., 2015; Harackiewicz et al., 2012; Simpkins et al., 2015). However, not all parents possess the necessary knowledge and skills to support their children's academic efforts. This especially applies to STEM content where parents might have limited STEM-related skills, knowledge, or vocabulary. Parents might also have negative attitudes about their children studying STEM (Kaya and Lundeen, 2010; Perera et al., 2014; Sha et al., 2015; Thomas and Strunk, 2017). These barriers can restrict parents' ability to support their children in meaningful STEM learning. Therefore, it is important to examine how parents can meaningfully engage in their children's education, especially in STEM areas. Using the High School Longitudinal Survey (HSLS:09), this study examines how parents' STEM-related activities, beliefs, and values influence their child's academic motivation and academic self-efficacy in STEM.

Expectancy-value theory suggests that students make choices about whether or not to engage in an academic task based on the interaction between their expectation of success and the subjective value of that task (Wigfield and Eccles, 2000). The theory emphasizes that the students' perception of expectancy of success and task value are constructed through socialization with significant others and situated within environmental and temporal factors (Eccles and Wigfield, 2020). As powerful influencers of students' expectancy-value beliefs, parents communicate their beliefs and values both implicitly and explicitly through their interactions and behaviors regarding academic topics. The influence of parents' beliefs and values on their child's motivation, particularly in science, has been historically under-investigated (Lee et al., 2019; Wigfield and Eccles, 1992).

Between 2009 and 2019, the number of students taking AP mathematics and science exams has increased in every STEM subject area (National Center for Science and Engineering Statistics (NCSES), 2019). However, the gender distribution represented by AP STEM areas remains unchanged from the previous decade (NSF, 2012). Female students took over half (56%) of the total number of AP exams in several STEM areas including biology (63%), environmental science (56%), statistics (52%), and chemistry (51%). However, for the majority of STEM AP subjects, female students accounted for less than half of the test takers (NCSES, 2019).

Students identifying as male (55%) were more likely than those identifying as female (48%) to report that they took a science course because they "really enjoy science" (NCES, 2021). On the other hand, students identifying as female (29%) were more likely than those identifying as male (26%) to report taking a science course because their "parents encouraged me to take it" (NCES, 2021). Further, male and female-identifying students varied in their perceptions of their math and science identity and ability. For example, about half of male students saw themselves as a "science person" compared to 46% of their female counterparts. Male students (71%) were more likely than female students (62%) to be confident in their "ability to do an excellent job on science tests" (NCES, 2021).

The influence of parents' beliefs and behaviors on students' expectancies and task values have been widely examined across a variety of academic content areas. For example, Simpkins et al. (2012), using the Childhood and Beyond Study, provided a comprehensive, longitudinal study of the connections between mothers' beliefs and behaviors in elementary school and youths' beliefs and behaviors in adolescence across sports, music, math, and reading. They found that while mothers' behaviors predicted youths' value in sports, music, and math, they did not predict youths' reading beliefs or math self-concept. Lee et al. (2019) explored gender differences in the effects of parents' beliefs on their children's motivation, achievement, and career aspirations in STEM-related careers. They found that parents' beliefs strongly predicted their sons' science motivation, but did not predict their daughters' science motivation suggesting that socializers beyond parents' beliefs were required to influence their motivation. Finally, Harackiewicz et al. (2012) found that an intervention which focused on increasing communication around the utility value of math and science courses between parents and their adolescent children, increased parents' value of STEM courses and increased the number of STEM courses the students took during their last two years of high school. However, a subsequent study found significant gender differences in the effectiveness of the same intervention and low-achieving daughters benefited the least (Rozek et al., 2015).

With current national and state level educational policies and initiatives focusing on improving the performance of students, particularly in areas of science, technology, engineering, and math, student course-taking behaviors in high school and college major choice is of particular concern (NSF, 2012). It is important to develop understanding about how parents influence students' decisions at consequential educational markers in order to best target effective interventions. The purpose of this study is to focus on specific parental behaviors and beliefs that influence students' motivational profiles in science, including science identity, utility, and competency.

Following is a brief overview of the current literature, specifically in regards to the parental factors that have demonstrated to influence high school students' science motivation.

Parental involvement defined. The definition of parental involvement is complex and multifaceted. Some researchers' definitions rely upon parent behaviors (An et al., 2019; Castro et al., 2015; De Silva et al., 2018; Sha et al. (2015), Shumow and Schmidt, 2014) while others interpret parents' science-related beliefs (Harackiewicz et al., 2012; Lee et al., 2019; Rozek et al., 2015; Simpkins et al., 2018; Vedder-Weiss and Fortus, 2013). Castro et al. (2015) and De Silva et al. (2018) define parental involvement as being actively involved in every aspect of their child's development. In addition to involvement in their academic development, specifically reading support, parents should also be involved in their emotional and social growth (Castro et al., 2015).

In contrast, Rodriguez et al. (2013) divided the different aspects of parental involvement into three major categories: "home environment, parents and school/community, and students and school/community" (p 51). Examples of the home environment include, assistance with homework, monitoring, peers/siblings as role models, and parental expectations (Rodriguez et al., 2013). When it comes to parents and the school/community, parents have multiple routes of communication, participating in the decision-making, volunteering at their child's school, and receiving support for parenting (Rodriguez et al., 2013). Parental engagement, as discussed by Shumow and Schmidt (2014), occurs at home (homework, rules, and routines), at school, and through educational planning. This view aligns with Vedder-Weiss and Fortus' (2013) parental involvement definition which places an emphasis on the achievement of goals.

Another aspect of parental involvement which was explored by Castro et al. (2015) was communication between students and parents on school activities. Here, parental involvement goes both ways. To involve parents, schools need to ensure that their curriculum and teaching is student-centered, socially relevant and culturally appropriate (Rodriguez et al., 2013). By providing homework that is culturally and socially appropriate, parental involvement may be increased (Rodriguez et al., 2013). Supporting the use of homework as an effective tool for parental involvement, Karaçöp et al. (2016) insists that although parents may not feel comfortable assisting students in science homework, they can encourage curiosity, the openness to learn, and consistent homework habits. In addition, the role played by parents during science activities may depend upon the parents' educational background and science literacy (Eş et al., 2019).

In contrast to using parental behaviors as their definition, other studies defined parental involvement as parents' science beliefs, specifically, parents' expectancy for success (Thomas and Strunk, 2017) and expectancy value of science (Harackiewicz, 2012). Uniquely, Rozek et al. (2015) defined parental involvement as the mothers' utility value for their student. As this overview has demonstrated, there exists a wide variety of definitions of parental involvement within the limited number of studies. Thus, defining parental involvement, especially in science, involves many interpretations.

The complexity of parent involvement and indicators of student science motivation and success. In general, parents are less involved in their student's science education than other subjects such as reading and math, due to low science self-efficacy and lack of school communication (Kaya and Lundeen, 2010). Students' motivation to learn science also declines as they progress through school, particularly during fifth through eighth grade (Vedder-Weiss and Fortus (2013)). But it is difficult to compare the relationship of parental involvement and student science motivation across grade levels due to the limited studies and the ranges in which they were explored. Across all ages, the indicators for student science motivation and success were also diversely defined.

Similar to the various perspectives of parental involvement, the definition of student motivation also fell within two broad categories, 1. student behaviors and 2. student beliefs. Karaçöp et al. (2016) assessed student success and motivation through school attendance and their positive attitudes towards school. In contrast, Vedder-Weiss and Fortus (2013) categorized indicators of science student motivation into three groups, extracurricular engagement, personal mastery, and classroom engagement. Sha et al. (2015) assessed student motivation in science through academic achievement on a pre and post test and their self-reported science self-efficacy. Test scores were also used by others to assess student motivation, but these test scores were collected from exams associated with the course and or grade-level (An et al., 2019; Castro et al., 2015; Lee et al., 2019; Thomas and Strunk, 2017). Two studies assessed academic achievement through student GPAs (Rozek et al., 2015; Shumow and Schmidt, 2014). In addition to GPAs, Rozek et al. (2015) also assessed student motivation through the number of science and math courses taken the junior and senior years, similar to Harackiewicz et al.'s study in 2012. Uniquely, Shumow and Schmidt (2014) defined student motivation as science homework completion as well as GPA. In contrast to the studies with student motivation assessed through observable behaviors such as grades, test scores, the number of science courses taken, etc. some researchers explicitly assessed students' motivational beliefs (De Silva et al., 2018) the value of science (Lee et al., 2019), the child's self-efficacy (Sha et al., 2015; Thomas and Strunk (2017); students' in-class beliefs (Shumow and Schmidt, 2014), and career aspirations (Lee et al., 2019). In summary, the few studies that exist do not all agree upon one definition of parental involvement nor upon the indicator for student academic science motivation and success.

Associations to parental involvement and student science motivation. A meta-analysis conducted by Castro et al. (2015) revealed that high expectations of parents have a strong and positive association with student academic achievement in all subjects and school grades. Parental involvement is also positively associated with school attendance and positive attitudes towards school (Karaçöp et al., 2016). Thus, parental involvement is important. This is especially true in elementary grades (Sha et al., 2015). In their meta-analysis of K-12 schooling of all subjects, Castro et al. (2015) found a strong association between parent aspirations and academic achievement. But, they declared the two science-specific studies' effect inadequate for interpretation because it contained a relatively large error (Castro et al., 2015). The literature on the associations to parental involvement and student motivation is limited, specifically within science. Within the limited literature specific to science, and in contrast to Castro et al. (2015), researchers agree that parental involvement is an indicator of student science motivation and or achievement (Harackiewicz et al., 2012; Perera et al., 2014; Sha et al., 2015; Shumow and Schmidt, 2014; Thomas and Strunk, 2017; Vedder-Weiss and Fortus, 2013). Notably, Thomas and Strunk (2017) found that parents have an influence on elementary students' achievement over and above children's own self-efficacy beliefs about science.

Parent attitudes about science (Perera et al., 2014), parents' expectancy (Thomas and Strunk, 2017), their engagement at-home and at-school (Shumow and Schmidt, 2014), and parent beliefs (Simpkins et al., 2018) are each a positive and significant indicator of students' science achievement. Additionally, students' personal mastery goals and extracurricular science engagement (Vedder-Weiss and Fortus, 2013), and students' interest in science, self-efficacy, and engagement (Sha et al., 2015), were also positively related to parental involvement. Both Harackiewicz et al. (2012) and Rozek et al. (2015) found that when parents received science-related content to assist with the support of their students, students were more likely to take an additional science course compared to students whose parents did not receive the information. Since assistance with homework is another way parents are able to be involved, it is also important to note that homework assistance decreases as students reach higher levels of science (Karaçöp et al., 2016). Moreover, Shumow and Schmidt (2014) found that the time parents spend with students working with science outside school was negatively associated with students' GPAs. If an increase in involvement with homework was due to a call home from the school to the parents in order to express concern, the call could lead to negative feelings in both parents and students (Shumow and Schmidt, 2014). Thus, it may be important to establish parent connections within the schools early in the school year to avoid communication only after a students' poor academic performance. Another way to involve parents before an academic or behavior issue prompts a call home is through positive science learning experiences such as "Family Science Night" (Kaya and Lundeen, 2010). These studies demonstrate that although the impact of parental involvement upon student science motivation and performance is complex, parents are indeed important.

Gender and socioeconomic status (SES). When considering population characteristics, findings indicated that there is a drop in effect size (Castro et al.'s, 2015). However, Simpkins et al.'s

(2018) found potential differences between gender and familism values in regards to parents and student science motivation. They found that although parents' have an impact on student beliefs, especially when students exhibit high familism, this is particularly true for males (Simpkins et al., 2018). Similarly, Lee et al. (2019) stated, "while parental perceptions of the value of science for their child was a significant predictor of their sons' value in science, they did not predict their daughters' value in science" (p 95). This was evident in the boys' higher selection of science, technology, engineering, and mathematics (STEM) career aspirations as well (Lee et al., 2019). Uniquely, Rozek et al. (2015) "…hypothesized that gender differences might emerge once we consider students' past performance" (p 3). When girls had performed well in 9th grade, the intervention increased their likelihood to take STEM courses in 12th grade (Rozek et al., 2015). The opposite was true for boys. The intervention led boys to take more STEM courses in 12th grade when they had not done well in 9th grade (Rozek et al. 2015). Regarding socioeconomic status (SES), Perera, et al. (2014) found that families with low SES benefit from parental involvement as much as families with high SES. Specifically, parents' expectations had a significantly positive impact on student achievement across all SES areas (An et al., 2019).

Purpose of the study. Using the NCES High School Longitudinal Survey (HSLS:09), we examined how parent beliefs and behaviors regarding their 9th grader's science education predicted the students' motivational profile towards science. Specifically, the research questions for this study are:

> How do parents' participation in their 9th grade child's academic science activities both at home and at school affect their child's academic motivation towards science?
>
> How do parents' beliefs about their own confidence in helping their 9th grade child with their science homework affect their child's academic motivation towards science?

By conducting a multiple, linear regression we were able to measure the predictive quality of these parent variables on the 9th grade students' academic motivation towards science.

Methods

Data source. The National Center for Educational Statistics (NCES) High School Longitudinal Study of 2009 (HSLS:09) (Image 2) surveyed a nationally representative sample ($n = 24{,}600$) of ninth-graders in the fall of 2009. Follow-up surveys reported data from 2012, 2013, and 2016. The final follow-up in 2016 surveyed the participants eight years after high school graduation when they were either in the workforce or continuing their education at the graduate level.

What makes HSLS unique from other NCES longitudinal survey initiatives (e.g., Education Longitudinal Study of 2002, High School and Beyond, National Education Longitudinal Study of 1988, etc.) is its focus on students' academic and career trajectories with an emphasis on STEM-oriented motivational beliefs. The sampling process was a two-stage stratified design (Ingels et al., 2011) and collected data in four waves: Wave (1) base year survey in 2009; Wave (2) first follow-up in 2012; Wave (3) 2013 update; and Wave (4) second follow-up student interview from 2016. The present study used the HSLS's public-use dataset from base year. Among other components, the base-year HSLS:09 survey included questionnaires for students, teachers, parents, school administrators, and school counselors. This project included data from both the base year parent and student questionnaires.

Measures. All variables are defined using the HSLS:09 base-year documentation (Ingels et al., 2011). A summary of the items, response sets, and descriptive output is provided in Table 1a–d.

Parent education. The parent education variable [X1PAREDU] indicates the highest level of education achieved by either parent living in the student's home. It is constructed from two composite variables that describe the highest level of education achieved by "Parent 1" and "Parent 2". The data range from "less than high school" to a "Ph.D./M.D/Law/other high level professional degree". If either of the two input variables are imputed and the highest level of education could not be inferred from non-imputed data, then the variable is flagged for that case.

Parent beliefs. Parent beliefs for this study included two variables: parent science efficacy [P1E04B] and beliefs about boys' and girls' aptitude for science [P1E05B]. Specifically, parents were asked how confident they were in helping their 9th grader with their science homework. Response options were "Very confident," "Somewhat confident," and "Not at all confident." Parents were also asked to compare females' and male's abilities in science. Response options were "Females are much better" or "…somewhat better," "Females and males are the same," and "Males are somewhat better" or "…much better."

Parent behaviors. Parent behaviors for this study is a composite variable derived from a set of items related to science-related activities the parents engaged in with their 9th grader. These items were dummy-coded (1 = participated; 0=not participated) and then added together to create an overall score of participation ranging from 0 to 6, with 0 indicating the parent participated in none of the science-related activities and 6 indicating the parent participated in all of the science-related activities. The activities included:

- Visiting a science or engineering museum with their 9th grader in the previous year (P1E07A);
- Worked or played on computer with 9th grader in the previous year (P1E07B);
- Built or fixed something with 9th grader in the previous year (P1E07C);
- Attended a school science fair with 9th grader in the previous year (P1E07D);
- Helped 9th grader with a school science fair project in the previous year (P1E07E); and
- Discussed STEM program or article with 9th grader in the previous year (P1E07F).

Outcome variables and weights. The HSLS:09 include items that reflect the many influences on students' values and expectations that factor into their most basic education-related choices. The student questionnaires gathered data on self-efficacy, identity, value, and interest in science. The science identity [X1SCIID] variable reflects the degree to which the students agreed with the statements "You see yourself as a science person" and/or "Others see me as a science person." The utility value of science [X1SCIUTI] is a scaled score of the students' perceptions of how useful science is to their lives, college goals, and career goals. The students' science self-efficacy [X1SCIEFF] reflects the students' confidence that they can do well on science tests, understand science textbooks, master science skills, and excel on science assignments. Finally, the students' science interest [X1SCIINT] reflected the students' description of their science classes as enjoyable, stimulating and useful. These composite variables were created through principal components factor analysis (weighted by W1STUDENT) and standardized to a mean of 0 and a standard deviation of 1.

Table 1 Summary of Items, Response Sets, and Descriptive Outputs Using the High School Longitudinal Survey (HSLS:09).

(a) Parent background, beliefs, and behaviors (HSLS:09 base-year)

			N	**%**
X1 parents'/guardians' highest level of education	Less than high school		1010	6.0%
	HS diploma or GED		5909	35.2%
	Associate's degree		2549	15.2%
	Bachelor's degree		4102	24.4%
	Master's degree		2116	12.6%
	Ph.D/M.D/Law/other		1096	6.5%
	Total		16,782	100.0%
P1 E04B confidence in helping with 9th grade science homework	Very confident		6166	26.2%
	Somewhat confident		7321	31.1%
	Not at all confident		2142	9.1%
	Missing		7874	33.5%
P1 E05B comparison of females' and males' abilities in science	Females are much better		376	1.6%
	Females are somewhat better		582	2.5%
	Females and males are the same		10,612	45.2%
	Males are somewhat better		2587	11.0%
	Males are much better		583	2.5%
	Missing		8763	37.3%
	Yes		No	
	N	**%**	***N***	**%**
P1E07A went to science or engineering museum	8253	53.4%	7195	46.6%
P1E07B worked or played on computer	13,300	86.1%	2148	13.9%
P1E07C built or fixed something	6987	45.2%	8461	54.8%
P1E07D attended a school science fair	2716	17.6%	12,732	82.4%
P1E07E helped 9th grader with a school science fair project	6071	39.3%	9377	60.7%
P1E07F discussed STEM program or article with 9th grader	10,199	66.0%	5249	34.0%

(b) Student academic motivation in science scaled scores (HSLS:09 Base year)

Descriptive statistics

	N	**Minimum**	**Maximum**	**Mean**	**Std. deviation**
X1 scale of student's science identity	21,112	−1.57	2.15	0.04	1.01
X1 scale of student's science utility	17,303	−3.10	1.69	0.01	0.99
X1 scale of student's science self-efficacy	17,264	−2.91	1.83	0.04	1.00
X1 scale of student's interest in fall 2009 science course	16,929	−2.59	2.03	0.03	0.99

(c) Parents'/guardians' highest level of education and Their Confidence in helping with 9th grade science homework Crosstabulation

		P1 E04B confidence in helping with 9th grade science homework							
		Very confident		**Somewhat confident**		**Not at all confident**		**Total**	
		N	**%**	***N***	**%**	***N***	**%**	***N***	**%**
X1 parents'/guardians' highest level of education	Less than high school	175	2.8%	362	4.9%	353	16.5%	890	5.7%
	High school diploma or GED	1520	24.7%	2895	39.5%	968	45.2%	5383	34.4%
	Associate's degree	939	15.2%	1179	16.1%	247	11.5%	2365	15.1%
	Bachelor's degree	1802	29.2%	1766	24.1%	328	15.3%	3896	24.9%
	Master's degree	1091	17.7%	783	10.7%	167	7.8%	2041	13.1%
	Ph.D/M.D/Law/other high lvl prof degree	638	10.3%	335	4.6%	78	3.6%	1051	6.7%
Total		6165	100.0%	7320	100.0%	2141	100.0%	15,626	100.0%

(d) Parents' beliefs about females' and males' abilities in science X Parent education

	Parents' beliefs comparing females' and males' abilities in science									
	Females are much better		**Females are somewhat better**		**Females and males are the same**		**Males are somewhat better**		**Males are much better**	
	N	**%**	***N***	**%**	***N***	**%**	***N***	**%**	***N***	**%**

Table 1 (continued)

(d) Parents' beliefs about females' and males' abilities in science X Parent education

		Parents' beliefs comparing females' and males' abilities in science									
		Females are much better		Females are somewhat better		Females and males are the same		Males are somewhat better		Males are much better	
		N	%	*N*	%	*N*	%	*N*	%	*N*	%
X1 parents'/guardians' highest level of education	Less than high school	56	6.63%	63	7.46%	594	70.30%	91	10.77%	41	4.85%
	High school diploma or GED	126	2.51%	233	4.64%	3555	70.73%	869	17.29%	243	4.83%
	Associate's degree	52	2.34%	79	3.56%	1560	70.21%	424	19.08%	107	4.82%
	Bachelor's degree	87	2.36%	123	3.34%	2688	73.00%	672	18.25%	112	3.04%
	Master's degree	36	1.83%	56	2.85%	1451	73.73%	373	18.95%	52	2.64%
	Ph.D/M.D/Law/other high lvl prof degree	19	1.91%	28	2.81%	762	76.58%	158	15.88%	28	2.81%
Total		376	2.55%	582	3.95%	10610	71.99%	2587	17.55%	583	3.96%

(e) Parent science – related behaviors X Parent education

X1 parents'/guardians' highest level of education

	Less than high school % (*n*)		High school diploma or GED % (*n*)		Associate's degree % (*n*)		Bachelor's degree % (*n*)		Master's degree % (*n*)		Ph.D/M.D/Law/ other high lvl prof degree % (*n*)		Total % (*n*)	
Parent behavior	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**
P1 E07A went to science or engineering museum with 9th grader in last year	36.6% (325)	63.4% (562)	44.6% (2368)	55.4% (2938)	53.2% (1238)	46.8% (1089)	58.5% (2253)	41.5% (1596)	66.6% (1353)	33.4% (680)	68.5% (715)	31.5% (329)	53.4% (8252)	46.6% (7194)
P1 E07B worked or played on computer with 9th grader in last year	66.7% (592)	33.3% (295)	84.6% (4487)	15.4% (819)	88.7% (2064)	11.3% (263)	89.7% (2415)	11.3% (434)	88.3% (1819)	10.5% (214)	88.3% (922)	11.7% (122)	86.1% (13,299	13.9% (2147)
P1 E07C built or fixed something with 9th grader in last year	41.3% (366)	58.7% (521)	47.0% (2492)	53.0% (2814)	48.6% (1130)	51.4% (1197)	44.3% (1705)	55.7% (2144)	42.5% (864)	57.5% (1169)	41.2% (430)	58.8% (614)	45.2% (6987)	54.8% (8459)
P1 E07D attended a school science fair with 9th grader in last year	15.9% (141)	84.1% (746)	13.3% (706)	86.7% (4600)	16.8% (390)	83.2% (1937)	20.4% (787)	79.6% (3062)	22.3% (453)	77.77% (1580)	22.9% (239)	77.1% (805)	17.6% (2716)	82.4% (12,730)
P1 E07E helped 9th grader with a school science fair	41.0% (364)	59.0% (523)	37.0% (1961)	63% (3345)	41.9% (976)	58.1% (1351)	39.8% (1530)	60.2% (2319)	10.5% (824)	59.5% (1209)	29.8% (416)	60.2% (628)	39.3% (6071)	60.7% (9375)

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Table 1 (continued)

(e) Parent science – related behaviors X Parent education

X1 parents'/guardians' highest level of education

Parent behavior	Less than high school % (*n*)		High school diploma or GED % (*n*)		Associate's degree % (*n*)		Bachelor's degree % (*n*)		Master's degree % (*n*)		Ph.D/M.D/Law/ other high lvl prof degree % (*n*)		Total % (*n*)	
	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
project in last year P1 E07F discussed STEM program or article with 9th grader in last year	43.3% (383)	56.8% (504)	59.3% (3144)	40.7% (2162)	66.4% (1544)	33.6% (783)	71.1% (2738)	28.9% (1111)	76.3% (1552)	23.7% (481)	80.3% (838)	19.7% (206)	66.0% (10,199)	34.0% (5247)

Data analysis and results

Using HSLS:09 base year, the data included 14,028 9th grade students. The analysis for this project was conducted in two parts. The first part includes the descriptive analysis for parent characteristics, beliefs, and behaviors. These variables were cross-tabulated to further examine how parent beliefs and behaviors varied by parent education. The second part of the analysis included a multiple linear regression to examine the combinations of factors that predict student science motivation. The description of the analysis also includes checking all assumptions for multiple regression analysis (i.e., multicollinearity, outliers, and homogeneity of variance).

Parent characteristics. Parent or Guardian's highest level of education was by each parent or guardian on the parent questionnaire. As Table 1a shows, 41.2% of the students' parent or guardian had a High School Diploma/GED or less. The remaining students' parent or guardian (58.8%) had received a post-secondary degree. Over 15% in the sample received an Associates degree, which NCES defines as a "sub-baccalaureate program of study, usually requiring 2 years (or equivalent) of full-time college-level study." (Ingels et al., 2011). Approximately one-quarter of the respondents' parent or guardian had a Bachelor's degree and another 19% had a Master's degree or higher. This indicates the sample differs slightly compared to the US population at the time when 32% of the population age 25 or older held a Bachelor's degree and another 7% held a Master's or higher degree (NCES, 2021).

Parent beliefs. When asked about their confidence level in helping their child with their 9th grade science homework, over 57% indicated that they were either "somewhat confident" or "very confident". When cross-tabulated with parent/guardian education level, it is clear that parent education interacts with that confidence (Table 1c). Over 61% of the parents who indicated that they were "not at all confident" when helping their child with their science homework held a High School diploma or less. Conversely, over 57% of parents who indicated that they felt "very confident" when helping their child held a Bachelor's degree or higher; another 27.5% held a High School diploma/GED or less.

When asked to compare males' and females' abilities in science, overall 72% of the parents indicated that they believed that "females and males are the same". Parents with higher levels of education agreed with this statement in slightly greater proportions than parents with less education. Although this belief was consistently high across parents' education levels, the distribution slightly skewed towards the belief that males are "somewhat better" or "much better" (Table 1d).

Parent behaviors. Items pertaining to parents' behaviors are summarized in Table 1e and also broken out by education level of the parent. As a group, parents "went to a science or engineering museum with their 9th grader" (53%), "worked or played on a computer with their 9th grader" (86%), and discussed "STEM program or article with their 9th grader" (66%). These parents less often "built or fixed something with their 9th grader" (45.2%), "attended a school science fair with their 9th grader" (17.6%), or "helped their 9th grader with a school science fair project" (39.3%).

When examined by the education level of the parent, there was considerable variability across these behaviors. For example, parents with a Bachelor's degree or higher more often visited science and engineering museums (between 58.5% and 68.5%), attended school science fairs (between 20.4% and 22.9%), and discussed a STEM program or article with their 9th grader

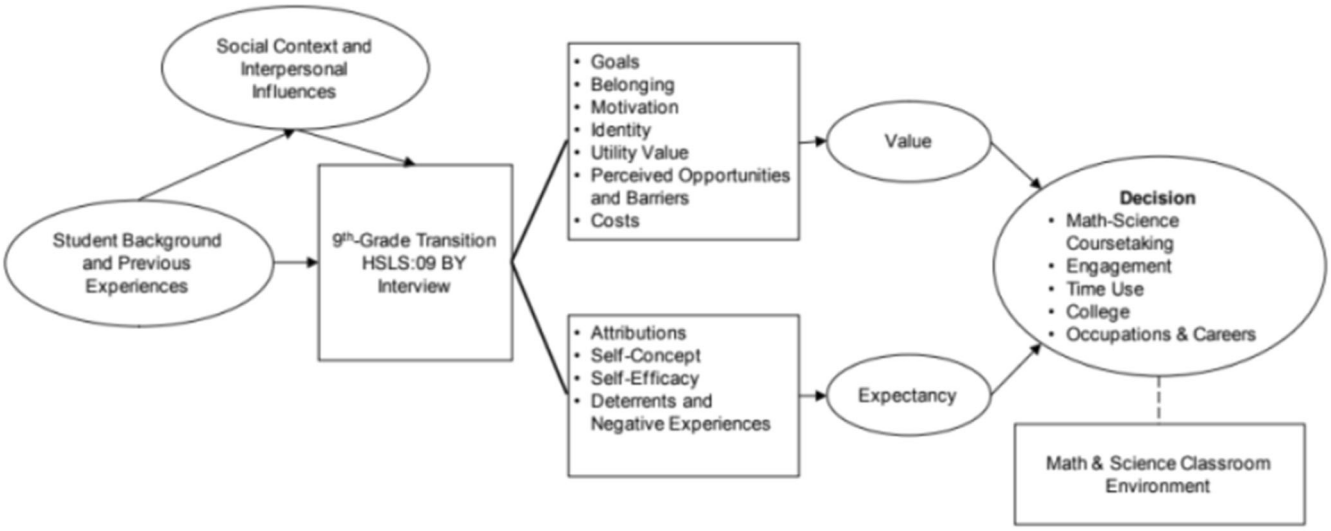

Fig. 1 High school longitudinal study of 2009 (HSLS:09).

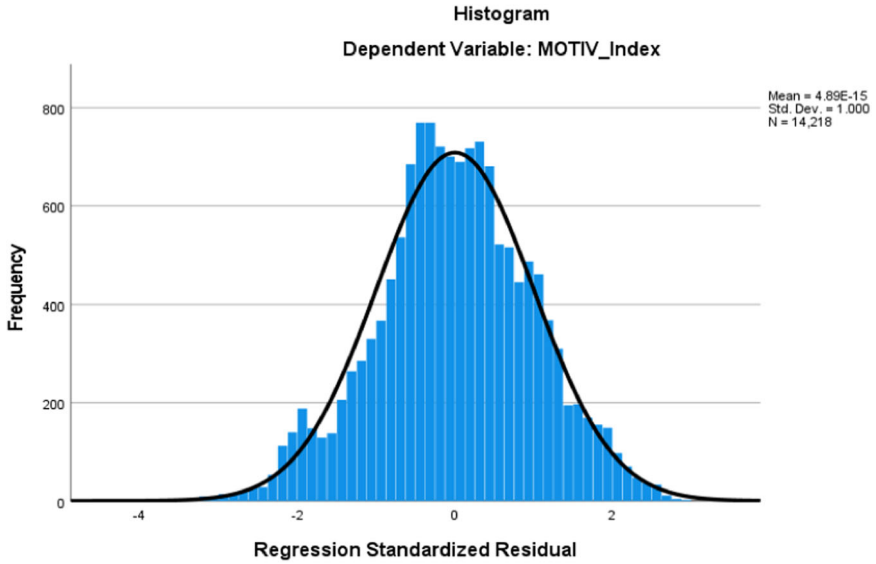

Fig. 2 Histogram distribution of standardized residuals.

(between 71.1% and 80.3%). Parents with less than a High School Diploma presented as outliers on going to museums (36.6%), working or playing on a computer (66.7%), and discussing a STEM program or article (43.2%).

When examined by the 9th grader's sex, parents' behaviors were evenly distributed across the male- and female-identifying students with one exception. The majority (54.8%) of parents indicated that they did not build or fix something with their 9th grader, but when examined by gender, 58% of parents of male students but only 32% of parents of female students indicated that they did engage in this behavior ($X^2 = 145.69$, $P < 0.001$) (Fig. 1).

Multiple regression analysis. Testing the assumptions of multiple regression included testing for multicollinearity, outliers, and homogeneity of variance. Multicollinearity occurs when two or more predictor variables are highly correlated to each other. Such a relationship indicates that the predictor variables would not provide unique or independent information in the regression model causing difficulty in interpreting the resulting model. Variance inflation factor (VIF) is a measure that detects multicollinearity in a regression with resulting scores greater than 5.0 indicating a moderate correlation between the predictor variables. The VIF across the predictor variables ranged from 1.07 to 1.13 indicating a weak correlation thus meeting the assumption for regression. An analysis of standard residuals indicated the presence of seven outliers that were removed from the data. The Durbin-Watson estimate determines the independence of residuals and ranges from zero to four. Values hovering around two indicate that the data points were independent. Values near zero indicate strong positive correlations and values closer to four indicate strong negative correlations. The data satisfies the assumption of independent errors with Durbin-Watson estimates (d) between 1.69 and 1.82. Finally, the scatterplot of standardized residuals showed that the data met the assumptions of homogeneity of variance and linearity (Figs. 2 and 3).

Multiple regression analyses were conducted to predict the overall student academic motivation in science from their parents' background, beliefs, and behaviors. The results of this analysis indicated that parent background, beliefs, and behaviors accounted for a significant amount of the students' academic

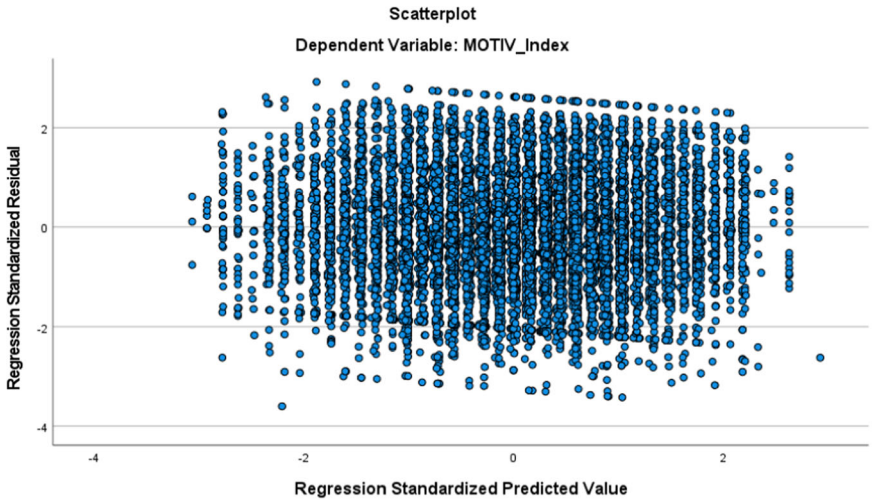

Fig. 3 Scatterplot of regression standardized residuals.

Table 2 Regression model summary.

Model summary

Model	*R*	*R* square	Adjusted *R* square	Std. error of the estimate	Change statistics					Durbin-Watson
					R square change	*F* change	df1	df2	Sig. *F* change	
1	0.151[a]	0.023	0.023	0.80042	0.023	349.821	1	14,940	0.000	1.695
2	0.168[b]	0.028	0.028	0.79827	0.005	81.908	1	14,939	0.000	1.770
3	0.196[c]	0.038	0.038	0.79424	0.010	26.323	6	14,933	0.000	1.815

[a]Predictors: (Constant), X1 Parents'/guardians' highest level of education.
[b]Predictors: (Constant), X1 Parents'/guardians' highest level of education, P1 E04B Confidence in helping with 9th grade science homework, P1 E05B Comparison of females' and males' abilities in science.
[c]Predictors: (Constant), X1 Parents'/guardians' highest level of education, P1 E04B Confidence in helping with 9th grade science homework, P1 E05B Comparison of females' and males' abilities in science, P1 E07E Helped 9th grader with a school science fair project in last year, P1 E07C Built or fixed something with 9th grader in last year, P1 E07B Worked or played on computer with 9th grader in last year, P1 E07A Went to science or engineering museum with 9th grader in last year, P1 E07F Discussed STEM program or article with 9th grader in last year, P1 E07D Attended a school science fair with 9th grader in last year.

motivation towards science, $adjR^2 = 0.04$, $F(6, 14{,}933) = 26.32$, $P < 0.001$. These findings indicated that students may have a stronger academic motivation in science with parents with higher levels of education, with more confidence in their ability to help their child in science, and who engage in more science activities with their child (Tables 2–4).

All of the predictors of student academic motivation in science were significant and added to the predictive power of the resulting model with parent education as the stronger predictor ($\Delta R^2 = 0.023$), followed by parent behaviors ($\Delta R^2 = 0.01$), and parent beliefs ($\Delta R^2 = 0.005$). Multiple comparisons of the students' science motivation and parents' education, behaviors, and beliefs showed that parent participation in three or more activities had a significant and positive effect on students' science identity (S1SCIID; $P < 0.001$) and on students' self-efficacy (S1SCIEFF, $P < 0.001$). Furthermore, the parents' education level at or greater than a Bachelor's degree had a significant and positive effect on students' science identity (S1SCIID; $P < 0.001$). Students' science self-efficacy was positively and significantly affected with every additional level of parent education. In other words, with each level of parent education, students' confidence that they would do well on science tests, understand science textbooks, master science skills, and excel on science assignments increased significantly. The main effects of parent education and parent behaviors had no significant effects on students' science utility or on students' interest. Although there were significant main effects of parent education and behaviors, there were no significant main effects of parent beliefs about student competency based on gender nor about their own confidence to help students with their science work on any of the four student science motivation outcome variables.

Significance of the findings

Multiple perspectives frame the importance of science in education. One focus is on the science, technology, engineering, and math (STEM) careers (Harackiewicz et al., 2012; Sha et al., 2015; Simpkins et al., 2015) and a second focus is on the role and importance of science literacy. For example, Perera et al. (2014) focused on science literacy, the ability to use evidence-based reasoning and science knowledge to ask questions and understand the natural world, thus preparing societal members' to understand, interpret and utilize scientific information and scientific methods in their everyday lives. Regardless of the perspective, science education is an important area of study. This is particularly true given the decreased interest in science for upper-level high school grades and a less diverse group of students within STEM college courses and STEM careers in the United States (Harackiewicz et al., 2012; Simpkins et al., 2015). Students in high school selected fewer science courses in their junior and senior years, unless, as Harackiewicz et al. (2012) suggest, parents were recruited to motivate students to take additional courses. If

students are not motivated to learn science in high school, this may contribute to diminished interest in STEM-associated college majors and career pursuits. However, even if students develop an interest to pursue STEM-associated college majors once in college, they would lack the foundation knowledge students are expected to have upon entering the major and thus would experience difficulty catching up. The factors that influence high school students' motivation to learn science are thus an important area of study for both perspectives.

The findings of this study indicate that the combination of parental education, beliefs, and involvement in science-related activities with their child are weak but significant predictors of students' academic motivation in science. In particular, parent education and parent involvement may have positive and significant effects on students' science identity and science self-efficacy. Parents' beliefs and behavior act as both explicit and implicit ways of communicating the value of science and their confidence that their child can be successful in science-related classes. Therefore, by emphasizing outreach and science programming directed at parents, science teachers and school administrators may see an increase in student engagement in science throughout high school and into college.

Table 3 Analysis of variance output (HSLS:09 base year).

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	224.123	1	224.123	349.821	.000[b]
	Residual	9571.752	14940	0.641		
	Total	9795.875	14941			
2	Regression	276.318	2	138.159	216.812	.000[c]
	Residual	9519.558	14939	0.637		
	Total	9795.875	14941			
3	Regression	375.949	8	46.994	74.497	.000[d]
	Residual	9419.927	14933	0.631		
	Total	9795.875	14941			

[a]Dependent Variable: MOTIV_Index
[b]Predictors: (Constant), X1 Parents'/guardians' highest level of education
[c]Predictors: (Constant), X1 Parents'/guardians' highest level of education, P1 E04B Confidence in helping with 9th grade science homework, P1 E05B Comarison of females' and males' abilities in science
[d]Predictors: (Constant), X1 Parents'/guardians' highest level of education, P1 E04B Confidence in helping with 9th grade science homework, P1 E05B Comarison of females' and males' abilities in science, P1 E07E Helped 9th grader with a school science fair project in last year, P1 E07C Built or fixed something with 9th grader in last year, P1 E07B Worked or played on computer with 9th grader in last year, P1 E07A Went to science or engineering museum with 9th grader in last year, P1 E07F Discussed STEM program or article with 9th grader in last year, P1 E07D Attended a school science fair with 9th grader in last year

Future research. The findings of this study raised additional questions about parental involvement in students' STEM education that would invite further research. The item that asked parents if they had "built or fixed" something with their child raised the prospect of the effect of gendered signaling in the way that we talk about STEM disciplines and activities. For example, cooking involves mathematics and science while also socially normed as a female pursuit. Considering cooking as a STEM activity may have increased the number of parents who indicated that they had interacted with their child in a STEM pursuit. More research is needed on the effects of inclusive messaging on parental attitudes towards and participation in their children's STEM education.

Another needed line of questioning around parental involvement could employ inductive strategies to learn from parents what activities they have engaged in to support their child's STEM education, particularly during the COVID-19 pandemic. For example, during the pandemic, museums were closed to the public but increased their effort to digitize their archives and create volumes of science education content online. Has this increased accessibility influenced parents' science literacy and/or attitudes towards their child's STEM education? There may be patterns of factors that influenced whether and how parents attempted to engage their child in both formal and informal STEM activities when they have been constrained by finances, location, health, or schedules.

Implications and recommendations for science teacher educators

Science teachers should be prepared to involve their future classroom parents during their educator preparation programs. To do so, science teacher educators should model these strategies, specifically, how to plan and coordinate field trips. By connecting preservice science teachers to local community organizations,

Table 4 Unstandardized and standardized coefficients[a] (HSLS:09 base-year).

		Unstandardized coefficients		Standardized coefficients			Correlations			Collinearity statistics	
Model		B	Std. error	Beta	t	Sig.	Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	−0.324	0.021		−15.156	0.000					
	X1PAREDU	0.089	0.005	0.151	18.704	0.000	0.151	0.151	0.151	1.000	1.000
2	(Constant)	−0.119	0.031		−3.838	0.000					
	X1PAREDU	0.078	0.005	0.132	15.813	0.000	0.151	0.128	0.128	0.934	1.070
	P1E04B	−0.090	0.010	−0.076	−9.050	0.000	−0.109	−0.074	−0.073	0.934	1.070
	P1E05B	−0.032	0.014	−0.020	−2.185	0.029	−0.021	−0.020	−0.020	0.998	1.002
3	(Constant)	−0.490	0.056		−8.738	0.000					
	X1PAREDU	0.069	0.005	0.116	13.618	0.000	0.151	0.111	0.109	0.886	1.129
	P1E04B	−0.071	0.010	−0.060	−7.115	0.000	−0.109	−0.058	−0.057	0.903	1.107
	P1E5B	−0.270	0.014	−0.018	−2.006	0.045	−0.021	−0.018	−0.018	0.997	1.003
	P1E07A	0.063	0.014	0.039	4.607	0.000	0.088	0.038	0.037	0.905	1.104
	P1 E07B	−0.044	0.020	−0.018	−2.213	0.027	0.027	−0.018	−0.018	0.923	1.084
	P1E07C	0.044	0.013	0.027	3.268	0.001	0.045	0.027	0.026	0.941	1.063
	P1E07D	0.079	0.019	0.037	4.275	0.000	0.071	0.035	0.034	0.848	1.180
	P1E07E	0.016	0.014	0.010	1.108	0.268	0.045	0.009	0.009	0.847	1.181
	P1E07F	0.110	0.015	0.064	7.458	0.000	0.110	0.061	0.060	0.869	1.150

[a]Dependent variable: MOTIV_Index.

they will begin to build the necessary relationships and confidence to coordinate future field trips for their students. Preservice science teachers should also be assisted in creating student handouts and/or parent emails which include student-friendly science content and easy, hands-on science activities. By preparing preservice science teachers to engage their future students' parents, science teacher educators may increase the likelihood of their future science teachers' strategies to connect families with the classroom. Students' science appreciation should also be cultivated, specifically within a real-world context. Science educators should model this strategy with their preservice science teachers by using media resources that disseminate current event information tied to science and require them to share what they learned with their peers. This may foster an appreciation for science in the preservice science teachers while also providing a strategy for their future classrooms.

Limitations

The data in this study were focused on students who completed the NCES HSLS:09 survey questionnaire. The limitations of this study are related to the measurement of parental involvement in their child's STEM activities, interests, and education. First, the parental involvement ratings were obtained through self-report. Although garnering self-report regarding parental support may provide useful data, self-perceptions are limited in scope and potentially introduce several sources of bias including social desirability bias and recall bias. A related limitation is that the items on the survey regarding parental involvement are rather general. In particular, the items primarily focused on parents' responses of how often they engaged in activities and discussed course and career selection with their child. Therefore, the data do not provide any information about the specific content nor the depth of those discussions. Finally, the overrepresentation of highly educated individuals in parents and guardians sample may introduce a bias. This bias can skew the outcomes by favoring perspectives, behaviors, that are more prevalent among those with higher levels of education.

Discussion

In agreement with previous research, this study explored the complex connection between parental involvement and student science motivation. Parental involvement, to summarize previous research, is defined through behaviors and or beliefs. Just as the multifaceted definition of parental involvement, student science motivation definitions also vary greatly. For this paper, the definition of parental involvement remained broad. But the definition of student science motivation was interpreted as student science academic achievement and science self-efficacy as reported in the NCES High School Longitudinal Survey (HSLS:09). Overall, the educational level of the parents warrant a deeper understanding due to its connection woven throughout the definition of parental involvement.

This research found that the parents with higher the education had children with higher science motivation and students science self-efficacy (Tables 2–4). This could be due in part to the increase in parental confidence to aid with science homework and engage in science activities. This aligns with the findings of Eş et al. (2019) that the role parents play within science activities may depend upon their educational background and science literacy. However, parents who engaged more with their child in science activities corresponded with higher science motivation of their child. This aligns with Karaçöp et al. (2016) who found that homework is an effective form of parental involvement since parents, regardless of parental education background, can demonstrate curiosity and an openness to new information. This is important to remember because, as Kaya and Lundeen (2010) discussed, parents help the least when it comes to science, especially without school communication. That is why it is so very important for schools to engage all parents in the science content.

In additional to parental educational level, parents' beliefs may also positively influence student academic motivation. This aligns with the work of Thomas and Strunk's (2017) examination of parents' expectancy for success, and Harackiewicz's (2012) focus on expectancy value of science since, what a parent believes, may impact their child's motivation. As previous literature discussed, this is especially true for males (Lee et al., 2019; Simpkins et al., 2018). The present research findings support the previous literature, demonstrating that, regardless of education level, parents hold the view that males are more likely to find success in science (Table 1d). Perhaps this is why we still see the same trend regarding females in science fields.

Noting that educators cannot directly influence their students' parents' educational background, it is still important to increase science motivation. In addition, it is important to increase the number of students involved in science, specifically girls and students of color. One possible way to positively influence students' science utility, identity, and competency through increased parental involvement is by increasing opportunities for families to attend STEM-related events and discuss STEM activities. This study demonstrated that the participation of parents in three or more activities had a significant and positive effect on students' science identity (S1SCIID; $P < 0.001$). Knowing this, science educators and teachers can intentionally create chances for families to engage with STEM through school-sponsored events and enrichment activities designed for parents, such as reading an engaging article or watching a STEM-related program together. These opportunities are beneficial for students regardless of their parents' education backgrounds. And, since our study indicates that parents may have significant influence in their children's motivational beliefs and behaviors in science, these small opportunities may have a large impact on our future STEM field population. Thus, it is important for schools and science educators to ally with parents in the STEM education of their students.

Data availability

Using the NCES High School Longitudinal Survey (HSLS:09): https://nces.ed.gov/surveys/hsls09/.

Received: 4 April 2023; Accepted: 18 January 2024;
Published online: 15 February 2024

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Author contributions

The authors confirm their contribution to the paper as follows: study conception and design: A Nolen; data collection: the NCES High School Longitudinal Survey (HSLS:09) was used; analysis and interpretation of the results: A Nolen and L Pinneo; draft manuscript preparation: L Pinneo and A Nolen. All authors reviewed the results and approved the final version of the manuscript.

Competing interests

The authors declare no competing interests.

Ethical approval

Ethical approval was not required as the study did not involve human participants performed by any of the authors.

Informed consent

Informed consent is not relevant to this article.

Additional information

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