

Article

Formation of Children's Interests in Physical Versus Life Sciences: Significance of Parent, Gender and Ethnicity Influences

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Abstract

Women and Hispanic people in the United States (U.S.) are underrepresented in many physical science and engineering fields, despite higher representation in life science fields. This study examines how science topic (physical vs. life science) influences the role that parents play in the development of their elementary school-age (fourth grade) children's science-related interests, attitudes, and problem-solving strategies, including differences related to parent and child ethnicity (Hispanic and non-Hispanic) and gender. The participants were 153 girls and boys in fourth grade and their parents in the Phoenix metropolitan area of the United States. Each parent-child dyad's behaviors as they completed hands-on physical science and life science activities together were examined. Parents and children were more talkative during physical science activities than during life science activities (for parents $M = 13.70$, $SD = 54.99$, $p = 0.004$, and for children $M = 20.88$, $SD = 34.93$, $p < 0.001$), where M = the difference between the number of utterances during physical versus life science problems. In addition, parents provided more explanations/answers, asked more questions to prompt their children, and asked more questions about their child's understanding during physical science activities as compared to life science activities. Regarding problem-solving strategies, the dyads used their existing knowledge/experience more during physical science activities, whereas they used assumptions more during life science activities. Interactions that occurred between topic and ethnicity or gender, and implications for representation of women and Hispanic students in physical versus life science majors in later years, are also presented.

Keywords: parents; elementary students; physical science; life science; gender; ethnicity; science interest; STEM



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1. Introduction

It is well-documented that participation in science, technology, engineering, and math (STEM) activities and occupations in the U.S. and globally varies as a function of many factors, including gender and ethnicity (Fussy et al., 2023; Lau & Ho, 2022; National Center for Science and Engineering Statistics, 2021; UNESCO, 2017). While participation of women and Hispanics in the STEM workforces in the U.S. has increased in recent decades, the increase in participation has not increased to the same extent in all fields such that disparities are greater for some specific disciplines of science than others. Indeed, women's interest and participation in physics-related fields in the U.S. has remained low

for many decades (Sax et al., 2016; Ceci, 2018), a pattern that has also been observed in many other countries (Avolio et al., 2020; Eren, 2021; Francis et al., 2017; Khan et al., 2022; Mujtaba & Reiss, 2013).

In the U.S. context, the location of this study, almost half (48.3%) of employed life scientists in the U.S. are female, whereas only 34.7% of employed physical scientists are female. Additionally, 9.2% of employed life scientists are Hispanic, whereas only 6.6% of employed physical scientists are Hispanic (National Center for Science and Engineering Statistics, 2021). Similarly, women earned 62.8% of all bachelor's degrees in biological sciences in 2018, but only 38.4% and 22.2% of degrees in physical sciences and engineering, respectively (National Center for Science and Engineering Statistics, 2021). While Hispanic women earn more than 7% of all bachelor's degrees in biological sciences, they earn only 3.7% and 2.3% of bachelor's degrees in physical sciences and engineering, respectively (National Science Foundation, 2017).

While it may be tempting to explain these differences in representation by gaps in educational scores, early signs do not predict such large differences in participation in physical science and engineering fields. In the U.S., there was no significant difference between girls' and boys' science scores overall and in physical sciences in grades four and eight, but male students do score higher in grade 12 (U.S. Department of Education, 2024). Life science is the exception, as female students have similar scores to male students through grade 12. The small differences in scores by gender alone cannot explain the larger differences in participation in physical versus life science majors and careers. With regard to Hispanic students, the score difference between Hispanic and non-Hispanic White students was the same for life and physical sciences at all grade levels, which also does not explain why Hispanic people (especially Hispanic women) are less likely to pursue physical science and engineering careers versus life science careers (U.S. Department of Education, 2019).

Since we do not see performance gaps by science discipline with regard to ethnicity or gender throughout most of elementary and secondary school, we must look to other potential reasons for this difference in career aspirations. Because parental encouragement and support have been documented to play a large role in students' interests and career aspirations, the focus of the present study is to learn how parents may (often subconsciously) influence their elementary (grade four, U.S.) children's interest, motivation, identity, and self-efficacy in studying physical versus life sciences. A majority of studies that examine differences in science disciplines focus on students in secondary school or college, such that this study is uniquely positioned to determine if differences emerge earlier in the educational journey. Parents contribute to their children's interests and attitudes, as they provide guidance, manage their children's opportunities, and expose them to different experiences. They nurture their interests, and they encourage and motivate them to persist in science, technology, engineering, and math (STEM) by many formal and informal mechanisms (Bhanot & Jovanovic, 2009; Jocz et al., 2014; Rice et al., 2013). In particular, parental influence was examined by observing the behaviors and discourse of parent-child dyads as they worked on physical and life science activities together. Furthermore, the role of (parent and child) gender and Hispanic ethnicity on these interactions was explored.

1.1. Previous Research Studies

1.1.1. Representation of Women in Science

Underrepresentation of women in science, especially physical and math-intensive disciplines, is not unique to the U.S. (Gupta, 2007; Fussy et al., 2023; UNESCO, 2017; Lau & Ho, 2022). Numerous reasons for this underrepresentation exist, including lower interest, self-efficacy, enjoyment and identity that often result from negative cultural influences, narratives and stereotypes. A study across the four high-achieving countries/economies of

China, Hong Kong, Canada and Finland found that enjoyment of science was the strongest predictor of science performance in school (Lau & Ho, 2022). Girls demonstrated lower attitudes and enjoyment, and therefore lower performance, as compared to boys in all of these countries except Finland. In Tanzania, girls remain woefully underrepresented in secondary science education due to “patriarchal ideologies about science, the lack of female science teachers, inadequate resources for science learning and heavy domestic workloads” (Fussy et al., 2023, p. 1141). Lau and Ho (2022) indicate this same patriarchal culture pervades Chinese society to the same end. Furthermore, countries and cultures with stronger “science = male” implicit stereotypes exhibit larger performance gaps between male and female students in eighth-grade science performance data from Trends in International Mathematics and Science Study (TIMSS) tests (Nosek et al., 2009).

Interestingly, the gender gaps in interest, self-efficacy, and attitudes about science are not present in the early years of education in most countries, but they become more pronounced during the middle and high school years (Archer et al., 2010; Baram-Tsabari & Yarden, 2011; Nosek & Smyth, 2011). This trend leads researchers to believe that these are learned cultural norms rather than biological differences. Indeed, self-efficacy and participation in leisure-time science activities, but not gender, were found to be predictors of interest in school science in grade four in Singapore (Jocz et al., 2014). Similarly, a large-scale study in the United Kingdom (U.K.) noted that most children at age 10–11 years have positive attitudes about science, but their enthusiasm and science identity largely declined by age 14, a process that is influenced by the children’s gender, ethnicity, and socioeconomic status (Archer et al., 2010). Parents are an integral part of their children’s cultural surroundings, especially during the elementary years.

1.1.2. Gender and Unique Challenges in Physical Sciences

While some studies have documented gender preferences for life or physical sciences at an early age, a more exact determination of when these preferences develop is still an active area of research. Children’s gender-stereotyped beliefs about science interest (Patrick et al., 2009), preferences for stereotypical science topics (Short-Meyerson et al., 2016; Hsieh et al., 2019), and math ability and performance have been documented as early as kindergarten to the fifth grade (Cvencek et al., 2011; del Río & Strasser, 2013). For example, a study with second- and fourth-grade boys and girls indicated that boys enjoyed a physical science activity more than girls, but girls indicated a stronger preference for life science TV shows about animals (Short-Meyerson et al., 2016). Additionally, Britner (2008) found that physiological states (i.e., emotional responses) predicted self-efficacy in science for high school girls, but not middle school girls. Further, the high school girls exhibited a negative emotional response to physical science regardless of their performance in coursework.

During the adolescent years, the decline of young women’s interest in and identification with the physical and math-intensive science disciplines has been documented globally. A study in the U.K. reported that 15-year-old girls were less likely than their male counterparts to respond positively to physics concepts, and were less likely to be encouraged by teachers, family, and friends to pursue physical sciences as a career option. Of the girls who did express an interest in studying physics, they demonstrated higher extrinsic motivation and positive perception of physics and physics teachers and were more introverted and more competitive (Mujtaba & Reiss, 2013). In India, a study with pre-college male and female students found that attitudes toward science are twice as likely to account for the variation in young women’s physics scores as compared to young men (Khan et al., 2022). When Baram-Tsabari et al. (2009) examined 79,000 questions sent in to an “Ask the Scientist” website, they discovered that male students asked more physical science questions as compared to female students over time. Additionally, female

students became more interested in life sciences while male students' interest in these topics decreased with age.

The reasons for the decline in interest in the physical sciences in particular are also tied to cultural influences. After interviewing 132 adolescents (age 15–16 years) and their parents, Francis et al. (2017) concluded that it is necessary to disrupt the cultural narratives that the physical sciences are “hard” and masculine before we can increase female participation in this sector. These findings are parallel to those of Lau and Ho (2022) for science attitudes overall as described earlier. In short, even though adolescent girls often earn higher math and science grades, girls with strong math and science skills aim for science careers that focus on people, such as biology and medicine, rather than things, such as physics and engineering (Ceci & Williams, 2011; Su et al., 2009) due to cultural narratives and pressures.

Adult women who pursue and succeed in physics are often distinct from women in other science disciplines (Sax et al., 2016). They tend to be more confident in their math skills and value theoretical contributions to science, as opposed to women in other science disciplines who are more likely to have a “social activist orientation.” Even so, at the undergraduate through postdoctoral level, women in physics often felt they were outside the predominant, masculine cultures of their programs (Eren, 2021). Two review articles that focused on potential reasons for the lack of gender balance in physical and math-intensive fields summarize these findings well (Cheryan et al., 2017; Avolio et al., 2020). They conclude that the perpetuation of masculine cultures in these fields does not foster women's sense of belonging and generates a concern among women that this culture will interfere with family commitments and promotion opportunities in their careers. Additionally, they describe how gender gaps in self-efficacy expand over time, and the lack of early educational experiences for young women in these disciplines. Therefore, cultural influences also discourage women in the physical sciences, in particular, and parents may play an early role in setting these cultural expectations.

1.1.3. Role of Culture, Ethnicity and Race on Representation in Sciences

Many reasons have been identified for the science achievement gap between Hispanic and non-Hispanic students. They include individual and family characteristics (such as socio-economic status and culture), psychological factors (such as self-efficacy), differential school resources and classroom environment (such as racial prejudice from teachers, less classroom resources or larger class sizes), interest in science-related careers, and family influences (such as parental support) (Crisp et al., 2009; Shoffner & Dockery, 2015; Wang, 2012). This differential performance, even when socioeconomic factors were controlled, was also documented in England with Black Caribbean students (Strand, 2012) due to differential teacher expectations and ability grouping in school that exposed children to different levels of the curriculum. Thus, the issue of differential school opportunities is not unique to minority groups in the U.S.

Ability self-concept is another important factor in the representation of Hispanic students in physical science degrees. A study with Hispanic students from more than 100 families reported that between ninth grade and 11th grade, students' ability self-concepts decreased in physics, remained steady in chemistry, and increased in biology. Additionally, their utility value decreased for all subjects, while their interest level remained steady (Hsieh et al., 2019).

The influence of science capital, described as the social and cultural influences that factor into a student's experiences with science, has been documented across many cultures (Habig et al., 2021). As one example, Lau and Ho (2022) determined that students in Hong Kong and China demonstrated lower self-efficacy than their Western peers in Canada and

Finland because their culture values modesty and strong efforts as a route to achievement, such that Chinese students may underrate their abilities. Similarly, the collectivistic family structure or culture of students from Mexico and Central America encourages children to solve problems in a group environment, which often opposes the individualistic educational environment of science and math classes in the U.S. (Greenfield & Quiroz, 2013; Hernandez & Lopez, 2004; Vasquez-Salgado et al., 2015). While this learning culture may be counter to the dominant U.S. education culture, Yosso's Community Cultural Wealth Framework highlights the strengths that Hispanic communities bring to the learning experience of Hispanic children through communal support and learning networks (Yosso, 2005). When parental education levels are low, siblings often act as role models and help to pass down science capital (Bettie, 2002). Parents encourage their children by encouraging their persistence through high expectations and encouraging them to act as role models for younger siblings (Peralta et al., 2013). A student's science capital is critically important, as it influences science career aspirations (Archer et al., 2015).

Even when science achievement is controlled, Hispanic students in the U.S. still have less interest in STEM fields as compared to their White or Asian peers who have the same assessment scores (Wang, 2012). One reason for lack of interest may be stereotype threat. High school students consistently experience stereotype threat—anxiety from the expectation of being subjected to a negative group stereotype—if they pursue a career in science (Beasley & Fischer, 2012). While this stereotype threat is a factor for all students, certain minority students experience this threat more strongly than their peers. Student interest and achievement in science and math are also related to student self-efficacy for Hispanic students and students overall (Garriott et al., 2014; Navarro et al., 2007). Moakler and Kim (2014) suggest providing more positive learning experiences for Hispanic and other underrepresented students to develop positive self-efficacy in science-related studies. For example, a project by Cordero et al. (2017) found that physics “theater type” presentations increased positive feelings about physical sciences in Hispanic students.

1.1.4. STEM and Parent Involvement

The influence of parents on the development of children's interest in science, persistence, self-efficacy, achievement, and overall science capital cannot be underestimated. Students who reported being encouraged by parents, teachers, and friends to pursue interests in science and math had more interest, better self-confidence, and were more likely to persist in STEM classes and majors (Garriott et al., 2014; Rice et al., 2013; Stake, 2006; Turner et al., 2004). Furthermore, appropriate forms of praise from parents and teachers that emphasize hard work and persistence can influence a child's self-efficacy on a task (Good et al., 2003; Mueller & Dweck, 1998). The influence of parental support on underrepresented middle school students' self-efficacy and development of math and science interests has been documented in studies of social cognitive career theory (Navarro et al., 2007; Garriott et al., 2014). At the high school level, Hyde et al. (2017) reported that 12th-grade adolescents' interest, utility value, and taking math and science courses increased when their mothers discussed and helped their children to make personal connections with math and science content during ninth grade. Simple acts of encouragement, such as enrolling children or participating with them in out-of-school STEM activities (Simpkins et al., 2006) or setting up a time and place for their child to study (O'Sullivan et al., 2014), will also enhance a child's self-efficacy and interest in science. Similarly, high school students expressed more positive attitudes about science when they had science advocates at home and school who could discuss the purpose of science literacy (Aschbacher et al., 2010). Indeed, students whose parents received brochures that highlighted the utility of taking STEM courses ended up

taking an extra semester of math and science classes in their last two years of high school as compared to a control group (Harackiewicz et al., 2012).

1.1.5. Gender, Science and Parental Involvement

Parents may influence the development of stereotypical gender norms in science, often due to biases that exist in their cultures. Subconsciously, parents can perpetuate science gender norms in many ways. For example, when working with their middle-school-aged children on science and non-science tasks, fathers but not mothers used more cognitively demanding speech (including conceptual questions, causal explanations, and scientific vocabulary) during physics tasks (H. Tenenbaum & Leaper, 2003). Similarly, a study by Shirefley and Leaper (2022) investigated mothers' and fathers' science talk while reading science books with their four- to seven-year-old sons and daughters. When reading physical science books, parents made more personal science connections with daughters than sons, but they utilized more science-learning talk with life science books. For both boys and girls, parents provided more science explanations for physical than life science books.

Parents may also be important in countering cultural norms and biases. According to a UNESCO (2017) report, parents and other family members are important science influencers in young women's lives. The authors cite programs in the Philippines and Nigeria that create a STEM culture at home and create STEM camps that foster peer-support networks to build self-confidence and community in STEM to counter cultural gender norms.

1.1.6. Ethnicity/Culture, Science and Parental Involvement

While science interests, attitudes, and career paths are influenced by various factors and agents, parents play an important role in the development of science capital and interest. Hispanic adolescents entering college in STEM fields reported that their parents played a significant role in their decision to attend college by encouraging them to persist, having high performance expectations for them, and by expecting them to be a positive role model for siblings and peers (Peralta et al., 2013). Smith et al. (2023) also found that Hispanic college students in engineering experienced numerous microaggressions that affected their self-efficacy and sense of belonging to their field of study, and that family support was helpful to counter harmful narratives about their ability and belonging.

Unfortunately, parental culture may clash with the dominant education culture, leading to reduced parental involvement. According to a report from the National Research Center on Latino Children and Families, Hispanic parents in the U.S. feel less confident about helping their child with science as compared to non-Hispanic Caucasian parents (Silander et al., 2018). Additionally, recently immigrated (to the U.S.) Hispanic parents view the parental role in education as focusing on moral development, while the role of the school is on academic development. In this context, immigrant Hispanic parents' view of parental involvement has a different meaning compared to non-immigrant families, who may focus more on partnering with the school on academic development (Liu et al., 2024).

Similarly, in a study of high school students by Simpkins et al. (2015), White male students reported higher science motivational beliefs (in biology, physics, and chemistry) and more parental support as compared to White females, Hispanic males, and Hispanic females. Additionally, Hispanic females reported significantly lower ability self-concept and lower parental science support behaviors compared to all three of the other groups.

Thus, family support is critical for fostering a student's sense of belonging and motivation, and maternal support and encouragement were found to be particularly important for multi-ethnic middle school students (Turner et al., 2004). Garriott et al. (2014) suggest that schools and community programs offer interventions to help parents learn the importance of supporting and encouraging Hispanic youth in STEM.

1.2. The Present Study

This study examined parent and child behaviors as the parent–child dyads worked on physical and life science activities together, with a focus on verbal interactions, to determine how parents supported and encouraged their children’s science interests and science capital, which may in turn influence their motivation and self-efficacy in the adolescent years. Many of these behaviors were identified in previous work (Shirefley & Leaper, 2022; Fender & Crowley, 2007; Messinger et al., 2016; Short-Meyerson et al., 2016; H. R. Tenenbaum & Callanan, 2008). While numerous studies cited above have examined the roles of parents in influencing science interests and capital overall, fewer have examined potential differences between life and physical sciences and how these manifest in parent–child behaviors at a young age (fourth grade). The behaviors of interest in the present study included types and amounts of help from the parent, encouragement from the parent, types and amounts of questions by the parent and child, problem-solving method, time to complete the activity, and amount of talk (number of parent and child utterances).

The research questions investigated include the following:

- (1) During hands-on science activities, do the following behaviors vary by science topic (i.e., physical versus life science)?
 - (a) Children’s inquiry (types and amount of questions, problem-solving method, amount of talk);
 - (b) Parents’ scaffolding (types and amounts of help, encouragement, questioning and talking);
 - (c) Parent–child interactions (amount of talk and/or time to complete the activity).
- (2) Furthermore, are these differences by science topic related to the following:
 - (a) Family ethnicity (Hispanic, non-Hispanic)?
 - (b) Parent and/or child gender?

The corresponding hypotheses for these research questions were as follows:

Hypothesis 1A. *There will not be differences by science topic (physical versus life science) for children’s behaviors.*

Hypothesis 1B. *Parents will provide more help, encouragement, and questions during the physical science activities as compared to life science activities.*

Hypothesis 1C. *Overall discussion and time to complete the activities will be greater during physical science activities as compared to life science activities.*

Hypothesis 2A. *There will be differences in behaviors by ethnicity for physical science activities as compared to life science activities.*

Hypothesis 2B. *There will be differences in behaviors by gender for physical science activities as compared to life science activities.*

2. Materials and Methods

2.1. Participants

A total of 153 fourth-grade children and their parents, guardians, or other adult relatives (such as grandparents, aunts, or uncles) participated in the study. For simplicity and brevity, all adult parental figures in the study will be referred to as parents, mothers, or fathers. The parents ranged in age from 23 to 61 years old ($M = 39.12$, $SD = 6.77$), and the children’s ages ranged from 8.87 years to 12.32 years old ($M = 9.89$, $SD = 0.55$). The ages of the children were

not significantly different by the child’s gender or ethnicity. Similarly, mothers and fathers were approximately the same age; however, the non-Hispanic parents were older than the Hispanic parents, with mean ages of 40.29 (SD = 6.96) years and 36.96 (SD = 6.02) years, respectively ($p = 0.005$). This study was part of a larger study that examined parent–child behaviors, and thus, the participant demographics are also published in other manuscripts by the same authors (Short-Meyerson et al., 2024; Sandrin et al., 2025).

Considerable efforts were made to balance the sample in terms of parent gender, child gender, parent ethnicity, and child ethnicity. Most parents and children associated with the same ethnicity; however, some dyads identified as mixed ethnicity (non-Hispanic parent with a Hispanic child). Most of the Hispanic parents self-identified as Mexican, Mexican American, or Chicano, and most of the non-Hispanic parents self-identified as Caucasian (the gender and ethnicity breakdown is described in Table 1, also Short-Meyerson et al., 2024; Sandrin et al., 2025).

Table 1. Number of dyads by gender and ethnicity. Mixed ethnicity refers to a dyad with a non-Hispanic parent and a Hispanic child. Unspecified dyads chose not to disclose their ethnicity.

Dyad Gender & Ethnicity	Both Hispanic	Both Non-Hispanic	Mixed Ethnicity	Unspecified	Totals
Father–son	13	16	5	1	35
Father–daughter	12	16	4	0	32
Mother–son	14	21	3	4	42
Mother–daughter	23	17	3	1	44
Totals	62	70	15	6	153

Additional demographic information from the parental questionnaire included the participating parent’s level of education, the family’s level of annual income, and number of siblings. There were no differences in the parents’ level of education by gender or ethnicity. Parents reported family income in \$10,000 increments from “0 = less than \$10,000” to “11 = \$110,000 or more”. Annual income was higher for non-Hispanic families as compared to Hispanic families (5.98 versus 2.83, respectively, $p = 0.001$), but not different by gender of the participating parent. The number of siblings was higher for Hispanic families as compared to non-Hispanic families (2.35 versus 1.78, respectively, $p = 0.012$), but not different by gender of the participating parent.

The families spoke a variety of languages as their first language, with English and Spanish representing the vast majority of families. Many of the Hispanic families, and some of the other non-Hispanic families, were bilingual. Some of the Hispanic parents spoke only Spanish, whereas all the Hispanic children spoke and read English along with varying levels of Spanish fluency.

Families were recruited using fliers (in English and Spanish) that were distributed through partnering school districts, partnering libraries and community centers, and parents at summer camps sponsored by the local YMCA and Boys & Girls Clubs in a large city in the Southwestern United States. Families participated one at a time in the sessions, which were held at local libraries, neighborhood schools, community centers, and a local university campus. Sessions were hosted by bilingual research associates. All families signed a consent form prior to participation, and they were assigned a random identification number to protect their anonymity. To thank them for their participation, each family received a \$50 gift card to a local department store or restaurant.

2.2. Procedure

All materials and instructions were provided in both English and Spanish, and bilingual (English and Spanish) research assistants hosted all sessions with bilingual or Spanish-speaking families to assist with questions. The families were instructed that they could talk and complete the activities in whichever language(s) they felt most comfortable. The session began with a short but fun warm-up game (Spot It!) to help the parent–child dyad feel comfortable in front of the camera (which was used to video and audio record their interactions for later analysis) and the researcher. Then the parent and child completed six hands-on science activities together, three each of physical and life sciences (brief description in Table 2, more extensive descriptions in Short-Meyerson et al., 2024; Sandrin et al., 2025). These activities were chosen and refined after use in a pilot study indicating that they were of similar difficulty level and were easily interpreted by the dyads (Short-Meyerson et al., 2016). Most activities utilized everyday toys/items that are readily available (such as Legos, corks, safety pins, juice, Q-tips, etc.) except for one each of the life science and physical science activities. One life science activity required a wearable device to detect pulse rate, and one life science activity included wires, a battery, and a small light bulb. While these are still relatively easy to access, they may not be standard items in every household, and thus each may elicit more enthusiasm and discussion. These more complex activities were balanced between life and physical science tasks so as not to bias the results. The six activities were presented to each family in a predetermined random order. Each activity included written instructions (in English and Spanish), materials needed to complete the activity, and an answer sheet on which to write their response. Each parent–child dyad could spend as much time as they needed on each activity. After the hands-on science activities, the parent completed a demographic questionnaire, and children were interviewed to learn about their science preferences.

Table 2. Brief description of science activities.

Physical Science	Electric Circuit Assembly	Sink or Float	Separating Materials (by Size and Magnetism)
Life Science	Tongue regions and flavor sensitivity	Heart rate and exercise	Plant location and sun exposure model

2.2.1. Transcription

Undergraduate and graduate students transcribed the video and audio recordings from each session using the Systematic Analysis of Language Transcript (SALT, Miller & Iglesias, 2008) conventions and program. In addition to transcribing dialog, the transcribers made notes about non-verbal behaviors to aid in interpreting the verbalizations. All Spanish language transcripts were translated into English for analysis.

2.2.2. Coding and Reliability

Two graduate students were trained by the second author to code the parent–child interactions while watching the video recordings and following along using the transcripts. Some of these behaviors were based on previous work (e.g., Fender & Crowley, 2007; Short-Meyerson et al., 2016; H. R. Tenenbaum & Callanan, 2008). Each of the following behavioral measures was coded and/or quantified for each of the six activities separately and also for all six activities together (i.e., the total for the session): (a) parental help, (b) parental encouragement, (c) questioning by the parent, (d) questioning by the child, (e) problem-solving strategy or method, (f) duration of the activity, (g) number of child utterances during the activity, and (h) number of parent utterances during the activity. The last three measures were not coded, as they were quantified by the SALT program. See

Table 3 below and Appendix A (and [Short-Meyerson et al., 2024](#)) for a full description of each coded behavioral measure.

Table 3. Description of dependent measures.

Dependent Measure	Description and Example
Help	
• Direction	Parent instructs child about what to do, such as “Connect these wires like this.”
• Observation	Parent describes something they observed, such as “It tasted tangy. . .”
• Explanation or answer	Parent explains something or provides an answer, such as “This one floats because. . .”
Encouragement	Parent makes an encouraging statement or exclamation, such as “Way to go!”
Parent Questions	
• Questions about understanding	Parent asks child about the activity or results, such as “Why do you think the cactus will grow there?”
• Prompting questions	Parent asks the child for more information, such as “What should we do next?”
• Other general questions	Parent asks a question that does not fit into the other categories
Child questions	Child asks any question of the parent, such as “Do you want to do jumping jacks?”
Method	
• Assumption	Dyad makes a prediction without reasoning, such as “It will sink.”
• Hypothesizing	Dyad makes a prediction based on reasoning, such as “Corks are less dense than water so they will float.”
• Using existing knowledge or experience	Dyad states prior knowledge to explain their strategy, such as “when we did this experiment in school. . .”
• Identify strategy	Dyad discusses experimental steps before conducting the experiment
• Making an observation	Dyad describes an observation, such as “My pulse is higher after jumping.”

Inter-rater reliability of coding of the remaining dependent measures described above was established between two independent coders and the second author and then checked in two phases. First, for training purposes, the primary rater (second author) and other coders coded six of the sessions. Agreement (between coders) was calculated as a percent agreement for each dependent measure. Discrepancies between the coders were discussed and resolved, and then revisions were made to the coding schemes, as appropriate. The revised coding schemes were then used to code all of the sessions by at least one trained coder. More than 20% of the parent–child sessions were coded by both coders, and the percent agreement was calculated for each dependent measure. As shown in Appendix B (and [Short-Meyerson et al., 2024](#)), the percentage agreement was higher than 80% for all codes, with a range of 81% to 99%.

2.2.3. Statistical Analyses

Prior to carrying out this study, a power analysis was performed to determine the minimum number of families necessary to account for differences by parent and child gender and ethnicity (assuming 2 parent and 2 child genders and 2 parent and 2 child ethnicities). This analysis indicated a minimum of 120 families were needed, balanced

regarding ethnicity and gender. We recruited over 150 families to allow for any incomplete family data sets. Out of the 153 families recruited, 138 had complete data sets and were included in the statistical analyses.

For each behavior, we investigated whether there was a difference as a function of topic (physical science vs. life science). This analysis involved a difference score, which was based on the family's behaviors during the three physical science activities (i.e., electric circuit, separating mixtures, sink-float) minus their behaviors during the three life science activities (i.e., heart rate, plant, taste). The use of difference scores allowed for simpler computations when comparing means by parent-child gender and ethnicity and provided a score that intuitively illustrated the difference between the physical science problems and life science problems. Thus, a positive difference score indicates a greater amount of the behavior during the physical science activities, whereas a negative difference score indicates a greater amount of the behavior during the life science activities, and a score near or at 0 indicates little or no difference between the physical and life science activities.

General linear models were used to determine whether each physical-life difference score was statistically significant. The physical science versus life science comparisons were made using separate general linear models of difference scores overall (for all families) and as a function of parent ethnicity (Hispanic vs. non-Hispanic), child ethnicity, parent gender, and child gender. Most commonly, parents and children identified with the same ethnicity, but this was not always the case; sometimes the children identified as Hispanic, but they attended the session with a parent who did not identify as Hispanic. The socioeconomic indicators of family income and parent education were included as covariates to assess whether variable effects remained after accounting for socioeconomic differences. These socioeconomic indicators did not explain any of the associations. Only p -values < 0.01 are considered statistically significant due to the number of tests performed. Square root transformations were used to account for outliers.

In general linear models, p -values correspond to the hypothesis test for removing only that variable and leaving all other variables in the model. Therefore, when family income and parent education p -values were large ($p > 0.01$) while the other variable's p -values were small ($p < 0.01$), we concluded that the socioeconomic variables did not contribute to the explanation provided by the model. The p -values reported in the results and supplementary tables are for differences in physical versus life science for all families, or for differences by parent or child gender or ethnicity.

3. Results

As a reminder, the scores reported are difference scores that compare the frequency of a behavior for physical science activities as compared to life science activities. A positive score indicated that this behavior was exhibited more often during physical science activities, whereas a negative score indicates higher behavior frequency during life science activities. Parent ethnicity and gender are reported for parental behaviors (such as parental helping and questioning by parents), whereas child ethnicity and gender are reported for child behaviors (such as problem-solving method and questioning by the child).

3.1. Parental Helping Behaviors

There was an effect of science topic in which parents helped by *providing an explanation or answer* more during physical science activities than during life science activities ($M = 0.58$, $SD = 1.23$, $p < 0.001$). There was also an interaction between topic and ethnicity (i.e., a different effect for one ethnicity than the other). Hispanic parents provided more help by providing an explanation or answer during physical science activities than during life

science activities ($M = 0.60$, $SD = 1.21$, $p < 0.001$), whereas there was no difference for non-Hispanic parents.

Furthermore, for help by *stating an observation*, there was an interaction between topic and parent gender that approached significance. Fathers provided marginally more of this type of help during life science activities than during physical science activities (approaching significance: $M = -0.34$, $SD = 1.09$, $p = 0.019$), whereas there was no difference for mothers.

3.2. Questioning by the Parent

There was an effect of topic for several types of parental questions. First, parents asked more *questions to prompt* their children during physical science activities than during life science activities ($M = 2.58$, $SD = 6.75$, $p < 0.001$). Additionally, there was an interaction between ethnicity and topic. Hispanic parents asked more questions to prompt than non-Hispanic parents ($M = 3.75$, $SD = 6.71$, $p < 0.001$).

Second, there was an effect of topic in which parents asked more *questions about their child's understanding* during physical science activities than during life science activities ($M = 0.81$, $SD = 2.85$, $p = 0.001$). Additionally, there was an interaction between topic and parent gender, and topic and parent ethnicity. Mothers asked more of these questions during physical science activities than during life science activities ($M = 1.04$, $SD = 2.79$, $p = 0.001$), whereas there was no difference for fathers. Also, non-Hispanic parents asked more of these types of questions during physical science activities than during life science activities ($M = 0.87$, $SD = 2.91$, $p = 0.010$).

Third, for *general questions*, there was an interaction between topic and parent ethnicity. Hispanic parents asked more general questions during physical science activities than during life science activities ($M = 2.68$, $SD = 6.01$, $p = 0.001$), whereas there was no difference for non-Hispanic parents.

3.3. Problem-Solving Methods

There was an effect of topic for the problem-solving method of *using existing knowledge or experience*. This method was used more during physical science activities than life science activities ($M = 0.41$, $SD = 0.76$, $p < 0.001$). This did not vary as a function of ethnicity or gender.

There was also an effect of topic for the problem-solving method based on *assumptions*. This method was used more during life science activities than physical science activities ($M = -0.27$, $SD = 0.96$, $p = 0.001$). Additionally, there was an interaction between topic and child ethnicity for the method based on assumption. Non-Hispanic children used this type of method more during life science activities than physical science activities ($M = -0.36$, $SD = 0.91$, $p = 0.002$), whereas there was no difference for Hispanic children. Furthermore, there was an interaction between topic and child gender for this method. Girls used this type of problem-solving method more during life science activities than physical science activities, but this was only approaching significance ($M = -0.32$, $SD = 0.93$, $p = 0.056$), whereas there was no difference for boys.

3.4. Number of Child Utterances

There was an effect of topic for the number of child utterances. Children were more talkative during physical science activities than during life science activities ($M = 20.88$, $SD = 34.93$, $p < 0.001$). This did not vary as a function of ethnicity or gender.

3.5. Number of Parental Utterances

There was an effect of topic for the number of parental utterances. Parents were more talkative during physical science activities than during life science activities ($M = 13.70$, $SD = 54.99$, $p = 0.004$). There was also an interaction between topic and parent ethnicity. Hispanic parents were more talkative during physical science activities than during life

science activities ($M = 27.75$, $SD = 62.72$, $p = 0.002$), whereas there was no difference for non-Hispanic parents.

3.6. Encouragement, Questioning by Child, Time to Complete Activities

There were no significant effects of topic (physical versus life science) on encouragement from the parent, questioning by the child, or the amount of time it took to complete the activities. This was true for all families and all dyad sub-groups by gender and ethnicity. The average time to complete *all* activities did vary by ethnicity, however. Dyads with Hispanic parents spent 41.53 min as compared to 35.62 min for non-Hispanic parents ($p = 0.003$).

See Tables 4 and 5 for summaries of the significant results by topic. Non-significant results and a more comprehensive statistical report are included in Supplementary Materials.

Table 4. Summary of significant results by topic for all families.

Behavior	Topic Effect: All Families	Mean of Phys-Life Difference (S.D.)	p-Value
Help by providing an explanation or answer	P > L	0.58 (1.23)	$p < 0.001$
Parent questions (prompting)	P > L	2.58 (6.75)	$p < 0.001$
Parent questions (about child's understanding)	P > L	0.81 (2.85)	0.001
Problem-solving method (using existing knowledge)	P > L	0.41 (0.76)	$p < 0.001$
Problem-solving method (assumptions)	L > P	−0.27 (0.96)	0.001
Number of child utterances	P > L	20.88 (34.93)	$p < 0.001$
Number of parent utterances	P > L ¹	13.70 (54.99)	0.004

¹ physical science is abbreviated as “P” and life science is abbreviated as “L”.

Table 5. Summary of significant results by topic related by dyad gender or ethnicity.

Behavior	Topic (Ethnicity)	Topic (Gender)	Mean of Phys-Life Difference (S.D.)	p-Value
Help by providing an explanation or answer	P > L (Hispanic parents only)		0.40 (0.92)	$p < 0.001$
Help by stating an observation		L > P (Fathers only)	−0.34 (1.09)	0.019 *
Parent questions (prompting)	P > L (Hispanic parents only)		3.75 (6.71)	$p < 0.001$
Parent questions (about child's understanding)		P > L (Mothers only)	1.04 (2.79)	0.001
Parent questions (about child's understanding)	P > L (non-H parents only)		0.87 (2.91)	0.010
Parent questions (general)	P > L (Hispanic parents only)		2.68 (6.01)	0.001
Problem-solving method (assumptions)	L > P (non-H children only)		−0.36 (0.91)	0.002
Problem-solving method (assumptions)		L > P (Girls only)	−0.32 (0.93)	0.056 *
Number of parent utterances	P > L (Hispanic parents only)		27.75 (62.72)	0.002

Physical science is abbreviated as “P” and life science is abbreviated as “L”. Non-H = non-Hispanic. * approaching significance.

4. Discussion

This research study adds to the literature by examining behaviors of fourth-grade children and their parents to determine if preferences for physical or life sciences emerge at

this early age. Numerous child and parent behaviors were investigated as they completed activities together. Additionally, descriptors of interactions were quantified, such as the amount of talk (i.e., number of parent and child utterances) and the amount of time parent-child dyads spent completing the activities. Finally, similarities and differences between science disciplines (physical versus life) for each behavior and descriptor were examined for families by ethnicity (parent and child, Hispanic and non-Hispanic) and for different gender combinations (mother-daughter, mother-son, father-daughter, father-son).

There were several interesting findings regarding physical science activities compared to life science activities. First, children and parents (especially Hispanic parents) were more talkative during the physical science activities than during the life science activities. These results are encouraging for Hispanic families in particular, as discussions about a topic help to build science capital (Habig et al., 2021; Moakler & Kim, 2014; Cordero et al., 2017) and thus may help to counter the trend away from physical science professions. Although this may be due in part to the particular six activities (three physical and three life science) of this study, there may be inherent differences between the topics that result in more discourse during physical science activities. Indeed, these results complement those of the Ask the Scientist program study by Baram-Tsabari et al. (2009) in which children at all levels asked more physical science than life science questions. The families did not spend any more time completing the physical science activities than they did completing the life science activities, so we cannot be sure why the physical science questions prompted more discussion. For example, are these problems more challenging or interesting and novel to the families? Further research could elucidate possible interpretations of our findings as well as provide more information about differences in interest and performance between the two science topics in high school, especially in Hispanic youth, as documented by Hsieh et al. (2019). When parents discuss science topics and make personal connections with them, their children are likely to take more science courses (Hyde et al., 2017), and so encouraging this trend in discussing physical science topics could help increase participation of female and Hispanic students in physical science majors and careers.

Regarding gender, our study results alone do not explain why high school girls do not perform as well on physical science standardized assessments in 12th grade, but they are consistent with the fact that boys and girls perform similarly in physical science assessments in fourth and eighth grade. The girls in our study were interested and engaged in both physical and life science activities, and there was no difference by child gender in the number of utterances or questions asked by the child for the two different topics. Our results also support those of other studies (Archer et al., 2010; Avolio et al., 2020; Baram-Tsabari et al., 2009; Britner, 2008; Cheryan et al., 2017; Hsieh et al., 2019) that indicate that the divergence in girls' interest in physical science occurs after the elementary years.

Many of the specific parent helping and questioning behaviors that were examined in this study occurred more during physical science activities than during life science activities. Specifically, parents (especially Hispanic parents) provided more explanations and answers during physical than life science activities. Parents also asked more prompting questions (especially Hispanic parents), questions about understanding (especially mothers and non-Hispanic parents), and general questions (Hispanic parents only) during physical as compared to life science activities. These findings are similar to those of previous researchers who found that fathers asked more conceptual questions than mothers (H. Tenenbaum & Leaper, 2003) and parents provided more explanations during physics activities as compared to life science (Shirefley & Leaper, 2022). Perhaps physical science activities are more conducive to these forms of scaffolding than life science activities, or more scaffolding is needed if the physical science activities are more cognitively challenging. In this study, there was no difference in children's questions between the topics. If

the physical science activities were more challenging than life science, we may expect the children to ask more questions during those activities. Either way, these findings are promising as they indicate that parents are generally willing to talk about and help their children with physical science activities when they are accessible and do not require a lot of science background knowledge. It is unclear if the same trends will continue as students enter more advanced grades with more complicated science content. As discussed by [Silander et al. \(2018\)](#), Hispanic (and likely other) parents may feel intimidated about helping their children with science problems if they lack the background knowledge and training. Fortunately, parental help in the form of setting up a time and place for children to study ([O'Sullivan et al., 2014](#)) or discussing the purpose of science literacy with them ([Aschbacher et al., 2010](#)) also enhances children's self-efficacy and positive attitudes about science, even without knowledge of the topic.

Interestingly, different parent helping and dyad behaviors dominated during life science activities. For all families, the problem-solving strategy of making assumptions (especially for mothers and non-Hispanic families) was employed more often during life versus physical science activities. Additional behaviors were observed more often with life science than physical science as well, but for specific groups only. For example, fathers offered more help in the form of observations during life science activities. Again, these results align with those of [Shirefley and Leaper \(2022\)](#), who found that parents make more inferences (assumptions) and personal connections (observations) when reading life science books with their children. [Short-Meyerson et al. \(2016\)](#) similarly, the method of making assumptions without support (especially for non-Hispanic dyads and for dyads with girls) was used more often during life science activities than physical activities. The use of inferences or assumptions was also more commonly used for life science books in [Shirefley and Leaper's \(2022\)](#) study. We are uncertain about why the children and families used different strategies for different types of problems. One hypothesis is related to comfort with a topic. If families spend more time reading about and learning about life science topics, they may feel more comfortable making assumptions without support because they feel that they already know the answer. This comfort with one topic over another may translate to a preference for life science later in adolescence—a trend that has been observed by [Hsieh et al. \(2019\)](#). Conversely, children relied on the problem-solving method of using existing knowledge or experience more during physical science activities than life science activities. As with the discussion above about parents providing more scaffolding with physical science activities, perhaps children also gain support with these topics by applying past experiences.

There was no difference between the topics in the encouragement provided by the parents. However, there was surprisingly little encouragement overall regardless of topic, as presented in more detail in another study by the same authors ([Short-Meyerson et al., 2024](#)). As we know from past studies, encouragement from parents and teachers was more likely to maintain their interest and self-confidence in science, leading to a greater likelihood that they would pursue a science major ([Garriott et al., 2014](#); [Peralta et al., 2013](#); [Rice et al., 2013](#); [Stake, 2006](#); [Turner et al., 2004](#)). Thus, it is important for teachers and outreach specialists to communicate to parents the significant influence that their encouragement has on their children's science interests and attitudes. Further, it may be beneficial for them to discuss the disparity between participation in life and physical sciences, and the variety of ways that careers in physical sciences benefit society. This messaging may help to counter cultural norms that lead young women and Hispanic youth to consider life science fields of study over physical science.

We did not see drastic differences in the ways that these families engaged with physical versus life science activities in this study, but rather subtle differences in how parents and

children addressed the topics. These findings are not surprising given those of past studies that indicate that gaps between disciplines in interest, self-efficacy, and attitudes tend to be small during early years, becoming more pronounced during middle and high school years (Archer et al., 2010; Baram-Tsabari & Yarden, 2011; Nosek & Smyth, 2011). We anticipate that as students get older and speech surrounding these topics becomes more cognitively demanding, more gaps by topic may emerge, as observed by H. Tenenbaum and Leaper (2003) for families with middle-school-aged children. Overall, the levels of parent–child engagement and discussion were encouraging, as they indicate that parents are willing and eager to work with their children on science activities that are accessible (for example, in the parent’s first language) and include adequate props to make the experience fun and engaging.

Limitations

This study is a study of fourth-grade students at one point in time, and as such, it cannot draw conclusions about behaviors at other stages of life. The goal of this study was to observe potential preferences and behaviors during physical science versus life science activities in a mid-elementary group of students. Further, it examines behaviors at this educational stage, but not the cause for these behaviors.

For this study, three particular physical science activities (completing an electric circuit, predicting whether objects will sink or float when placed in water, and determining how to separate iron filings from other materials) and three particular life science activities (predicting which areas of the tongue will be most sensitive to different flavors, determining the best locations to grow plants, and predicting how one’s heart rate will be affected by exercise) were chosen to represent each of those topics (i.e., disciplines). Although it was advantageous to include multiple activities from each topic and the specific activities were purposefully chosen (they had been piloted along with five other physical and life science activities in a prior study, see Short-Meyerson et al., 2016), it is possible that the results would not have generalized to other physical science and life science activities. In future research, it would be interesting to include other activities to see if the results would be replicated with a different array of activities. Furthermore, this study focused only on the disciplines of physical science and life science. The impact of topic would be further informed by investigation of a broader array of disciplines, such as earth science and engineering.

5. Conclusions

The findings of this study speak to the development of science attitudes and interests in students’ mid-elementary years, especially as they begin to differentiate between physical and life sciences. Furthermore, the results demonstrate how parents may influence the development of these attitudes and interests and potentially pass on biases about science topics in subtle ways through how they help and ask questions, time on task (which may indicate greater interest), and exploration of different science topics. These findings are relevant to parents and educators of all children, regardless of ethnicity or gender.

The distinction between different science topics (physical and life) in the present study has additional important implications for educational researchers. Given our findings that parents used more helping behaviors and asked more questions during physical science activities than during life science activities, future researchers who are investigating these parental behaviors in elementary children may benefit from focusing on physical science disciplines. Further examination may also tease apart whether these helping behaviors are used primarily to provide assistance when their child is challenged, or alternatively, to maintain or increase engagement.

We observed differences in how parents and children interact with physical versus life science activities. For example, they talked more about physical science activities, but they

did not spend more time on task on these activities, as compared to life science. However, it is encouraging to see that parents spent equal amounts of time engaged with each topic, as it indicates that parents are willing and often even enthusiastic about helping their children with hands-on science activities, regardless of topic. During the high school years, physical science classes tend to incorporate more math as compared to life science, and this may lead parents (many of whom have not flexed their high school math muscles in many years) to feel intimidated by helping their children with these classes, signaling that they are “harder”. Just as Sax et al. (2016) reported that women who go into physical sciences have better math skills, it may also be true that parents who are comfortable helping their high school children with physical science homework also have better math skills. If the science and education communities can communicate to parents that parental help can come in many forms, including setting aside quiet study spaces and discussing applications of science content, parents may feel more comfortable helping and encouraging their children in both physical and life science topics. Also, by discussing how each topic benefits society, and by countering cultural norms with regard to discussions about who is represented in physical versus life science professions, parents may help to cultivate interest in both fields of study more equitably. With regard to gender and ethnicity, we observed some differences in how physical and life science activities were addressed, but additional studies with parents, children, and teachers (ranging from elementary to high school age) are necessary to fully explain the gaps in participation between physical and life science majors and careers for women and Hispanic students. Furthermore, the findings from this study showed that Hispanic families and dyads with mothers often provided more help or prompted more questions and talked more about physical science activities, which is contradictory to the gaps we see later in life. Therefore, it is likely these gaps emerge during adolescence, perhaps due to stereotype threat and other social cues. Fortunately, these threats and cues also may be countered by parents through encouragement, direct or indirect help, and thoughtful and positive discussions about physical science careers and topics.

We conclude by proposing that parental influence is often underestimated, perhaps by parents most of all. Educating parents about their influence and about a wider range of career paths in science, in conjunction with other efforts, has the potential to reduce the gender and ethnicity gap between physical and life science participation.

Supplementary Materials: The following supporting information can be downloaded at <https://www.mdpi.com/article/10.3390/educsci16081240/s1>. Table S1: Statistical test results for physical and life science comparisons.

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Abbreviations

The following abbreviations are used in this manuscript:

STEM	Science, Technology, Engineering and Math
NSF	National Science Foundation
UNESCO	United Nations Educational, Scientific and Cultural Organization
U.S.	United States
U.K.	United Kingdom

Appendix A. Behavioral Measures

1. Help from Parent: Binary coding was used for each of three types of help for each activity: Direction: Telling the child what to do to solve the problem, without explanation of why, or directing scientific experimentation (e.g., “Connect these wires like this”, “Let’s make a prediction”).

Explanation or Answer: Providing an explanation, or stating an answer or prediction (e.g., “This one floats because it is so much lighter than the water”, “I think it is going to sink).

Observation: Stating an observation relating to the solution of the problem, or reflecting on the outcome of a prediction (e.g., “It tasted tangy around the tip” or “Alright we got one right”).

2. Encouragement from Parent: Encouragement was coded as binary for each parental conversational turn. It included encouragement in a general form (e.g., “good job”), providing detailed or complex encouragement (e.g., “that’s a good idea to try to add them up first”), and encouraging the child to continue with the activity (e.g., “Keep going, almost there” to continue exercising during the heart-rate activity).

3. Questioning by the Parent: Each question asked by the parent was coded as one of three types:

Question About Understanding: Questions to determine or deepen child’s understanding, or asking for child’s explanation (e.g., “Why would you plant the cactus there?” or “Can you explain that to me?”).

Prompting Question: Questions aimed at prompting the child to perform an action, make a choice, or make a prediction (e.g., “How should we use the magnet to separate the mixture?” or “Is it going to sink or is it going to float?”).

Other General Question: Any general type of question not included in the categories above, such as asking for repetition of a word or phrase from the child (e.g., “What?” or “Ready?”).

4. Questioning by the Child: Child questions were coded as binary (i.e., the child’s conversational turn either included a question or it did not). Some of the examples of the questions we observed included asking about the process used to solve the problem (e.g., “What should we do first?”), their previous experience with the process (e.g., “Like at the museum with the magnet?”), the materials (e.g., “How do I use the heart rate monitor?”), what the parents’ answer or hypothesis is (e.g., “What is your hypothesis?”), whether they solved the problem correctly (e.g., “Was that right?”), and asking for repetition of a

word or phrase from the parent (e.g., “What?”, “Huh?”). Unlike the parents’ questions, the children’s questions were not coded by type because it was often difficult to determine the intent of the children’s questions.

5. Problem-Solving Method: Five methods for working through the activity were identified, and binary coding was used for each method for each activity:

Making an Assumption: Making a prediction, without any reasoning, knowledge, or theory to support it (e.g., “it will sink”, without saying why they predict the object will sink, or “because I just know it”).

Hypothesizing: Making a prediction based on reasoning, knowledge, or theory (e.g., “The golf ball will go under because it is heavy.”).

Identifying a Strategy: Explaining the experimental strategy or algorithm they intend to use (e.g., “I’ll put another bulb on there”).

Using Existing Knowledge or Experience: Stating prior experience with the activity (e.g., “I’ve done this before”).

Making an Observation: Observation about what they are noticing about the activity (e.g., “I can see the water coming through”), or stating observations about predictions (e.g., “I thought it was going to float. We predicted correct.”).

6. Duration (Amount of Time to Complete the Activities): This is the number of minutes the parent–child dyad spent working on an activity (from when they picked up the materials and started reading the instructions to when they finished writing their response and finished talking about the problem and put the materials away).

7. Number of Child Utterances During the Activity: Following the conventions of SALT (Miller & Iglesias, 2008), utterances were similar to sentences and were distinguished by pauses, intonation, and grammatical rules. A child’s utterance could consist of a single word or multiple words.

8. Number of Parent Utterances During the Activity: A parent’s utterance could also consist of a single word or multiple words.

Appendix B

Table A1. Inter-rater reliability (percent agreement) for coding of dependent measures.

Dependent Measure	Percent Agreement
Help	86.23
• Direction	84.06
• Observation	87.68
• Explanation or answer	86.96
Encouragement	98.96
Parent Questions	86.41
• Questions about understanding	94.18
• Prompting questions	84.19
• Other general questions	80.86
Child questions	99.41
Method	92.03
• Assumption	94.20
• Hypothesizing	92.03
• Using existing knowledge or experience	93.48
• Identify strategy	87.68
• Making an observation	92.75

References

- Archer, L., Dawson, E., DeWitt, J., Seakins, A., & Wong, B. (2015). “Science capital”: A conceptual, methodological, and empirical argument for extending bourdieusian notions of capital beyond the arts. *Journal of Research in Science Teaching*, 52, 922–948. [\[CrossRef\]](#)
- Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2010). “Doing” science versus “being” a scientist: Examining 10/11-year-old schoolchildren’s constructions of science through the lens of identity. *Science Education*, 94(4), 617–639. [\[CrossRef\]](#)
- Aschbacher, P., Li, E., & Roth, E. (2010). Is science me? High school students’ identities, participation and aspirations in science, engineering, and medicine. *Journal of Research in Science Teaching*, 47(5), 564–582. [\[CrossRef\]](#)
- Avolio, B., Chávez, J., & Vélchez-Román, C. (2020). Factors that contribute to the underrepresentation of women in science careers worldwide: A literature review. *Social Psychology of Education*, 23(3), 773–794. [\[CrossRef\]](#)
- Baram-Tsabari, A., Sethi, R., Bry, L., & Yarden, A. (2009). Asking scientists: A decade of questions analyzed by age, gender and country. *Science Education*, 93(1), 131–160.
- Baram-Tsabari, A., & Yarden, A. (2011). Quantifying the gender gap in science interest. *International Journal of Science and Mathematics Education*, 9(3), 523–550.
- Beasley, M., & Fischer, M. (2012). Why they leave: The impact of stereotype threat on the attrition of women and minorities from science, math and engineering majors. *Social Psychology of Education*, 15(4), 427–448. [\[CrossRef\]](#)
- Bettie, J. (2002). Exceptions to the rule: Upwardly mobile white and Mexican American high school girls. *Gender & Society*, 16(3), 403–422. [\[CrossRef\]](#)
- Bhanot, R. T., & Jovanovic, J. (2009). The links between parent behaviors and boys’ and girls’ science achievement beliefs. *Applied Developmental Science*, 13(1), 42–59. [\[CrossRef\]](#)
- Britner, S. (2008). Motivation in high school science students: A comparison of gender differences in life, physical and earth science classes. *Journal of Research in Science Teaching*, 45(8), 955–970. [\[CrossRef\]](#)
- Ceci, S. J. (2018). Women in academic science: Experimental findings from hiring studies. *Educational Psychologist*, 53(1), 22–41.
- Ceci, S. J., & Williams, W. M. (2011). Understanding current causes of women’s underrepresentation in science. *Proceedings of the National Academy of Sciences*, 108(8), 3157–3162. [\[CrossRef\]](#) [\[PubMed\]](#)
- Cheryan, S., Ziegler, S. A., Montoya, A. K., & Jiang, L. (2017). Why are some stem fields more gender balanced than others? *Psychological Bulletin*, 143(1), 1–35. [\[CrossRef\]](#) [\[PubMed\]](#)
- Cordero, H., Lombardi, G., Fuenmayor, E., & Verrilli, D. (2017). El teatro como estrategia movilizadora de emociones y actitudes hacia las clases de física [The theater as a mobilizing strategy of emotions and attitudes towards physics classes]. *Investigações em Ensino de Ciências*, 22(1), 189–221. [\[CrossRef\]](#)
- Crisp, G., Nora, A., & Taggart, A. (2009). Student characteristics, pre-college, college, and environmental factors as predictors of majoring in and earning a STEM degree: An analysis of students attending a Hispanic Serving Institution. *American Educational Research Journal*, 46(4), 924–942. [\[CrossRef\]](#)
- Cvencek, D., Meltzoff, A., & Greenwald, A. (2011). Math-gender stereotypes in elementary school children. *Child Development*, 82(3), 766–779. [\[CrossRef\]](#) [\[PubMed\]](#)
- del Río, M. F., & Strasser, K. (2013). Preschool children’s beliefs about gender differences in academic skills. *Sex Roles*, 68(3–4), 231–238.
- Eren, E. (2021). Exploring science identity development of women in physics and physical sciences in higher education. *Science & Education*, 30, 1131–1158. [\[CrossRef\]](#)
- Fender, J., & Crowley, K. (2007). How parent explanation changes what children learn from everyday scientific thinking. *Journal of Applied Developmental Psychology*, 28(3), 189–210. [\[CrossRef\]](#)
- Francis, B., Archer, L., Moote, J., DeWitt, J., MacLeod, E., & Yeomans, L. (2017). The construction of physics as a quintessentially masculine subject: Young people’s perceptions of gender issues in access to physics. *Sex Roles*, 76(3–4), 156–174. [\[CrossRef\]](#)
- Fussy, D. S., Iddy, H., Amani, J., & Mkimibili, S. T. (2023). Girls’ participation in science education: Structural limitations and sustainable alternatives. *International Journal of Science Education*, 45(14), 1141–1161. [\[CrossRef\]](#)
- Garriott, P., Flores, L., Prabhakar, B., Mazzotta, E., Liskov, A., & Shapiro, J. (2014). Parental support and underrepresented students’ math/science interests: The mediating role of learning experiences. *Journal of Career Assessment*, 22(4), 627–641.
- Good, C., Aronson, J., & Inzlicht, M. (2003). Improving adolescents’ standardized test performance: An intervention to reduce the effects of stereotype threat. *Applied Developmental Psychology*, 24, 645–662. [\[CrossRef\]](#)
- Greenfield, P. M., & Quiroz, B. (2013). Context and culture in the socialization and development of personal achievement values: Comparing Latino immigrant families, European American families, and elementary school teachers. *Journal of Applied Developmental Psychology*, 34, 108–118. [\[CrossRef\]](#)
- Gupta, N. (2007). Indian women in doctoral education in science and engineering: A study of informal milieu at the reputed Indian institutes of technology. *Science, Technology, & Human Values*, 32(5), 507–533. [\[CrossRef\]](#)
- Habig, B., Gupta, P., & Adams, J. D. (2021). Disrupting deficit narratives in informal science education: Applying community cultural wealth theory to youth learning and engagement. *Cultural Studies of Science Education*, 16, 509–548. [\[CrossRef\]](#)

- Harackiewicz, J. M., Rozek, C. S., Hulleman, C. S., & Hyde, J. S. (2012). Helping parents to motivate adolescents in mathematics and science. *Psychological Science*, 23(8), 899–906. [CrossRef] [PubMed]
- Hernandez, J. C., & Lopez, M. A. (2004). Leaking pipeline: Issues impacting Latino/a college student retention. *Journal of College Student Retention*, 6(1), 37–60. [CrossRef]
- Hsieh, T.-y., Liu, Y., & Simpkins, S. D. (2019). Changes in United States Latino/a high school students' science motivational beliefs: Within group differences across science subjects, gender, immigrant status, and perceived support. *Frontiers in Psychology*, 10, 380. [CrossRef] [PubMed]
- Hyde, J. S., Canning, E. A., Rozek, C. S., Clarke, E., Hulleman, C. S., & Harackiewicz, J. M. (2017). The role of mothers' communication in promoting motivation for math and science course-taking in high school. *Journal of Research on Adolescence*, 27(1), 49–64. [CrossRef] [PubMed]
- Jocz, J. A., Zhai, J., & Tan, A. L. (2014). Inquiry learning in the Singaporean context: Factors affecting student interest in school science. *International Journal of Science Education*, 36(15), 2596–2618. [CrossRef]
- Khan, M., Abid Siddiqui, M., & Malone, K. L. (2022). Scientific attitudes: Gender differences, impact on physics scores and choices to study physics at higher levels among pre-college STEM students. *International Journal of Science Education*, 44(11), 1816–1839. [CrossRef]
- Lau, K.-C., & Ho, S.-C. E. (2022). Attitudes towards science, teaching practices, and science performance in PISA 2015: Multilevel analysis of the Chinese and western top performers. *Research in Science Education*, 52, 415–426. [CrossRef]
- Liu, A., Heath, M., & Grzywacz, J. G. (2024). Cultural meaning of education and parents' involvement in education: Perspectives of immigrant Latinos. *Family Relations*, 73(1), 262–281. [CrossRef]
- Messinger, K., Sandrin, S., Trudel, A., & Short-Meyerson, K. (2016, January 7–9). *Differential parental encouragement and guidance during science problem solving? Examining implicit biases based on gender and ethnicity* [Paper presentation]. Association for Science Teacher Education (ASTE) International Conference, Reno, NV, USA.
- Miller, J. F., & Iglesias, A. (2008). *Systematic analysis of language transcripts (SALT), English & Spanish* (Version 9) [Computer software]. University of Wisconsin—Madison, Waisman Center, Language Analysis Laboratory.
- Moakler, M., & Kim, M. (2014). College major career choice in STEM: Revisiting confidence and demographic factors. *The Career Development Quarterly*, 62, 128–142. [CrossRef]
- Mueller, C. M., & Dweck, C. S. (1998). Praise for intelligence can undermine children's motivation and performance. *Journal of Personality and Social Psychology*, 75(1), 33–52. [CrossRef] [PubMed]
- Mujtaba, T., & Reiss, M. J. (2013). What sort of girl wants to study physics after the age of 16? Findings from a large-scale UK survey. *International Journal of Science Education*, 35, 2979–2998. [CrossRef]
- National Center for Science and Engineering Statistics. (2021). *Women, minorities, and persons with disabilities in science and engineering*. Special report NSF 21-321. National Science Foundation. Available online: <https://ncses.nsf.gov/pubs/nsf21321/report> (accessed on 19 January 2026).
- National Science Foundation, National Center for Science and Engineering Statistics. (2017). *Women, minorities, and persons with disabilities in science and engineering*. Special report NSF 17-310. Available online: <https://www.nsf.gov/statistics/2017/nsf17310/> (accessed on 19 January 2026).
- Navarro, R., Flores, L., & Worthington, R. (2007). Mexican American middle school students' goal intentions in mathematics and science: A level of social cognitive career theory. *Journal of Counseling Psychology*, 54, 320. [CrossRef]
- Nosek, B. A., & Smyth, F. L. (2011). Implicit social cognitions predict sex differences in math engagement and achievement. *American Educational Research Journal*, 48(5), 1125–1156. [CrossRef]
- Nosek, B. A., Smyth, F. L., Sriram, N., Lindner, N. M., Devos, T., Ayala, A., Bar-Anan, Y., Bergh, R., Cai, H., Gonsalkorale, K., Kesebir, S., Maliszewski, N., Neto, F., Olli, E., Park, J., Schnabel, K., Shiomura, K., Tulbure, B. T., Wiers, R. W., . . . Greenwald, A. G. (2009). National differences in gender–science stereotypes predict national sex differences in science and math achievement. *Proceedings of the National Academy of Sciences*, 106(26), 10593–10597. [CrossRef] [PubMed]
- O'Sullivan, R. H., Chen, Y., & Fish, M. C. (2014). Parental mathematics homework involvement of low-income families with middle school students. *School Community Journal*, 24(2), 165–188.
- Patrick, H., Mantzicopoulos, P., & Samarapungavan, A. (2009). Motivation for learning science in kindergarten: Is there a gender gap and does integrated inquiry and literacy instruction make a difference? *Journal of Research on Science Teaching*, 46, 166–191. [CrossRef]
- Peralta, C., Caspary, M., & Boothe, D. (2013). Success factors impacting Latina/o persistence in higher education leading to STEM opportunities. *Cultural Studies of Science Education*, 8, 905–918. [CrossRef]
- Rice, L., Barth, J., Guadagno, R., Smith, G., & McCallum, D. (2013). The role of social support in students' perceived abilities and attitudes toward math and science. *Journal of Youth and Adolescence*, 42(7), 1028–1040. [CrossRef] [PubMed]
- Sandrin, S., Broatch, J., & Short-Meyerson, K. (2025). Role of parent language and ethnicity on family science problem-solving processes. *Education Sciences*, 15(12), 1573. [CrossRef]

- Sax, L., Lehman, K., Barthelemy, R., & Lim, G. (2016). Women in physics: A comparison to science, technology, engineering, and math education over four decades. *Physics Review Physics Education Research*, 12(2), 1–17. [CrossRef]
- Shirefley, T. A., & Leaper, C. (2022). Mothers' and fathers' science-related talk with daughters and sons while reading life and physical science books. *Frontiers in Psychology*, 12, 813572. [CrossRef] [PubMed]
- Shoffner, M., & Dockery, D. (2015). Promoting interest in and entry into science, technology, engineering, and mathematics careers. In P. Hartung, M. Svickas, & W. Walsh (Eds.), *APA handbooks in psychology. APA handbook of career intervention, Vol. 2. Applications* (pp. 125–137). American Psychological Association.
- Short-Meyerson, K., Sandrin, S., & Edwards, C. (2016). Gender influences on parent-child problem solving behaviors. *Journal of Research in Childhood Education*, 30, 334–348. [CrossRef]
- Short-Meyerson, K., Sandrin, S., & Jimenez-Silva, M. (2024). Informal elementary science: Repertoires of parental support. *Education Sciences*, 14(6), 611. [CrossRef]
- Silander, M., Grindal, T., Hupert, N., Garcia, E., Anderson, K., Vahey, P., & Pasnik, S. (2018). *What parents talk about when they talk about learning: A national survey about young children and science*. Education Development Center, Inc., & SRI International.
- Simpkins, S. D., Davis-Kean, P. E., & Eccles, J. S. (2006). Math and science motivation: A longitudinal examination of the links between choices and beliefs. *Developmental Psychology*, 42, 70–83. [CrossRef] [PubMed]
- Simpkins, S. D., Price, C. D., & Garcia, K. (2015). Parental support and high school students' motivation in biology, chemistry, and physics: Understanding differences among Latino and Caucasian boys and girls. *Journal of Research in Science Teaching*, 52(10), 1386–1407. [CrossRef]
- Smith, K. C., Poleacovschi, C., Feinstein, S., & Luster-Teasley, S. (2023). Ethnicity, race, and gender in engineering education: The nuanced experiences of male and female Latinx engineering undergraduates targeted by microaggressions. *Psychological Reports*, 126(5), 2345–2382. [CrossRef] [PubMed]
- Stake, J. (2006). The critical mediating role of social encouragement for science motivation and confidence among high school girls and boys. *Journal of Applied Social Psychology*, 36(4), 1017–1045. [CrossRef]
- Strand, S. (2012). The White British-Black Caribbean achievement gap: Tests, tiers and teacher expectations. *British Educational Research Journal*, 38, 75–101. [CrossRef]
- Su, R., Rounds, J., & Armstrong, P. I. (2009). Men and things, women and people: A meta-analysis of sex differences in interests. *Psychological Bulletin*, 135(6), 859–884. [CrossRef] [PubMed]
- Tenenbaum, H., & Leaper, C. (2003). Parent-child conversations about science: The socialization of gender inequities? *Developmental Psychology*, 39, 34–47. [CrossRef] [PubMed]
- Tenenbaum, H. R., & Callanan, M. A. (2008). Parents' science talk to their children in Mexican-descent families residing in the USA. *International Journal of Behavioral Development*, 32(1), 1–12. [CrossRef]
- Turner, S., Steward, J., & Lapan, R. (2004). Family factors associated with sixth-grade adolescents' math and science career interests. *Career Development Quarterly*, 53, 41–52. [CrossRef]
- UNESCO. (2017). *Cracking the code: Girls' and women's education in science, technology, engineering and mathematics (STEM)*. UNESCO.
- U.S. Department of Education. (2019). *Institute of Education Sciences, National Center for Education Statistics, National Assessment of Educational Progress (NAEP), science & mathematics assessment*. Available online: <https://www.nationsreportcard.gov/science/> (accessed on 19 January 2026).
- U.S. Department of Education. (2024). *Institute of Education Sciences, National Center for Education Statistics, National Assessment of Educational Progress (NAEP), 2024 science assessment*. Available online: <https://www.nationsreportcard.gov/ndecore/xplore/NDE> (accessed on 19 January 2026).
- Vasquez-Salgado, Y., Greenfield, P. M., & Burgos-Cienfuegos, R. (2015). Exploring home-school value conflicts: Implications for academic achievement and well-being among Latino first-generation college students. *Journal of Adolescent Research*, 30, 271–305.
- Wang, X. (2012). *Modeling student choice of STEM fields of study: Testing a conceptual framework of motivation, high school learning, and postsecondary context of support* (Working paper). Wisconsin Center for the Advancement of Postsecondary Education.
- Yosso, T. (2005). Whose culture has capital? A critical race theory discussion of community cultural wealth. *Race Ethnicity and Education*, 8, 69–91. [CrossRef]

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