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# Falling in love and staying in love with science: ongoing informal science experiences support fascination for all children

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## ABSTRACT

Ages 10–14 mark a period in which children develop a strong sense of whether science is ‘for them,’ a time that typically coincides with the start of middle school in the United States and their first exposure to more rigorous science classes and testing. Experiences with science in and out of school can shape children’s motivation to choose science careers or participate in voluntary science classes later on, for better or worse. We explore the hypothesis that children who engage in more informal educational science experiences at the start of this period are more likely than their peers to obtain and maintain interest, curiosity, and mastery goals in science (together forming a construct called fascination). We measured 983 children’s fascination with science at the beginning and middle of sixth grade. We found that the children who participated in informal science during this time were more likely to maintain or have greater fascination than at the start. These findings held while also controlling for many potentially confounding covariates and are robust across subgroups by gender and race/ethnicity. Further, the effects are largest for those children whose family generally supports their learning.

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motivation; context effects

## Introduction

Science education is critical both to supporting adults’ abilities to apply science knowledge and skills to everyday decision-making (Crowell & Schunn, 2016) and to meeting the demand of ever-expanding STEM fields, in which white males still hold a disproportionate number of jobs (DeBoer, 2000; Estrada, Woodcock, Hernandez, & Schultz, 2011; National Research Council, 1996; National Science Board, 2015). Young children tend to start out highly motivated in science, regardless of gender, race, or even academic achievement (Patrick, Mantzicopoulos, Samarapungavan, & French, 2008). Mounting evidence shows that as children get older, particularly between ages 10 and 14, children’s intentions to maintain a lifelong relationship with science solidifies, based on interests and other motivational factors (Tai et al., 2006; Maltese & Tai, 2011). In the United States, the start of this period coincides with middle school; science curriculum and testing become more challenging at this stage, and for many children it is their only ‘real’ exposure

to science before they have to start making trajectory-altering decisions about what classes and activities to participate in during high school. Unfortunately, many children's interest in science decreases in middle school (Christidou, 2011; Potvin & Hasni, 2014). Children are also often acclimating to a new school and new peer groups, experiencing many biological transitions associated with early adolescence, and negotiating new kinds of relationships with peers, parents, and teachers (Wentzel, 1998). All of these factors can impact motivation to engage in science and science practices, e.g. willingness to engage in the scientific practice of argumentation, which children may feel runs counter to the goal of making friends and playing nice (Bathgate et al., 2015).

Girls face additional challenges with staying or growing motivated with respect to science. Regardless of ability, girls' attitudes towards science in middle school are typically more science-averse than male, non-minority peers' (Catsambis, 1995; Jones, Howe, & Rua, 2000). Parents encourage sons in science regardless of their beliefs about their interest or competence in science, but are less likely to encourage daughters, who they believe will not like it or find it difficult (Tenenbaum & Leaper, 2003). This effect can be found in other countries; Shin and colleagues (2015) found that Korean girls had lower intrinsic motivation to engage in science and intentions to pursue science careers than boys, and that the parents' expectations for girls' participation in science were also lower regardless of parents' values, education, or income.

Children from non-dominant cultures may also face barriers to getting and staying engaged with science. Ways of knowing differ by culture, as do values and means of communicating thought and knowledge (Gutiérrez, Baquedano-López, & Tejada, 1999). Children from non-dominant communities, such as African American children, have faced discrimination in the form of poor science instruction, tracking, and low teacher expectations as compared to dominant-culture counterparts (Atwater, 2000; Oakes, 1990). Children of colour have been found to have 'exceptionally negative attitudes' toward science and their futures in that field, and attitudes decline toward science in middle or high school for many children (Atwater, Wiggins, & Gardner, 1995; as cited in Zacharia & Barton, 2004).

Research suggests that for all children, local, culturally-relevant informal science experiences may help support children's motivation to engage in science during the critical 10–14 age range and distinguish kids who flourish from those who lose the motivation to pursue science early on (National Research Council, 2009). Informal experiences with science are one of several forms of 'science capital' that enables children's motivation and ability to engage with and excel in science and stay on a pathway to STEM careers (Archer, Dawson, DeWitt, Seakins, & Wong, 2015; DeWitt & Archer, 2015). Informal environments for science learning are non-school, informal settings that are typically 'learner-motivated, guided by learner interests, voluntary, personal, ongoing, contextually relevant, collaborative, nonlinear, and open-ended' (NRC, 2009). Because of these features, informal learning experiences have been argued to be essential for supporting children's interest in and motivation for science (Dabney et al., 2012; Eccles et al., 1993; National Research Council, 2009). Whether conducted at home with parents or in organisations dedicated to informal learning, such as museums and science centres, the evidence shows that informal science experiences relate to interests in early childhood or middle school that, when sustained, may lead to continued STEM participation and/or STEM degrees and careers (Crowley, et al., 2015; Maltese & Tai, 2010).

### ***Science fascination: interest, curiosity, and mastery goals***

In this study, we specifically explore the relationship of informal science learning activities with children's science fascination. Science fascination is a motivational construct that integrates interest towards a topic (Baram-Tsabari & Yarden, 2005; Girod, 2001; Hidi & Renninger, 2006; Hulleman & Harackiewicz, 2009; Kind, Jones, & Barmby, 2007; Reid, 2006), curiosity (Gardner, 1987; Litman & Spielberger, 2003; Loewenstein, 1994), and mastery goals (Ames, 1992). Dorph, Cannady, and Schunn (2016) argued that conceptually it was likely that these three traits would co-occur in children – i.e. a child with strong interest in science would also have more scientific curiosity and be less focused on grades than on learning more about science. They also found, psychometrically, that interest, mastery, and curiosity cohere into a single factor and that, together, they capture an 'emotional and cognitive attachment/obsession with science topics and tasks' (p. 54) that they hypothesise to be a core driver of children's sustained participation and engagement with science content in and out of school. We next describe the three components of fascination in more detail.

Hidi and Renninger (2006) defined interest as a 'psychological state of engaging or the predisposition to re-engage with particular classes of objects, events, or ideas over time.' In other words, children are initially exposed to science and related topics, and those whose interest in science increases will be likely to pursue more information about it, participate in activities related to it, or choose careers based on it. Over half of scientists and science-related workers in a study reported early interest in science-related topics (Crowley et al., 2014). By eighth grade, children's STEM career interests can be predictive of later career choices (Cannady, Greenwald, & Harris, 2014). But interests need to be supported to flourish. And that is sometimes difficult across the in and out-of-school boundary. Anderhag et al. (2016) found, for example, that middle schoolers' pre-existing interests were not supported in the transition from elementary-level to middle school-level grades. Bell, Bricker, Reeve, Zimmerman, and Tzou (2013) describe detailed cases of how discontinuous boundaries between home and school can threaten children's developing STEM interests and regular participation.

Second, we consider curiosity. Kagan (1972) conceived of the desire to resolve uncertainty or the 'need to know' as a basic human motive, yet not all children who initially have questions about their natural environment, bodies, or how things work eventually connect such questions to STEM learning. Curiosity, and its satisfaction, may both grow from interest and serve to support the transition from early exposure to science, to a sustained, well-developed interest. Loewenstein (1994) built on theories of curiosity as a human drive, need, or pursuit of competence into an 'information gap theory,' which stated that children who have foundational knowledge of something (perhaps acquired through the pursuit of an interest) may then become aware of a gap in their knowledge and seek to resolve it. A caveat, however, is that children must recognise the gap, and also believe that this reference point is potentially attainable. For middle school girls of all ability levels, a commonly occurring lack of belief in their science competence has been shown to present a barrier to the willingness to engage in science practices and learning (Vincent-Ruz & Schunn, 2017).

Mastery goals may be key to overcoming or preventing a lack of confidence in girls and other children. Dweck and Leggett (1988) found that middle schoolers with mastery goals

seek to master material, understand underlying theory, and focus less on external expectations when confronted with difficult material; in comparison to their 'helpless' peers, such students persist through challenges and learn more (see also Darnon, Butera, & Harackiewicz, 2007). Because mastery-focused children challenge their own understanding, they are more likely to find gaps in their knowledge to bridge and will be less focused on the possibility of failure.

Thus, fascination is a construct that draws on all three components. The idea is that children who are fascinated with science will seek more opportunities related to science, become aware of gaps in their knowledge, persist through closing challenging gaps, and gain pleasure from building competence, knowledge, and skills in science. Participating in informal experiences prior to the start of sixth grade, particularly activities at home, has been found to predict children's levels of science fascination (Lin & Schunn, 2016) or interest (Simpkins, Davis-Kean, & Eccles, 2006) entering middle school. Evaluations of particular informal science experiences designed to increase interest or curiosity have often found positive effects on fascination-related motivational constructs (e.g. Mohr-Schroeder et al., 2014; Sheridan, Szczepankiewicz, Mekelburg, & Schwabel, 2011). But less clear is the effect of typically-occurring (rather than especially well-designed) informal learning experiences.

This study expands on prior research of middle school children's motivation to participate in and engage with science and explores the relationship of informal science experiences to science fascination during and after the start of middle school with the following questions:

- (1) What is the relationship of children's informal science experiences and characteristics to fascination before middle school science?
- (2) What is the relationship of children's initial informal science participation and science fascination to their participation in informal science during their first semester of middle school science?
- (3) What is the relationship of children's informal experiences to fascination after their first semester of middle school science, accounting for prior participation and fascination?
- (4) Do characteristics such as gender, race, and levels of family support influence the relationship between informal science experiences and fascination?

We account for children's characteristics throughout the analyses. We hypothesised that for all children, informal science learning supports science fascination both before and during a period of demotivation for many children. We anticipated that higher fascination and participation would be less likely in children with certain characteristics, such as girls, minority children, and those reporting low family support for education.

## Methods

### *Participants*

Participants were the 983 sixth-grade students from the ALES14 data set (Activated Learning Enables Success 2014). Forty-four percent of our sample was collected in Pittsburgh,

Pennsylvania from a mid-sized, urban, public school district; 64% of children identified as a race that we categorised as underrepresented in STEM fields. The other children lived in the San Francisco Bay Area (56%) and attended five public schools across three districts, where 68% of children identified as an underrepresented minority. Both samples were balanced by gender. Schools were targeted to broadly represent variation in student demographics (predominantly low socio-economic student body to predominantly high socio-economic student body) and school configurations (e.g. stand-alone comprehensive middle schools, magnet schools with varying foci). Teachers within those schools were recruited with permission from district officials at professional development events. School district and university IRBs approved the study.

### Procedure

Children completed 45-minute, paper-based surveys in science class in September 2014 and January 2015 (i.e. at the beginning and end of the first semester of the school year). Surveys were completed in class during science period using research IDs that protected student anonymity but allowed for linking responses across time-points. Demographic questions were administered after the fascination survey to reduce stereotype threat effects on responses.

### Measures

In this article, we analysed survey items focusing on science fascination as well as items about human resources, family characteristics, and informal science experiences hypothesised to influence fascination. These instruments were initially developed through an extensive, iterative validation procedure including expert review, cognitive interviews, factor analyses to insure coherence within construct and discriminant validity across constructs, and item-response theory analyses to insure adequate measurement across the range of student levels, roughly equivalent distance across Likert response levels such that a mean score is meaningful, as well as removing items that showed differential discrimination by gender or ethnicity. All multi-item constructs had strong reliability. See Moore, Bathgate, Chung, & Cannady, 2011 technical report for complete technical details on the instruments. Table 1, summarises the scales included in the current study and times of data collection. As children's three science experience scores were of particular interest to our research questions, the 91 children without scores for these items at September (prior experiences) or January (recent experiences) were removed from the sample. Some variables (as noted below) were dichotomised to address skew issues. Analyses include variables for race and gender, collected in September 2014.

**Table 1.** Scales included in the current analysis: items and Cronbach alphas.

Surveyed September 2014	Items	Alpha	Surveyed January 2015	Items	Alpha
Science fascination	8	0.83	Science fascination	8	0.85
Prior informal experiences	16	0.81	Recent informal experiences	8	0.79
Family support <sup>a</sup>	5	0.72	School-related experiences	4	0.70
Home resources <sup>a</sup>	7	0.72			

<sup>a</sup>denotes dichotomised variables.

### Science fascination

The main dependent variable was a mean score calculated (separately at pre and post) across eight survey items designed to measure the three core theoretical components of fascination: interest, curiosity, and mastery goals for science (Table 2).

### Recent informal experiences

The main predictor variable of changes in Fascination was calculated as the mean response across eight items assessing the extent to which children participated in informal science learning during the school year, as children took their first unit of middle school science. Activities were selected based on prior literature (e.g. Braund & Reiss, 2006): watching science-related television, reading about science, experimenting, attending museums or science centres, science-related web searches, collecting bugs or nature, taking things apart, or attending science clubs. For each item children could answer: 1 = 'never,' 2 = 'once,' 3 = 'a few times,' 4 = 'many times.' This approach to measuring frequency was selected because of the likely non-linear nature of the effects of learning experiences and the approximate nature of children's memories for such events. A question stem 'Since the beginning of the school year' in bold font emphasised the particular time frame of these experiences.

### Recent school-related experiences

In addition to optional science learning centred in the family, teachers and schools sometimes provide optional science learning experiences. To understand whether this source of science learning moderated the effects of informal learning, a mean was calculated across the four items assessing the extent to which students participated in science experiences that were related to school but did not take place during science class, and then a binary variable was created indicating whether children's average response was low (between 1 and 2) or high (between 3 and 4). Activities included: doing homework or projects with friends; doing a science extra-credit project; getting outside reading recommendations from teachers; and having a science study group. For each item children could answer 1 = 'never,' 2 = 'once,' 3 = 'a few times,' 4 = 'many times.'

**Table 2.** Survey questions for each of the components of the fascination scale and possible responses with response coding.

Fascination component	Question	Likert scale responses
Interest (2)	In general, I find science:	4 = very interesting, 3 = interesting, 2 = boring, 1 = very boring
	In general, when I work on science I:	4 = love it, 3 = like it, 2 = don't like it, 1 = hate it
Curiosity (3)	I wonder about how nature works.	4 = every day, 3 = once a week, 2 = once a month, 1 = never
	I need to know how objects work. After a really interesting science activity is over, I look for more information about it.	4 = YES!, 3 = yes, 2 = no, 1 = NO! 4 = YES!, 3 = yes, 2 = no, 1 = NO!
Mastery (3)	I want to know everything about science.	4 = YES!, 3 = yes, 2 = no, 1 = NO!
	I want to know how to do everything that scientists do. I want to read everything I can find about science.	4 = YES!, 3 = yes, 2 = no, 1 = NO! 4 = YES!, 3 = yes, 2 = no, 1 = NO!

### **Family support**

Family support for learning was assessed using five items indicating the extent to which the children perceived that their family supports their learning. Statements included: my learning in school is important to someone in my family; someone in my family takes me to places where I can learn new things; when I work on homework at home, I have someone who can help me with it if I need help; someone in my family is interested in teaching me things; and someone in my family makes sure I finish my homework every day. For each, children could answer: 1 = NO!; 2 = no; 3 = yes; or 4 = YES!. Because of the responses were skewed from having a high mean, a binary variable was created based on a median split (3.6), indicating that these children varied between being strongly supported (i.e. generally a strong endorsement of the family support statements) vs. only mildly-supported (i.e. having a more lukewarm endorsements of the family support statements).

### **Home resources**

As a proxy of income, particularly income devoted to child learning, this measure consisted of seven items measuring perceived availability of resources to support science learning at home. Resources included: calculator, computer, internet connection, dictionary, study or homework area, e-reader/iPad, and books about science. For each, children could answer: 1 = never; 2 = rarely; 3 = most of the time; and 4 = always. Again, a binary variable was created based on a median split (3.4) based on the skewed distribution towards the positive end of the scale.

### **Prior informal experiences**

To control for additional unmeasured factors that influence the likelihood of participating in informal science learning experiences that may also influence changes in science-related motivation, we included a measure of participation in a broad range of informal science learning experiences prior to the start of sixth grade. A mean response was calculated across sixteen items assessing whether children had ever participated in or attended various informal science activities outside of science classes and assignments prior to beginning sixth grade (see Lin & Schunn, 2016). Activities included: science activities/museums on vacation; science activities/museums near home; science camp; after-school science programmes; school family science night; community festival/event related to science; played with science objects/kits; science; read science books; watched science-related TV or listened to audio; visited science websites; taken care of pets/animals; taken care of a garden; spent time in nature; robotics camp/club; and built something. For each, children could answer: 1 = never; 2 = once; or 3 = more than once.

### **Non-minority**

A dichotomous variable was created to indicate whether children's self-selected race did not include those underrepresented in STEM fields (i.e. only white or Asian = 1; all other combinations = 0). Children selected one or more races from a list: white, black or African American, Asian, Indian/Middle Eastern, Native American/Pacific Islander, Hispanic/Latino/Mexican, Unknown, or other. Children who selected 'other' were asked to write in a response, which were categorised based on the original categories.



## Male

Children selected from three options: male, female, or prefer not to answer (4%). Male is a dichotomous variable based on answering male (1) vs. female/other (0).

## Overview of analysis

The analyses are presented in four parts. First, we present multiple-regression models for the predictors of fascination at the start of the schoolyear, before children have taken their first middle school science unit. Second, we present the multiple-regression models for predictors of participation in informal science during the schoolyear. Third, we present multiple-regression models for predictors of fascination in the middle of the schoolyear. Fourth, we explore differences in growth or decline in fascination by child characteristics.

In all multiple regression models (Tables 3–5), we report standardised coefficients and include maximum variance inflation factors to establish that there are no multicollinearity

**Table 3.** Standardised coefficients and standard errors for predictors of science fascination before middle school science, ( $n = 983$ ).

	Model 1		Model 2	
	$\beta$	SE	$\beta$	SE
Prior informal exp.	0.34***	0.04	0.32***	0.05
Male			0.12***	0.03
Non-minority			-0.05	0.04
High family support score			0.12***	0.04
High home resource score			-0.01	0.04
$R^2$	0.12		0.15	
Max VIF	1.00	(Prior)	1.19	(Family)

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

**Table 4.** Standardised coefficients for predictors of recent informal experience scores,  $n = 983$ .

	Model 1		Model 2		Model 3	
	$\beta$	SE	$\beta$	SE	$\beta$	SE
Initial fascination	0.36***	0.04	0.26***	0.04	0.24***	0.04
Prior informal exp.			0.28***	0.05	0.28***	0.06
Male				0.09**	0.09**	0.04
Non-minority				-0.1***	-0.1***	0.04
High family support					0.04	0.04
High home resources					0.04	0.04
$R^2$	0.13		0.20		0.20	
Max VIF	1.00	(Fasc)	1.13	(Prior, Fasc)	1.26	(Prior)

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

**Table 5.** Mean response to recent informal science experience items.

	$n$	Mean	SD
1. Watched science-related TV shows	981	2.89	1.06
2. Read science-related books or fiction	978	2.57	1.05
3. Visited a science museum or centre	971	2.52	1.08
4. Experimented at home	976	2.51	1.12
5. Visited websites to look up science	966	2.36	1.07
6. Collected rocks/bugs/nature	970	2.23	1.12
7. Took things apart to see how they work	969	2.17	1.17
8. Attended a science club	973	1.41	0.89

problems. We used  $p < .05$  as our threshold for statistical significance for all analyses. Nested models were examined but are not reported here because nested effects by classroom, teacher, school, or region accounted for relatively little variance and did not change the pattern of results.

## Results

Children started sixth grade with a variety of informal learning experiences. On average, they had tried most if not all of the types of experiences at least once in their life, with an average of 2.1 of 1–3 possible points (see Appendix 1 for descriptive statistics and correlation matrix). For the most part, they also started the year with mid to high levels of fascination with science, 2.8 on the 4-point fascination scale (3 = ‘like it’); some children had mean scores at the extremes, 1 (least fascinated) and 4 (most fascinated).

RQ1. What is the relationship of children’s informal science experiences and characteristics to their fascination before middle school science?

As hypothesised, children with higher prior informal science experience scores started the school year with higher fascination. In the models shown in Table 3, this variable also had the largest effect size. Independently, prior experiences explained 12% of the variation in children’s initial fascination scores; adding child and family characteristics increased the explained variance to 15%. Boys and students with high family support scores also had higher fascination before middle school science. Notably, at the start of the schoolyear, no gap is present in minority and non-minority children’s fascination.

RQ2: What is the relationship of children’s initial informal science participation and science fascination to their participation in informal science during their first semester of middle school science?

Children typically reported having tried a variety of informal science activities at least once during the schoolyear, with an average score of 2.3 (2 = ‘once’); observed responses ranged from 1 = ‘never’ to 4 = ‘many times’ and were approximately normally distributed (see Appendix 1). Children who are more fascinated before taking middle school science tend to participate more in informal science during the schoolyear ( $p < .001$ ); in Model 1, initial fascination explains 13% of the variation in participation scores when not accounting for other scores or characteristics (see Table 4). In Model 2, however, another 7% of the variation is explained when accounting for prior informal experiences ( $p < .001$ ), with the largest positive effects for recent informal participation. Interestingly, being a non-minority is negatively associated with participation in Model 3 ( $p < .001$ ), while being male has the expected positive association ( $p = .002$ ). The negative effect for non-minority children may reflect a declining amount of informal science relative to prior levels of informal experiences as children’s interests become more narrowed with development. Overall, however, the largest drivers of new informal experiences are past participation in informal science learning and child fascination with science.

For a closer look at the kinds of experiences in which children participated, Table 5 presents a ranked order of participation responses for recent informal science experiences. Most children reported watching television related to science more than once, on average, but averaged between ‘once’ and ‘more than once’ for reading science-related

books or fiction, visiting museums or science centres, and experimenting at home. Most children did not attend a science or robotics club during the first months of their sixth-grade school year. This suggests that children may participate more in activities that have fewer barriers; for example, anyone with television may watch science-related television shows, but science clubs may require a long-term commitment on both the part of the child and parents.

RQ3. What is the relationship of children's informal experiences to fascination after their first semester of middle school science, accounting for prior participation and fascination?

For the majority of the children in this study, the first semester of their sixth-grade science classes marked a period of declining or relatively stable fascination. On average, children's science fascination declined half a standard deviation during their first unit of middle school science, from 2.8–2.6 on the 4-point scale (Appendix 1); a paired *t*-test showed that this difference was statistically significant ( $p < .001$ ). Sixty percent of children's fascination scores decreased after their first unit of middle school science; only 20% of scores increased. Thirty-one percent of all children's scores saw large declines of half a point or more, with some scores dropping more than 2 points on the 1–4 point scale during one semester (e.g. from 3 = 'liking' science to 1 = 'hating' it). Thus, the commonly reported mean decline in motivation (Eccles et al., 1993) was observed here as well, but the more salient effect was a heterogeneity of change; some children showed large declines and some children showed large gains, raising the question of what role informal learning played in these changes.

A sequence of regression models was implemented to determine significant predictors of changes in science fascination, starting with a simple pre–post model, then adding experience predictors, and then adding demographic characteristics to ensure that experience *per se* was the important predictor (see Table 6). Over this relatively short window of time, there is clear overall stability in fascination; children's initial fascination score is the largest significant predictor of fascination by the middle of sixth grade ( $p < .001$ ), explaining 35% of the variation in children's final fascination scores (see Table 6, Model 1). Another 10% of variation is explained by accounting for recent informal science experiences ( $p < .001$ ), the second largest predictor of fascination (Model 2). Importantly, it was recent and not prior informal experiences that accounted for changes in fascination,

**Table 6.** Standardised coefficients for predictors of science fascination by the middle of sixth grade, ( $n = 983$ ).

	Model 1		Model 2		Model 3	
	$\beta$	SE	$\beta$	SE	$\beta$	SE
Initial fascination	0.59***	0.03	0.46***	0.03	0.46***	0.03
Prior informal exp.			0.00	0.04	0.00	0.04
Recent informal exp.			0.29***	0.03	0.29***	0.03
Low school-related exp.			–0.04	0.03	–0.04	0.03
High school-related exp.			0.05	0.05	0.05	0.05
Male					0.06*	0.03
Non-minority					0.05*	0.03
High family support					0.01	0.03
High home resources					0.03	0.03
$R^2$	0.35		0.45		0.45	
Max VIF	1.00	(Fasc)	1.64	(Recent)	1.66	(Recent)

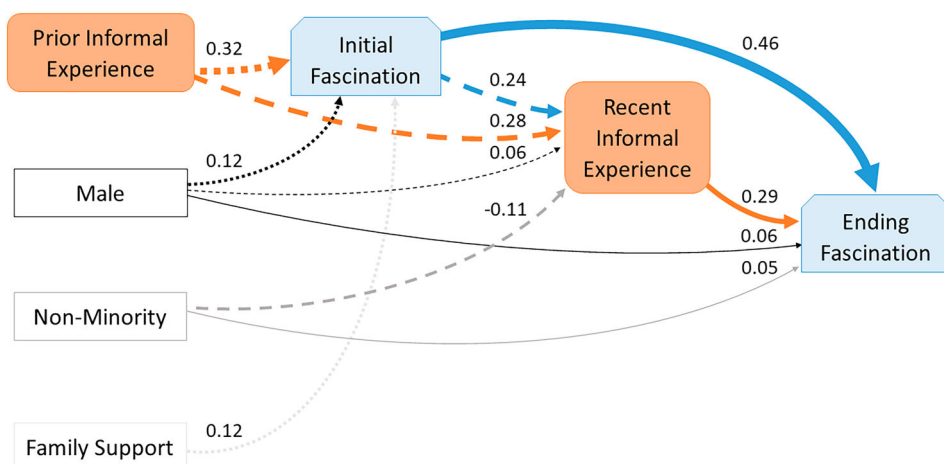
\* $p < .05$ , \*\* $p < .01$ , \*\*\* $p < .001$ .

ruling out reverse causal associations as the only underlying causal structure. In Model 3, male ( $p = .019$ ) and non-minority ( $p = .040$ ) are the only other positive, significant predictors of fascination, and the variation explained remains at 45%. School-related experiences were included in Models 2 and 3 to account for the possibility that children's fascination changes due to extra-curricular activity related to school, but are not significant.

Comparing these three sets of regressions in Figure 1 reveals that, consistently, informal experiences are positive predictors of fascination. Children who get involved in informal science before middle school and stay involved have a higher fascination, which in turn predicts greater involvement in informal science during the school. More family support predicts more fascination before middle school science but is not significant in predicting later fascination, when accounting for informal science experiences. Boys report being more fascinated and participating in more informal experiences throughout. Non-minority children, on the other hand, start middle school with equally high fascination, report fewer informal experiences during the schoolyear, yet have higher fascination by the middle of the schoolyear than minority peers.

RQ4. Do children's other characteristics, like gender, race, and family support, influence the relationship between informal science experiences and fascination?

The initial role of family support that dropped out warranted further analysis. Further, the heterogeneity of change (from decline to growth) raised the question of whether informal experiences increased fascination (i.e. deepened a situational fascination developed at school) or prevented declines in fascination (e.g. served as a buffer from negative school-related experiences). Using a threshold of 0.5 change (approximately one standard deviation or approximately half of the responses on the scale items changing), students were categorised as showing a significant decline (drop by at least 0.5), a significant increase (gain by at least 0.5), or little change.



**Figure 1.** Layered significant ( $p < .05$ ) results from the final regression models (see Tables 3, 4, and 6), showing coefficients of relationships between characteristics, experiences, and fascination scores at the start and middle of sixth grade.

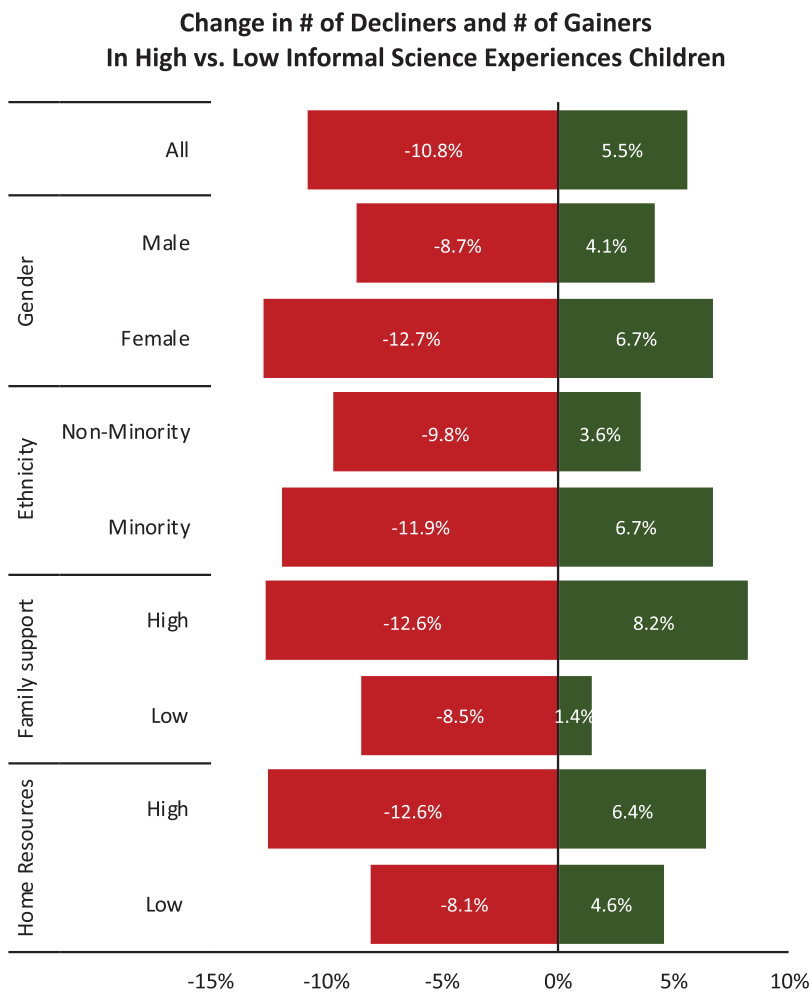


**Figure 2.** Frequency of gain, little change, and decline in fascination across sixth grade separately by students with low or high levels of recent informal science experiences, overall and then separately by gender, ethnicity, amount of family support and amount of home family resources.

Figure 2 shows the relative frequency of each category separately for children with high vs. low levels of informal science participation (using a median split). While many children

showed little change during this time window, there were non-trivial amounts of growth and decline and important variation in relative amounts of growth and decline across sub-groups. Overall across all children (top left), children with high levels of informal science participation both show more increases and fewer declines. This pattern generally holds across gender, ethnicity, and home resources, but with some variation. Most salient is the variation across levels of family support and home resources; children with both more support and informal learning experiences were less likely to have declined than children with only one of the two.

This pattern of differences is more salient in Figure 3, which directly shows the difference in the percentage of declining students in high vs. low informal participation in red, and difference in percentage of increasing students in high vs. low informal participation in green. This representation reveals the effect of informal science appears larger among



**Figure 3.** Difference in percent of children who decline (left) and percent of children who increase (right) when percentage with low recent informal experience scores are subtracted from the percentage with high scores (high – low = %), for all children, and separately by gender, ethnicity, family support, and home resources.

females, minorities, children with high levels of family support, and children with higher home resources.

In follow-up statistical models, we found two significant interactions: between family support and high or low informal experience scores ( $p = .028$ ); and between home resources and high or low informal experience scores ( $p = .026$ ). Both of these variables were not significant in predicting fascination in the middle of the schoolyear when included without the interaction term. No other interactions (e.g. between male and high or low informal experience scores) were significant. Children with more resources and family support experienced more gains in combination with informal learning experiences than those without.

## Discussion

Children who develop and sustain motivation to participate in and engage with science during the critical ages of 10–14 (middle school, in the United States) are better positioned to join the STEM workforce as adults and be scientifically literate citizens, but there is still much to learn about the role of informal learning in scaffolding that process throughout middle school. This study focuses on the relationship between informal learning and fascination, before and during middle school science classes. We found that children who participate in informal science experiences start out more fascinated than non-participating peers and retain their fascination better during middle school. This is true for both gender and minority status subgroups, but a lack of family support or resources at home can diminish the impact of informal learning experiences.

For most children, the start of sixth grade was a period of declining fascination, sometimes as drastic as from 'liking' to 'hating' science, consistent with Anderhag et al.'s (2016) findings that middle school children's interest in science is often not supported in school. Informal science and fascination, however, are positively linked. It may be that children's informal science experiences boost science fascination, or that parents first observe children's levels of interest for science and then support their participation in informal science, as suggested by Tenenbaum and Leaper's (2003) study, where parents encouraged girls' science participation only when aware of the girls' interest in science. In our study, informal experiences were positive and strong predictors of fascination, as predicted by Hidi and Renninger's four-phase model of deepening interest wherein children must re-engage with subject matter over time (2006). Informal settings may be better than schools at supporting this repeated, deepening participation, due to higher levels of free choice (Falk, Storksdieck, & Dierking, 2007). This raises a question: if teachers in schools were to use simple, easily administered tools like Activation Lab's fascination scale in formative assessments, how might this change education?

We found that boys reported participating in more informal activities and also reported being more fascinated with science. This is consistent with prior studies suggesting that girls are less interested in science than boys in middle school (Jones et al., 2000), and that parents might be less consistent in their support for science with girls than boys (Archer et al., 2010; Crowley, Callanan, Tenenbaum, & Allen, 2001). We are interested in learning more about how often girls vs. boys participate in informal science. Our survey listed a number of common informal experiences, but future research should

explore the extent to which these are the ‘right’ list for STEM. It is possible, for instance, that girls participate in informal science in less traditional ways, such as writing science fiction or blending arts and STEM practices in makerspaces (Sheffield, Koul, Blackley, & Maynard, 2017).

Fascination levels of minority and non-minority children were similar at the sixth grade but diverged as the year progressed. After accounting for prior levels of experience, minority children’s participation had typically increased while non-minority children’s participation appeared to decrease. There was no interaction between minority status and reported level of informal science participation when predicting final fascination, supporting Atwater’s argument (2000) that the impact of children’s in-school experiences is disparate when comparing children of different cultures and races. Informal science experiences may be the key to closing gaps in science, especially if they involve ongoing participation and are designed around issues relevant to girls, such as Barton, Tan, and Greenberg’s (2016) study of a club where African American girls connected to STEM through the personally-relevant problem of sexual assault.

Children’s perceived family support significantly predicted children’s fascination at the start of sixth grade. After the start of sixth grade, however, having high participation in informal learning predicted greater gains when children also perceived that their family supported their learning and/or had the resources to support it. This observed relationship may result from differences in actual support (e.g. parents working long hours may be unavailable to take children to clubs or museums) or perceived differences (e.g. thinking parents would object and not asking to participate). Further, the direct influence of parents might change in nature and/or frequency as children move from elementary to middle and high school (Wentzel, 1998). Future research should explore the mechanisms by which parents’ involvement in the informal learning life of their children impacts participation, fascination, and learning.

In this study, we see the positive effect of participating frequently in varied, typically-occurring informal learning experiences on science fascination. That is to say, when children participated in whatever experiences available to them, it helped to foster or sustain a love of science, whether the activities available to them had a low bar for entry (e.g. finding things around the house to tinker with) or a high (e.g. getting a parent to take them to a science museum). While regular participation in well-designed learning experiences could have an even greater effect, this demonstrates the valuable, everyday ways in which parents and teachers can support children’s love of science. This point is important for efforts that seek to scale and broaden access to informal science learning: it appears that it is not only the highly-resourced (e.g. expensive materials and highly-trained staff), most well-designed experiences that provide benefits for students.

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