The Contributions Made by Five Science Education Resources to Youth's Interest in Science

In an increasingly scientific and technological world, the need for youth to be engaged in and appreciative of science and technology has never been greater. Fueled largely by new digital technologies and media, information about science and technology has increasingly become a daily part of youth's lives. Meanwhile, there has also been a relentless blurring of the boundaries of where, when, and how children and youth learn about the science they know and use every day (Carnegie Corporation of New York, 2009; National Research Council, 2015). Although historically most of the attention related to the youth's science learning has focused on understanding and knowledge, an increasing number of investigators have begun to equally focus on interest, often defined as the emotional state of engagement and predisposition to reengage with a particular topic, object, or activity (Hidi & Renninger, 2006; Renninger & Hidi, 2016).

Early interest and participation in STEM appears to be critical to long-term STEM learning and participation in STEM-related practices (cf., Bonnette, Crowley & Schunn, 2019; Galton, 2009; Osborne et al., 2003; Vedder-Weiss & Fortus, 2011). For example, STEM interest during early adolescence, particularly between ages 10 to 14 years, has been shown to be a key variable in predicting involvement in further science education and careers (Lacey & Wright, 2009; Maltese & Tai, 2011; Pan & Gauvain, 2012; Sjøberg & Schreiner, 2010). However early adolescence is also the age when interest in science tends to decline (cf., Osborne, Simon & Collins, 2003, Potvin & Hasni, 2014). These declines have been a source of great concern within the science education community. Supported by a range of findings in other contexts (e.g., Eccles, 2005; Lent & Brown, 2000; Lent, Brown, & Hackett, 1994; Wigfield & Eccles, 2000), it is widely assumed that declining interest in science at this age will directly affect youth's future engagement with science during both later adolescence and adulthood.

Documenting declines in interest is one thing, establishing why interest declines turns out to be more complex. Historically, most assumed that topics like science were exclusively influenced by events within the formal education classroom, but these beliefs are becoming increasingly challenged as a range of detailed, longitudinal investigations have begun to track the lives of youth across their life and are revealing just how varied are the sources of youth science interest/disinterest (e.g., Archer, et al., 2010; Barron, 2010; Bell, Bricker, Reeve, & Zimmerman, 2010; Bricker & Bell, 2014; Falk, et al., 2016a). These studies are beginning to show that although overall science interest declines in youth during the middle school years, that is not necessarily the pattern for all youth. In fact, longitudinal studies are beginning to show that every possible pattern of interest pathway occurs at this age – youth interest increasing, staying the same and declining (cf., Staus, et al., in press). Clearly, the factors effecting youth's science interest trajectories are complex and there is need for additional work in this area.

One area where solid data has been lacking has been on where and how interest in science develops. Recent research has highlighted how new interests rarely develop in a vacuum, but nearly always happen within the context of an individuals' past interests, experiences and preferences and, consequently, are more likely to be sparked and sustained if they connect to, reinforce, or extend prior interests or preferences (Azevedo, 2011, 2018; National Academies of Sciences, Engineering, and Medicine (NASEM), 2018; Pattison, 2014). And even if an interest sparked in a particular moment appears to be new to an outside observer, the success of sparking and maintaining that interest is likely due to strong continuities and connections to prior interests, experiences and preferences of the individual, even if these are not apparent in the moment (Azevedo, 2018).

In today's science education landscape, a wide variety of media strive to engage and support youth in science learning, including schooling, broadcast media, the internet, books and magazines and science centers. Many in the informal/free-choice learning sector have specifically argued that the promotion of interest in science is there primary function, with preliminary evidence beginning to show that these institutions do indeed make a significant contribution to this age group's interest (Bonnette, Crowley & Schunn, 2019; Falk, et al., 2016a; 2016b;). However, to date the question of the relative contribution of these influences are in dispute. This study represented an initial attempt to determine the relative influence that five major sources of public science education had on youth's interest in science.

Literature Review

As suggested above, most discussions about how and why children and youth develop an interest in science have focused on the role of school-based instruction. Although school is clearly an important setting for individuals to learn about and become interested in science, it is not the only setting where this can happen. In fact, considerably more time, and in fact opportunity for science-related experiences happen outside of school (Fall & Dierking, 2010; National Research Council, 2009). Since children and youth actually spend a surprisingly small percentage of their time in school science instruction (Stevens & Bransford, 2007), out-of-school experiences have the potential to make-up a significant portion of their exposure to and commitment to science (Bonnette, Crowley & Schunn, 2019; Dorph, Schunn, Crowley, & Shields, 2012; National Research Council, 2015), particularly those in the early years of schooling. These informal/free-choice experiences with science could be considered a form of science capital (Archer, Dawson, DeWitt, Seakins, & Wong, 2015; DeWitt & Archer, 2015) or science identity-building (Carlone & Johnson, 2007; Calabrese, et al., 2012), experiences that support children and youth's interest in and motivation towards science sufficient to opt to continue in science over time. Although evidence now shows that individually or collectively out-of-school experiences do contribute to youth's science interest, challenges remain due to the fact that these experiences all too frequently are lumped into the single category of informal/free-choice science education (Falk, et al., 2015; National Research Council, 2015).

In general, youth have opportunities to develop an interest in science both within the classroom and beyond via a wide range of free-choice media, including by visiting science centers, using the internet to search for science content, watching science-related broadcast media and reading science-related books and magazines and evidence exists suggesting that all of these sources contribute to both science interest and understanding (see Falk & Needham, 2013; National Research Council, 2009; 2015). Specifically, evidence for positive influences on science interest have been reported for school (Bulunuz & Jarret, 2010; Maltese & Tai, 2010; Trumper, 2006), science centers (e.g., Bulunuz & Jarret, 2010; Falk, et al., 2016b; Falk & Needham, 2011; Martin, Durksen, Williamson, Kiss, & Ginns, 2016; National Research Council, 2009), broadcast media (e.g., Dudo, et al., 2011; Happer & Philo, 2013; Mares, Cantor, & Steinbach, 1999; Nisbet, et al., 2002; Takahashi & Tandoc, 2015), the internet (e.g., Horrigan, 2006; National Science Board, 2016; Takahashi & Tandoc, 2015) and published materials (e.g., Falk, 2001; Happer & Philo, 2013; Lewenstein, 2009; Maltese & Tai, 2010; National Science Board, 2016). Thus, at a minimum, distinguishing between these various sources seems important. The reality though is that despite evidence that all of these various sources likely contribute to the short and potentially long-term science interests of children and youth, comprehensive data supporting these claims, let alone comparisons between these various sources on the basis of the quality of the experience, are relatively scarce (see Falk, Pattison, Meier, Livingston, & Bibas, 2018). Further complicating the situation is how "interest" in science has been historically defined and measured.

A significant shortcoming of much of the previous research on science interest has been the lack of a common and theoretically sound measures for this key variable. As a consequence, it is often next to impossible to validly or meaningfully compare data between studies unless someone delves deeply into the methodologies used. Although there are many different theoretically-driven conceptualizations of interest, we were guided by the deep and long-standing work of Hidi and Renninger (2006; Renniger & Hidi, 2016) and Krapp (2002) who conceptualized interest as a complex, multi-dimensional construct that includes both "the psychological state of a person while engaging with some type of content (e.g., mathematics, bass fishing, music) and also to the cognitive and affective motivational predisposition to reengage with that content over time" (Renninger & Hidi, 2016, p. 8). Therefore, when measuring science-related interest it is not sufficient to focus exclusively on the single question of whether or not an individual "likes" science. At a minimum, one must be able to distinguish between how important or valuable to their life a person perceives science to be, which requires a sense of how they conceptualize, connect with and personally value science as a topic area, the social and emotional feelings elicited when actually engaging in a science task and their feelings of self-efficacy about their abilities relative to science. Ideally, one would also want to understand the interactions and developmental processes of interest development, though these process-oriented issues are more difficult to measure.

Also poorly understood is how the constituents of experience contribute to interest. Although meaningful and engaging experiences are at the core of all science education practice, exactly what is meant by experience, let alone meaningful engagement are complex and subject to considerable confusion (cf. review by Fredricks, Blumenfeld, & Paris, 2004, also, Sha, Shunn, & Bathgate, 2015). For example, studies have suggested that novelty, personal relevance, appropriate levels of challenge, hands-on activities, understandability, intensity, social interaction, and individual choice all contribute to whether or not an experience triggers and/or maintains situational interest (Hidi & Renninger, 2006; Lewalter & Scholta, 2009; Palmer, 2004; Renninger, 2010; Renninger & Hidi, 2011; Renninger, Nieswandt & Hidi, 2015; Rotgans & Schmidt, 2011; Schmidt, Rosenberg, & Beymer, 2018). Mindful of these challenges we opted to create and validate a new measure of experience (for details see, Falk, Pattison, Meier, Livingston, & Bibas, 2018).

This article examines the contributions that classroom-based science experiences, experiences at science centers, internet-related science experiences, watching science-related television shows and reading science-related books and magazines had on youth's self-reported interest in science. In order to minimize complexity in the preliminary analyses reported in this article, we focused on a single subset of the dimensions of interest measured during data collection – how youth conceptualized, and personally connected with and valued science as a topic area – which we have labeled as "interest (relevance)". We recognize that further analysis is needed to understand how the multiple dimensions of interest relate to each other and the factors that influence these dimensions, either uniquely or collectively. We asked middle-school aged youth to report both current experiences and recalled experiences – specifically several years earlier while they were in 3rd and 4th grades in school. By necessity, this article should be viewed as an initial, effort to determine the relative contributions that each of these five types of experiences make to youth's science interest. Undoubtedly, reality is a highly complex mélange of multiple factors, but given that empirical evidence related to these types of fundamental contributions has been almost nonexistent (Falk & Needham, 2013; Miller, 2010), the scope of this article is limited purposefully to this relatively narrow goal with the following two, multipart research questions:

- What is the relationship between 10-14 year old youth's current science interest (relevance) and the frequency of 10-14 year old youth's current and prior visits to science centers, use of the internet to find out more about science, watching of science television and reading science-related books and magazines?
- What is the relationship between 10-14 year old youth's current science interest (relevance) and the quality of their current and prior experiences as part of science

classes in school, visiting science centers, using the internet to find out more about science (not for school), watching science television and/or reading science-related books and magazines (not for school)?

Methods

Data Collection

To examine the five types of science education experiences and their relative contribution to 10-14 year old youth's interest in science, data for this article were obtained in 2015 from online surveys and paper surveys. Since it was not feasible to collect a true random sample of youth in each of the three target cities – Los Angeles, Phoenix and Philadelphia – collaborators from the California Science Center, Arizona Science Center and The Franklin Institute, respectively, utilized local and state education department records, U.S. Census Bureau data (2016), and other pertinent statistics to identify a set of schools in each city that collectively mirrored the demographic profile of young people in that city. Research team members then recruited these schools to participate in the study and coordinated online and paper survey data collection with the assistance of contact personnel at each of the participating schools. Both online and paper surveys were available in English and Spanish and the majority of the surveys were completed during school hours.

In total, 1,762 youth from 24 schools participated in the study, completing 1,106 (63%) online and 656 (37%) paper surveys. Although the study focused on 10-14 year old youth, as shown in Table 1, a few 9 year olds and a few 15 year olds ended up in the sample. Given the small numbers of these outliers, and no evidence that their inclusion skewed results, they were included in the final sample, which had an average age of 12 years. Within the three locations, 775 or 44% of participants were from Los Angeles, 403 or 23% were from Phoenix, and 584 or 33% were from Philadelphia. Two paper surveys from Los Angeles were completed in Spanish while all other online and paper surveys were completed in English. To help minimize potential sampling bias, where possible results were weighted to equate with youth demographics of same year U.S. Census data from each of the three jurisdictions: greater Los Angeles, Phoenix, and Philadelphia (Table 1).

Table 1. Youth sample demographics

		Actual/Un-Weighted Percentages			Weighted Percentages		
Demographic	Category	Los Angeles	Philadelphia	Phoenix	Los Angeles	Philadelphia	Phoenix
Gender	Male	46.75%	45.99%	46.15%	47.62%	49.69%	47.21%
	Female	53.25%	54.01%	53.85%	52.38%	50.31%	52.79%
Ethnicity	White	11.57%	75.82%	45.50%	28.24%	36.15%	45.09%
	African American or Black	4.39%	5.18%	5.25%	8.57%	41.81%	6.62%
	Asian or Asian American	2.93%	6.04%	2.75%	11.22%	6.73%	2.89%
	Hispanic or Latino	60.11%	3.45%	26.25%	49.26%	13.27%	41.29%
	Other/Multiple	21.0%	9.5%	20.25%	2.71%	2.05%	4.10%
English as First Language	Yes	63.78%	94.66%	87.06%	65.15%	90.89%	84.56%
	No	36.22%	5.34%	12.94%	34.85%	9.11%	15.44%
Languages Spoken in Household	English Only	20.05%	82.96%	62.70%	27.67%	73.95%	58.39%
	Spanish Only	40.25%	3.52%	11.89%	33.73%	11.23%	16.08%
	English and Spanish	30.83%	3.15%	17.84%	21.94%	6.29%	20.16%
	English and a language(s) other than Spanish	3.82%	4.26%	4.59%	6.40%	2.94%	3.14%
	Language(s) other than English or Spanish	5.05%	6.11%	2.97%	10.26%	5.59%	2.23%
Age (Years)	Range	11 to 15	11 to 14	9 to 14	11 to 15	11 to 14	9 to 14
	Mean	12.07	12.36	11.86	12.05	12.37	11.86
	Standard Deviation	.772	.679	.729	.742	.710	.748

Analysis Variables

The survey assessed current levels of science interest across the three areas discussed in the introduction -- how important or valuable to their life a person perceived science to be (personal science value), the social and emotional feelings elicited when actually engaging in a science task and their feelings of self-efficacy about their abilities relative to science, youth's perceptions of past and present usage and experiences within each of the five different learning contexts, and a variety of demographic variables. Each of these measures is described in more detail below. A copy of the survey is included as a supplement.

Science interest

The primary dependent variable of the study was "interest," which was framed as containing both cognitive and affective dimensions, as suggested by Hidi and Renninger (2006; 2016) and expanded on by Falk and colleagues (2016a; 2018). At the outset of the project, we assembled a set of Likert-like survey questions from prior research studies that had investigated science interest using survey methods, including our previous research on the use and impact of the California Science Center (e.g., Falk & Amin, 1997; Falk, Brooks, & Amin, 2001; Falk & Needham, 2011; Falk, et al., 2016b). All items used four-point Likert-like response scales, ranging from "disagree a lot" to "agree a lot." Our goal was to capture the multiple dimensionality of interest outlined by Renninger and Hidi (2016).

Using the collected data, we conducted principal components analyses (PCA) to understand the dimensionality and reliability of the items and to identify the final set for subsequent analyses. The initial PCA run suggested that the 16 items represented at least three distinct dimensions of science-related interest, which we labeled – relevance, social relationships, and self-efficacy. These three dimensions were consistent with the prior research described above that showed that interest and interest development were multifaceted and tended to be made up of these types of factors. Given that all three dimensions of interest were potentially independent, and thus would require that each be treated as a separate independent variable, for the purposes of the analyses reported in this article, we focused on only the first of these three dimensions of science interest – relevance. This was the dimension with the largest set of items (seven) that loaded on a single factor and did not load substantially on any other factor. Though not necessarily more or less important than the other two dimensions of interest, this dimension arguably represents an important and critical aspect of youth's science interest. Based on the factor loadings with the original 16 items, we believe this subset of seven items adequately captured the aspects of science interest that were specifically related to how youth personally perceived the relevance of science to themselves, e.g., their perceptions of how important and valuable science was to themselves, both in the present and the future, and importance of science to society generally.

The final PCA results for these seven "relevance of science" items are shown in Table 2. Factor loadings ranged from 0.407 to 0.646 and the single factor solution for the seven items explained over 41% of the variance in item responses. Internal consistency was moderate, with a Cronbach's alpha value of 0.75.

Table 2. Single factor PCA results for subset of science interest (relevance) items

	Factor loadings
Item	
Q1 Science will be useful in my future.	.646
Q2 I will need to know science to get a good job.	.565
Q3 It will be useful to me in the future to know some science.	.592
Q9 Science tells us about how people think and behave.	.407
Q10 Science helps me understand the world around me.	.534
Q11 I use science ideas in my everyday life.	.415
Q12 Science has improved the quality of human life.	.500
Eigenvalues	1.749
% of variance	41.490
Cronbach's α	.752

Following standard multiple-item scale construction procedures for items found to relate to a single underlying construct (Groves, Fowler, Couper, Lepkowski, & Singer, 2009), for subsequent analyses mean scores were calculated for each participant across all seven values and cognitive predisposition items (with a minimum of four completed items) to generate a single measure of science interest (relevance).

Current and Retrospective Self-Reports

We utilized self-reports for both current and past indicators of frequency and quality of experience. Self-reports are generally assumed to be unreliable sources of data (cf., Stone, Shiffman, Atienza, & Nebeling, 2007; Tourangeau, Rips, & Rasinski, 2000), however as documented by a number of studies from various disciplines, self-reports are actually reasonable surrogates for more direct measures, especially when using survey data (Chan, 2009; Gonyea, 2005; Vaske, 2008). The same is true for retrospective self-reports (Lam & Bengo, 2003; Mueller & Gaus, 2015; Schwartz, 2007), particularly given how challenging information about past events can be to collect.

Frequency of science experiences

One of the major independent variables in the study was the frequency with which individuals engaged with each of the four major non-school sources of science education – science centers, the internet science resources, broadcast science media, and print science media – both currently and when they were in $3^{th}/4^{th}$ grade. Building off earlier studies (e.g., Falk & Amin, 1997; Falk, Brooks, & Amin, 2001; Falk & Needham, 2011; Falk, et al., 2016b; National Science Board, 2016) respondents were asked to self-report the frequency with which they utilized each educational medium for science-related purposes on a 6-point Likert scale ranging from "never" to "every day."

Perception of science experience

The other major independent variable in the study was the perceived quality of the "science experiences" individuals had when engaging with each of the five major sources of science education: school science courses, science centers, the internet science resources, broadcast science media, and print science media. "Science experiences" were operationalized as course-grained attributes related to individual's perceptions of their affect, identity, and the social value experienced while using the educational medium.[1] We opted, in part to go with more course-grained measures because earlier efforts by us (e.g., Falk, et al., 2016b) had found that more fine-grained measures of experiences were ineffective, in part due to inherent challenges of capturing the almost infinite variety of experiences any individual might have when reading, visiting a science center or participating in a school class.

This new measure was not drawn from previous research but was developed through an iterative testing and piloting process. Based on initial discussions within the project team, consultations with researchers, and input from a day-long workshop with science learning experts from across the country,[2] we drafted an initial set of 14 items to capture the multiple ways individuals might reflect on their perceived enjoyment of and value for an experience and how that experience connected with their personal needs, interests and identities. This initial set of items was then piloted using a cognitive interview protocol (Groves et al., 2009). Item wording was subsequently updated based on input and questions from participants and several confusing or ambiguous items were dropped. This updated set was then reviewed again by project advisors and a final version created with nine distinct items (Table 3).

For each of the learning contexts, respondents were asked to rate each of the nine questions related to the nature of their experience using a four-point Likert-like scale, ranging from “Disagree a Lot” to “Agree a Lot.” The same nine questions were asked of each type of experience; the language was modified as necessary to make contextual sense (e.g., “When I watch science shows [on TV] I am able to explore ideas that are interesting to me” or “When I read a science book or magazine article I am able to explore ideas that are interesting to me”).

Using the data collected, we again conducted a series of PCAs to understand the dimensionality and reliability of the items and to identify the final sets for subsequent analyses. Initially, the items were hypothesized to represent at least two different constructs related to the perception of prior science experiences in each context, including a more cognitive component related to knowledge and ideas activated during experiences and a more affective component related to enjoyment and feelings. The dimensionality analyses across all the learning contexts strongly suggested that a single construct explained the majority of variance across the items.

The final PCA results for these nine items and all ten learning contexts (five retrospective and five current) are shown in Table 3. Factor loadings ranged from 0.428 to 0.816, with the nine items explaining between 51% and 59% of the variance for the different learning contexts. Cronbach’s alpha internal consistency values were high, ranging from 0.873 to 0.910. As with the interest measure, mean scores were calculated for each participant (with a minimum of five completed items) to generate measures of perceived science learning experiences for each of the learning contexts.

Table 3. Single factor PCA results for perceived experience by learning context

	Factor loadings								
Item	Current Science Center	Current Internet	Current T.V.	Current Reading	Current School	Younger Science Center	Younger Internet	Younger T.V.	Younger Reading
Q1 …I am able to explore ideas that are interesting to me.	.632	.573	.691	.704	.735	.690	.661	.745	.725
Q2 …makes me think in new ways.	.662	.663	.681	.681	.761	.734	.735	.764	.771
Q3 My family enjoys *doing this*.	.522	.533	.568	.628	.428	.603	.600	.611	.625
Q4 …helps me understand the world around me.	.647	.638	.631	.648	.682	.722	.723	.683	.738
Q5 I think my friends would enjoy *this*.	.634	.579	.613	.638	.629	.666	.642	.667	.653
Q6 …makes me feel excited.	.753	.766	.789	.794	.815	.796	.791	.816	.778
Q7 …keeps me interested.	.766	.740	.756	.742	.809	.806	.777	.805	.781
Q8 … *do it* again.	.772	.751	.803	.797	.731	.770	.742	.803	.802
Q9 …makes me feel good about myself.	.695	.706	.691	.729	.734	.642	.738	.694	.681
Eigenvalues	3.149	3.637	4.085	4.253	4.489	3.718	4.210	4.120	4.365
% of variance	52.150	51.300	54.160	56.370	57.250	56.410	56.440	58.960	58.310
Cronbach’s α	.881	.873	.889	.898	.897	.900	.900	.910	.907

Demographic Variables.

All participants were asked to report their gender and age, their race/ethnicity (U.S. census categories), if English was their first language, and what languages were spoken at home.

Data analysis

Results below are reported at the 95% confidence level. The margin of error for the sample was ± 2% for response proportions on individual items. This means that if the survey were replicated 100 times with the same approach and population, the true population values for each of the items would be within the 2% margins of error for the sample estimates in 95 out of 100 of those replications (Dillman, 2000; Vaske, 2008).

Results

Independent Measures

The key independent measures investigated were use of one or more of these five science educational resources and if used, the nature of the experience an individual had. Each of these variables was also investigated as a function of key demographics, such as gender and race/ethnicity. Figure 1 summarizes self-reported current youth use/non-use of each of the four "not at school" science educational resources. NOTE: We assumed that youth of this age daily attended some kind of science class. Visiting a science center was the most utilized medium overall, with roughly 87% of all participants engaging in this activity at least annually, while science reading was the least utilized resource overall with roughly 57% of participants engaging in this activity at least annually. Other activities though were used more regularly. Internet use, television viewing, and reading were very similar, with small percentages of participants engaging in at least one of these activities on a daily basis. Over one-third of participants self-reported engaging in either science-related Internet use, television viewing, or reading multiple times per week.

Figure 1. Current percent use of science rich media.

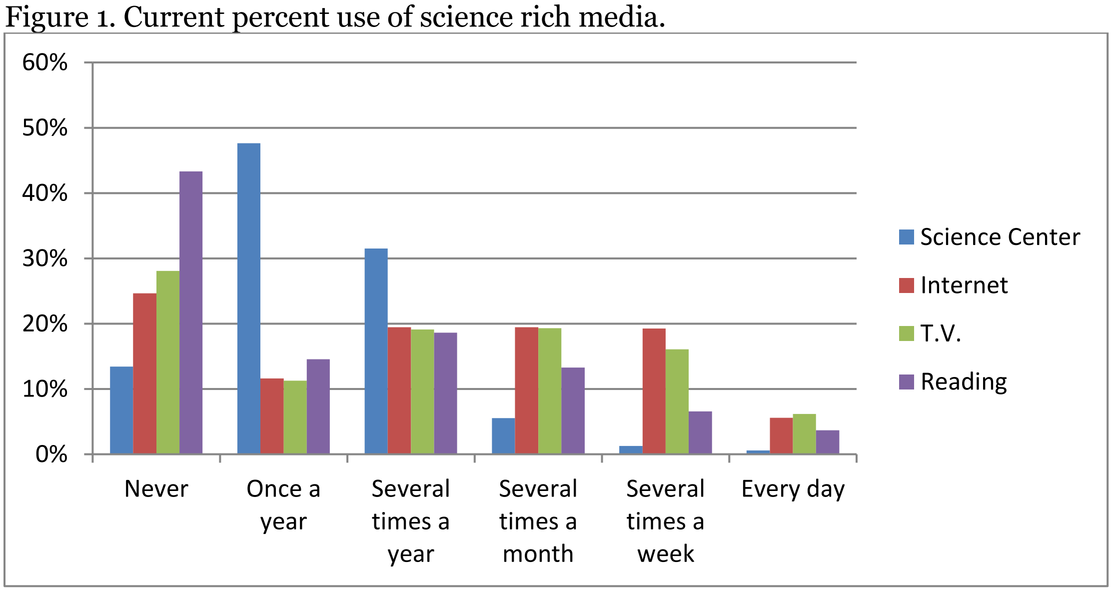

Figure 2. Younger percent use of science rich media.

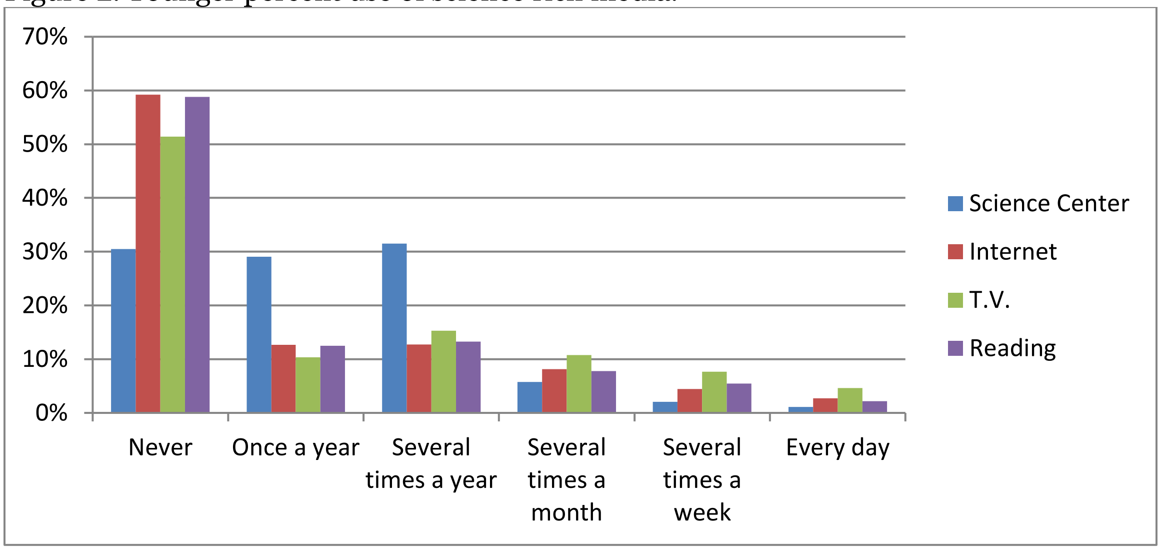

Figure 2 summarizes youth's self-reported use/non-use of each of the four relevant science experiences when they were younger (3rd or 4th grade). NOTE: We cannot assume that youth of this age regularly participated in science lessons in school. Since we did not collect data on retrospective school use, we cannot say what actual primary school science participation levels were. Again, youth self-reported frequent past use of these out-of-school science educational resources, but self-reported past use was generally lower than current use. Visiting a science center was again the most utilized medium overall for participants when they were younger, with roughly 70% engaging in this activity at least annually. Science learning related internet use and reading were the least utilized with roughly 40% of participants engaging in these activities at least annually. Approximately 50% of participants self-reported that they watched some science-related television during this time period in their life, with 15% indicating they watched science-related television several times a month, 8% saying they watched several times per week, and 5% reporting watching every day.

On a scale of one to four, with four being the best possible positive experience, the science learning experience composite mean for science reading was 2.87, 2.92 for internet experiences, 2.98 for television experiences, and 3.05 for school experiences. The mean for science center experiences was the highest at 3.28. Mean distributions were negatively skewed for both school and science center experiences and more normally distributed for internet, television, and reading experiences.

Correlations between all of the utilization and nature of the experience data were positive (Table 4). The correlation between current science center utilization and the nature of science center experience was significant and positive at .14. The correlations for internet, television, and reading utilization and experiences were significant and positive as well at.39, .46, and .48 respectively.

Table 4. *Rank-order correlations between current use and current experience variables*

Variable	1.	2.	3.	4.	5.	6.	7.	8.
1. U-Center								
2. U-Internet	.16***							
3. U-T.V.	.05	.43***						
4. U-Reading	.12**	.37***	.48***					
5. E-Center	.14**	.21***	.18***	.16***				
6. E-Internet	.15***	.39***	.29***	.31***	.58***			
7. E-T.V.	.09	.31***	.46***	.28***	.52***	.66***		
8. E-Reading	.14**	.30***	.27***	.48***	.51***	.66***	.64***	
9. E-School	.11*	.28***	.29***	.30***	.53***	.61***	.59***	.59***

Note. U-Center = Current Science Center Use. U-Internet = Current Internet Use. U-T.V. = Current T.V. Use. U-Reading = Current Reading Use. E-Center = Current Science Center Science Experiences. E-Internet = Current Internet Science Experiences. E-T.V. = Current Reading Science Experiences. E-Reading = Current Reading Science Experiences. E-School = Current School Science Experiences.
$^*p < .05$, $^{**}p < .01$, $^{***}p < .001$

Table 5. Weighted multiple regression of current science experiences predicting science interest (relevance)

Predictor Variables	B	95% CI
Science Centers	.172**	[.075, .269]
Internet	.124*	[.009, .239]
T.V.	.020	[-.066, .106]
Reading	.012	[-.071, .095]
School	.114**	[.033, .194]
Control Variables	B	95% CI
Age	.013	[-.032, .059]
Ethnicity (Hispanic)	-.065	[-.141, .012]
Ethnicity (African American)	-.198*	[-.358, -.038]
Ethnicity (Asian)	-.010	[-.164, .144]
Ethnicity (Other Non-White)	-.091*	[-.173, -.009]
Gender (Male)	-.035	[-.106, .036]
English as first language (No)	-.001	[-.091, .089]
R^2	.272	
F	15.130***	
N	557	

Note. Ethnicity reference variable is White. Gender reference variable is Female. English as first language reference is Yes.

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

A linear multiple regression model was used for determining the unique associations of self-reported quality of youth's current experiences visiting science centers, using the internet for science related purposes, watching science-related television, reading science-related books and magazines, and school science experiences on respondent current interest (relevance) in science; age, race/ethnicity, gender, and if English was the participant's first language were included in the model as control variables (Table 5). A significant regression equation was found (F(11, 557) = 15.130, p < .001), with an R^2 of .272. Current science center experiences, internet science usage experiences, and school science experiences were found to be significant predictors of youth's current science interest (relevance), controlling for all other predictor variables. The relation with science-related television watching and reading were not significant. Ethnicity, gender, and English as first language were all dummy coded so that White females with English as their first language were the reference. Among the control variables, African American and other/multiple race/ethnicities were found to be significantly related to current science interest (relevance), while age, Hispanic/Latino/a, and Asian race/ethnicities, gender, and English as a first language were not significantly related to current youth science interest (relevance).

A second linear multiple regression model was calculated to determine the contributions of self-reported quality of participant's retrospective experiences as 3rd and 4th graders when visiting science centers, utilizing the internet for science related purposes, watching science-related television, reading science-related books and magazines and participating in school-based science lessons on participant current interest (relevance); age, race/ethnicity, gender, and if English was the participant's first language were again included in the model as control variables (Table 6). A significant regression equation was found (F(12, 281) = 3.760, p < .001), with an R^2 of .168. Recalled younger science center visitation was found to be a significant predictor of current 10 – 14 year old youth's science interest (relevance). While internet usage for science related purposes, watching science related television, reading science-related books and magazines (not for school) and participating in school-based science were not significant, controlling for all other predictor variables. None of the control variables were found to be significantly related to current 10 – 14 year old youth's science interest (relevance).

Table 6. Weighted multiple regression of younger science experiences predicting science interest (relevance)

Predictor Variables	B	95% CI
Science Centers	.187**	[.066, .308]
Internet	.070	[-.050, .190]
T.V.	.072	[-.026, .170]
Reading	.047	[-.085, .179]
Control Variables	B	95% CI
Age	-.011	[-.064, .042]
Ethnicity (Hispanic)	-.130**	[-.223, -.036]
Ethnicity (African American)	-.175	[-.374, .024]
Ethnicity (Asian)	-.152	[-.506, .203]
Ethnicity (Other Non-White)	-.138*	[-.243, -.033]
Gender (Male)	-.011	[-.097, .074]
English as first language (No)	-.000	[-.118, .118]
R^2	.242	
F	5.450***	
N	377	

Note. Ethnicity reference variable is White. Gender reference variable is Female. English as first language reference is Yes.
$^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$

Discussion

Data from this study show that overall, a broad and representative cross-section of youth living in three large American cities regularly engage in a wide array of science-related activities, both in and outside of school. Virtually all children and youth engage with some kind of informal/free-choice science learning experience every year with nearly ninety percent of 10-14 year old youth in these three cities self-reporting that they visited a science center at least once a year, though many of these visits might have been with their school class. Large majorities also self-report regularly using the internet to learn about science and watching science-related television. Although the least utilized resource, more than half of the youth in this age cohort claimed that they read science-related materials outside of school. Not surprisingly, daily engagement in all of these activities was limited, but roughly a quarter of youth reported engaging in free-choice science learning experiences on a regular basis, i.e., several times per week. The results were consistent with other sources (e.g., Horrigan, 2006; National Science Board, 2016), showing that the internet and science-related television were the most frequently used resources, but it is striking how pervasive science center use was for this age group. Of course use of a resource does not necessarily mean that significant outcomes like increased learning or interest occurred, but it is reasonable to assume that in the absence of use, no resource-related outcomes would be possible.

Youth reported that, overall, their use of all of free-choice learning resources was greater currently than when they were younger. This was somewhat surprising given that it is generally assumed and reported (e.g., Falk, et al., 2016a), that free-choice science experiences taper off as children move into adolescence. Perhaps these self-reports suffered from some kind of recency bias, with events happening in the past being less salient/memorable than those happening in the present. Less surprising was that youth reported increased current use of the internet.

Individuals who utilized any one of these various science education media were also likely to have utilized other science education media as well. This finding is consistent with previous data (Falk & Needham, 2013; Falk, et al., 2018; National Science Board, 2016). Also consistent with earlier findings (e.g., Falk, et al., 2018) was that individuals with the best experiences were likely to be the most frequent users. All of this is not surprising, but it is important to keep in mind as a baseline understanding. Specifically, self-selection is not a variable that should, or arguably even can be controlled for within free-choice learning contexts since it is intrinsic to most informal/free-choice learning situations (Falk & Dierking, 2014; Renninger & Hidi, 2016). In fact, a study in the U.K. found that motivating youth to want become interested in, and continuously engage with science was universally seen as the primary goal of both formal and informal/free-choice science educators alike (Falk, et al., 2015).

Following from this argument, one of the important findings from this study is that increased participation in science-related experiences in- and out-of-school during childhood correlates with participation in comparable experiences later during the critical early adolescence period. These findings can be combined with our earlier research (Falk, et al., 2018) showing a similar correlation between science-related experiences during early adolescence and later adult behaviors to suggest that engagement with science experiences is indeed an on-going, cumulative phenomenon; that every point in an individual's life represents both an opportunity and a threat to long-term interest and participation with science. Other studies have come to similar conclusions (e.g., Bonnette, Crowley & Schunn, 2019; Falk & Needham, 2013; Tai, et al., 2006).

Our analysis also highlights that although a diversity of positive, current science-related experiences correlated with current 10-14 year old youth's interest (relevance), only some of these experiences were uniquely predictive of their interest after controlling for other variables in the models. Specifically, positive current free-choice learning experiences such as visiting a science center and using the internet to learn more about science and current school science classes all significantly correlated with current 10-14 year old youth's science interest (relevance), while positive experiences doing more individual activities such as watching science related television or reading books and magazines did not. By contrast, only positive experiences visiting a science center several years prior significantly and uniquely predicted 10-14 year old youth's current science interest (relevance). Earlier positive experiences reading science-related books, using the internet to learn about science, watching science-related television and science classroom experiences did not positively correlate with the current science interest (relevance) of our sample of 10-14 year old youth. Again, these latter data do not suggest that youth, when they were younger, never had positive experiences while reading science-related books, using the internet to learn about science, watching science-related television and/or participating in school science. Rather the data indicate that having these kinds of positive experiences at an earlier age did not appear to result in any longer term science interest (relevance).

One conclusion suggested by the data, is that 10-14 year old youth develop science interest (relevance) as a consequence of experiences across a range of science education platforms, but that one of these five educational platforms – science centers – emerged as, overall, more important than the others. Although other experiences variously had an influence, including current school science, only past and present use of science centers consistently influenced 10-14 year old youth to be interested (relevance) in science. Similar types of data collected from adults and previously published (Falk, et al., 2018) revealed similar results – adults' past experiences when visiting science centers and their current science center experiences were the only educational experiences of these same five resources that consistently resulted in significant correlations with adults' current science interest (relevance).

Even though these are preliminary and course-grained findings, they raise important questions about the prevailing assumptions held by most science and technology professionals, educators, and policy makers about the relative importance of various educational resources for promoting children and youth's interest in science. These results highlight the potential importance that continued, multi-modal participation in science education experiences, in and out of school, have on children and youth's science interest. Results did show that having positive classroom science experiences at the middle school level, but not at the elementary school level significantly contributed to 10-14 year old youth's current science interest (relevance) but so too did other experiences, including and particularly science center experiences. Given that nearly all federal, state and local science education funding in these three communities currently goes to support school-based solutions, these results should give some pause. Despite considerably less support, non-school experiences appeared to have yielded comparable and in some cases greater benefits; at least with regard to how relevant youth perceived that science was to their lives. As suggested in the literature review (e.g., Bonnette, Crowley & Shunn, 2019; National Research Council, 2015; Tai, et al., 2006), interest is potentially a critically important variable since it is highly correlated with more traditionally measured outcomes such as science understanding and persistence in science-related activities.

Of course, it is reasonable to assume that the generic and overall group experience quality measures we generated do not equally apply to all individuals nor all learning situations. For example, although there were almost certainly some elementary classroom teachers who worked hard at making science fun and exciting for these youth, and who emphasized the importance of science for youth's future lives, it appears from this data that either too few teachers focused on these dimensions or as a whole this message did not break-through the more typical school focus on other school subjects. Similar conclusions could be reached for efforts made to stimulate interest in science through print, broadcast and internet-related platforms.

The findings from this study do not allow direct inferences about exactly how these various experiences influenced or interacted with current 10-14 year old youth's science interest (relevance), and it cannot be determined what the directionality or relationship is among these various factors. For example, do positive science center experiences predict science interest (relevance), or is the reverse true? Do individuals with positive science center experiences during the elementary school years self-select to further engage in science-related activities, which results in the development of science interest (relevance) at the middle school years? Do early adolescent's out of school science-related activities pre-dispose individuals to be more engaged with school science, which in turn results in youth more inclined to participate outside of school in free-choice science learning experiences like using the internet or visiting science centers, or does the interest cultivated outside of school develop totally independently of what happens within school? These questions still remain because of the inherently complex ecology of multiple factors that influence human interest development. Interactions among these factors were not tested in this study, although it seems reasonable to assume they existed given what is known about the complex and iterative nature of learning (e.g., Bonnette, Crowley & Shunn, 2019; Falk, Storksdieck & Dierking, 2007; National Research Council, 2015; NASEM, 2018). As with any complex system, these relationships likely existed and played some kind of mutually reinforcing influence. Regardless of these complexities, there is no escaping the fact that it appears that informal/free-choice experiences, both when children are approximately aged 7 to 9 years of age and when they are 10-14 years of age emerged as significant predictors of 10-14 year old youth's science interest (relevance).

The data suggest that issues like race/ethnicity did significantly influence youth's perceived interest (relevance) in science. In particular, African Americans were significantly less likely to report higher interest (relevance) in science than were White respondents; other minority groups were statistically comparable. Contrary to a number of other reported studies (e.g., Alexander, Johnson, & Kelley, 2012; Babarović, Gracin, Burušić, Dević, & Velić, 2016; Falk, et al., 2018; Osborne, Simon, & Collins, 2003), there was no evidence in this study of gender-related differences in science interest (relevance). Similarly, English as a first language did not emerge as a significant influence in this study on 10-14 year old youth's self-reported science interest (relevance).

Limitations

Clearly, these results cannot be taken as the definitive case for what factors contribute to 10 to 14 year old youth's science interest (relevance) because this study, like all studies, possesses limitations. One clear limitation would be the validity of using self-reports for both the dependent and independent measures. However as stated in Methods, a number of studies from various disciplines have established that self-report data, though not perfect are actually reasonable surrogates for more direct measures, especially when using survey data (Chan, 2009; Gonyea, 2005; Vaske, 2008). Nonetheless, future research might look to find more direct measures of both interest and participation in order to try and circumvent these issues. Similar challenges arose due to the use of retrospective data as a surrogate for actual early adolescent experiences, though as above, several investigators have found such approaches yield quite acceptable results (Lam & Bengo, 2003; Mueller & Gaus, 2015; Schwartz, 2007). Again, in the future, it would be ideal to test these findings using longitudinal, direct observational approaches.

The finding that formal schooling during elementary school, as well as experiences using the internet, reading and television watching were not unique predictors of 10 to 14 year old youth's science interest (relevance) can be argued to have arisen from the fact that results were generic to all these experiences, and to the fact that it is well known that both the quality and quantity of these science experiences varies considerably. This criticism could be countered however, by pointing out that the measures utilized in this study were exactly comparable across all five platforms of science experience; all five resources were assessed using the same course grained, summative indicators of quality rather than fine grained measures of specific experiential quality in any one particular setting or situation. In other words, it is almost certain that each of platforms investigated – science center exhibitions and programs, books, magazines and other print media, school science courses and broadcast and digital media – all were subject to considerable variability in quality, with the quality of any individual's experience likely influenced by a wide range of personal learning and situational factors (for a detailed account of how this variability effects, for example, individual museum experiences see Falk & Dierking, 2018). It is possible though, that greater variability exists within any one of these domains, e.g., the elementary school classroom realm, which may have impacted the results. It remains a question for future research to determine whether: a) there is greater variability in the quality of some media, e.g., in elementary school classroom experiences, than in others; and b) even if such variability exists, would controlling for such variability appreciably change the results.

A further potentially confounding variable is likely the continued blurring of the boundaries within and between these five categories of educational resource, e.g., school and science centers, or television and the Internet. A youth's actual experience with any one of these science education resources is likely to be a blending of modalities. For example, many science center experiences now incorporate formal presentations, broadcast media, and Internet experiences, while many classrooms now include a range of traditionally informal education delivery vehicles such as hands-on learning. In addition, school-aged youth are regularly assigned science-related books to read, media to watch and encouraged to visit science centers; and thus the dependence on self-report in our study could have resulted in conflation of experiences or outright mistakes in the way youth responded. Although an attempt was made during data collection to clarify for respondents these distinctions, it is reasonable to assume that some bias in reporting might have occurred.

This study focused on only three different types of science education outcome: interest (relevance), participation and the quality of experience when using an educational resource. We believe that the dimensions of interest (relevance), participation and experience that we selected are robust and that heightened science interest (relevance) as well as participation and positive science experiences are indisputably reasonable and important science education outcomes. We do not argue however that these are the only or even necessarily the most important science education outcomes. Thus, whether or not the specific dimensions of interest (relevance), participation and quality of experience we measured directly correlated with other science education outcomes like the ability to understand scientific argumentation or generic measures of science literacy cannot be answered by our current data set. However based on the literature cited above, it is quite reasonable to assume that such correlations were highly likely. Still fully answering this particular question remains something that will need to be explored in subsequent research.

Finally, our data was collected in three unique, highly diverse (socio-economically, race/ethnicity, linguistically, etc.) localities – Los Angeles, Phoenix and Philadelphia. We are quite confident that findings reliably reflect these three U.S. communities, but we cannot be equally confident that the findings would be fully generalized to other parts of the U.S., let alone other parts of the world. That said, given the effort to collect data from multiple geographic locations and a research approach specifically designed to capture a fair and to the degree possible random representation of all appropriately aged residents within those locales, there is no obvious reason to assume that results are not broadly generalizable. However, whether fully generalizable or not, given the pioneering nature of this study these findings provide a useful and reasonable baseline for understanding the relative contributions that various educational resources make to 10 to 14 year old youth's interest in science generally and science interest (relevance) in particular. There is no doubt that future efforts, particularly longitudinal or panel studies designed to assess the influence of both quantity and quality of learning experiences across an individual's lifetime, will reveal a more complete and complex picture of how and why the public becomes interested in science. The relative contributory patterns suggested by this research, however, provide a useful framework for understanding a child's lifetime science learning journey. In addition to providing a foundation for further research, these data can also provide a departure point for science education discussions related to resource distribution, equity, and national policy.

Conclusions

This study highlights the complex and synergistic nature of the science learning ecosystem—an ecosystem that we only somewhat understand. More research is clearly needed in order to clarify the cumulative and complementary influences of all the various science resources an individual utilizes across their lifetime. This study though strongly reinforces that real progress in public science education will require taking such an ecosystem-wide approach. The primary take-home message of this research is that the data broadly support the contention made in the introduction that the public's science education is supported not by a single, dominant resource (e.g., formal schooling), but rather by a vast array of educational resources of which schools are just one of many, and not always the most important. In fact, the data suggest that informal/free-choice learning experiences, both during the elementary/primary school years of childhood as well as during the middle school years provide critical supports for fostering the science interest (relevance) of 10 to 14 year old youth. These findings, along with evidence that informal/free-choice experiences appear to contribute more to adult science interest and understanding than schooling (Falk, et al., 2018; Falk & Needham, 2013; Jones, Corin, Andre, Childers & Stevens, 2017), provide additional support for the argument that the current, overwhelming emphasis in science education policy and financial support towards school-based science is misplaced. At a minimum, the results argue for the need to give greater attention and potentially greater support to free-choice learning in general and science center experiences in particular.

The results also provide additional evidence that there is a need to improve science education equity and access. Although it has long been argued that schools are the great levelers in terms of social inequalities, the data, as well as previously cited research do not fully support this contention. Collectively, out-of-school resources were shown to have had a more significant influence on youth's levels of science interest than did schooling, specifically the perception of science as something that is relevant to one's current and future life. Rather than relying on past assumptions, the best available evidence now suggests that equity goals could best be advanced through investments that insure that all children and youth have equal access to informal education experiences. In fact, given the evidence that visiting a science center was the only type of childhood science learning experience that significantly correlated with early adolescent science interest (relevance), a case could be made that the single most cost-effective mechanism for increasing the science interest of historically underserved populations would be insuring frequent and repeated access to science center experiences. Although this approach may be too radical, results from a growing body of research at a minimum now suggest that the current policy of privileging school-based solutions is highly unlikely to change either the short-term or the long-term societal goal of enhancing the science interest and engagement of historically underserved populations.

Although the data generally tilt in the direction of informal/free-choice learning experiences, overall the results reinforce the synergistic and cumulative nature of science interest development and learning. Individuals having positive science-related experiences both in and outside of school are more likely to engage in science-related activities, which in turn correlates with later, i.e., adult, interest in and engagement with science (Bonnette, Crowley &

Shunn, 2019; Falk, et al., 2018; Falk & Needham, 2013). Thus to create a citizenry who are persistently interested in science requires building all parts of the science learning infrastructure and focusing on all citizens, not just a few parts and some individuals. Given that a large majority of youth engage in some kind of science-related experience outside of school, it behooves the broader science education community to invest time and resources in improving not only the quality of these experiences; both through enhanced professional learning and improvement in the quality of offerings, but in the coordination of efforts. Currently, there is virtually no coordination between what happens inside and outside of school; learners are left to their own devices to figure out how best to navigate the science education ecosystem. For this to happen, education policy-makers would have to not only reorder their funding priorities, but would also need to reorder their view of what constitutes public education. In other words, if learning is truly an ecosystem-wide phenomenon, than sound science education policy would focus on supporting not a single type of science resource but multiple sources.

There has been increasing rhetorical acknowledgement amongst policy-makers about the importance of this kind of broad, multi-sector strategy (e.g., National Research Council, 2015; National Science and Technology Council, 2018), but there has been relatively little real substantive movement in this direction. Formal schooling continues to be the instrument of choice for virtually all local, state, and national efforts for enhancing public interest and understanding of science. There appear to be no significant proposals to more equitably distribute education financial resources of any kind beyond schools; in fact the policies of the current U.S. and other governments seem to be towards significantly reversing what little progress in this direction were made over the past decade. It is hoped that this study might provide some impetus for changing the nature of the debate on these issues. Although strategies and policies for addressing the need for a more science (or history or art or civics) interested, engaged, and literate society remain mired in the past, research is increasingly demonstrating that the solution to these challenges will require embracing the changing realities of when, where and how the public actually becomes engaged, interest and knowledgeable.

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END NOTES

[1] Because data on past school experiences were accidentally left off of some surveys, multiple imputation utilizing simulated datasets (Rubin, 1987; 1996) was employed to reconstruct this variable when missing.

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