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RESEARCH ARTICLE

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The contribution of science-rich resources to public science interest

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Abstract

This preliminary study examined the effect that five major sources of public science education—schools, science centers, broadcast media, print media, and the Internet—had on adults' science interest *values and cognitive predispositions*. Over 3,000 adults were sampled in three U.S. metropolitan areas: Los Angeles, California, Phoenix, Arizona, and Philadelphia, Pennsylvania. To minimize potential sampling bias, the results were weighted by current U.S. Census data to be comparable to demographics from each of the three jurisdictions. Participants were asked to self-report their current and early adolescent usage of these five science-related resources, the quality of their experiences with each, and their current abilities, values, and cognitive predispositions relative to science. Data showed that overall, a broad cross-section of adults living in these cities engaged in a wide array of science-related activities and that large majorities did so frequently. Nearly two-thirds of all respondents self-reported currently participating in some kind of science-related activity every week and nearly half doing so daily. Results suggested that having frequent; positive science-related experiences in- and out-of-school, both early and later in life, correlated with having a strong interest in and positive perception of science as an adult. Although a diversity of positive science-related experiences correlated with current adult science interest values and cognitive predispositions, only five factors uniquely and significantly predicted adult science interest, values, and cognitive predispositions in the multivariate models: (a) early adolescent experiences visiting a science center, (b) early adolescent experiences watching science-related television, (c) adult visits to a science center, (d) adults reading books and magazines about science, and (e) adults using the internet to learn more about science. Discussed are issues of self-selection, quality of experiences, and the complex and synergistic nature of the science learning ecosystem.

KEYWORDS
free-choice learning, informal, learning ecosystem, science interest

1 | INTRODUCTION

In an increasingly scientific and technological world, the need for a citizenry 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 part of the daily lives of most citizens. Meanwhile, there has also been a relentless blurring of the boundaries of where, when, and how people 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 public science literacy has focused on understanding, 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).

Considerable concern remains within the science education community about the pervasive dip in science interest that occurs in youth after around the age of 12 or 13, with fewer and fewer young people choosing to major in scientific fields or even taking science coursework at the high school and university level (Osborne, Simon, & Collins, 2003); the assumption being that these declines will have significant consequences over time as fewer youth will pursue science-related careers and fewer adults will possess the necessary science literacy to be knowledgeable and engaged decision makers (Lacey & Wright, 2009; Maltese & Tai, 2011; National Research Council, 2007).

Supporting this concern is a core finding of several major international studies that key commitments by learners to science occurs very early in the life of citizens; usually prior to adolescence (Martin et al., 2000; PISA, 2007; Sjøberg & Schreiner, 2010). Thus, early interest in science appears to be critical to long-term science learning and participation in science-related practices (cf., Galton, 2009; Osborne et al., 2003; Vedder-Weiss & Fortus, 2011). For example, science 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 (Maltese & Tai 2010, 2011; Tytler, Osborne, Williams, Tytler, & Cripps Clark, 2008) and many of the leading academic and career pathway theories position interest as a central variable driving the choices of youth and young adults (Lent & Brown, 2000; Lent, Brown, & Hackett, 1994; Wigfield & Eccles, 2000).

These results have been reinforced by research in the United States (Maltese & Tai, 2010; Tai, Qi Liu, Maltese, & Fan, 2006) which show that attitudes toward science careers in early adolescence appeared to be the single most important factor in determining children's future career choices (and success) in science. Other investigators (e.g., Barron, 2010; Bell, Bricker, Reeve, & Zimmerman, 2010; Bricker & Bell, 2014; Falk, Dierking, Staus, et al., 2016) have come to similar conclusions by looking ethnographically at small numbers of children and youth across their daily life. There is also growing evidence that long-term dispositions toward science can start as early as preschool and elementary school (e.g., Alexander, Johnson, & Kelley, 2012; Mantzicopoulos, Patrick, & Samarapungavan, 2008; Pattison, 2014; Pattison & Dierking, Submitted for Publication). That said, although there is a clearly a decline in youth science interest starting in middle school years, these declines in interest and even in knowledge appear to dissipate in adulthood, with large majorities of adults expressing strong interest in science, particularly in the United States (Falk & Dierking, 2010; National Science Board, 2016). Clearly, the relationship between early and future public science interest is complex.

Lacking has been solid data on where and how interest in science develops. Historically, the assumption was from schooling but there is a growing appreciation that many science education entities from across the entire science learning ecosystem likely contribute to public science interest over the course of a person's life (e.g., Falk & Dierking, 2010; Falk & Needham, 2013; National Research Council, 2015). However, considerable debate continues to surround the question of the relative contribution and "directionality" of influence of these various sources, that is, does interest start in school and migrate outward or the other way around? Although a case could be made that each of the various major sources of public science education, for example, schools, science centers, broadcast media, print media, the Internet, contribute to the public's science interest, direct comparisons have been historically lacking. This study represented an initial attempt to determine the effect that five major sources of public science education had on adult interest in science.

2 | LITERATURE REVIEW

Typically discussions about how and why the public develops 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 (Falk & Dierking, 2010; National Research Council, 2009), with the actual time devoted to science instruction representing a surprisingly small percentage of even school-aged children's time (Stevens & Bransford, 2007). Across an entire lifetime, the actual amount of time the average person participates in some kind of formal science experiences is minuscule. For example, most U.S. youth take only a single science course in high school and even for the roughly one third of the U.S. population that completes a bachelor's degree, only a small minority take any science-related courses (U.S. Census Bureau, 2016). By contrast, most adults receive almost daily exposure to some kind of science-related media (National Science Board, 2016). Informal/free-choice/out-of-school experiences do contribute to the public's science interest but these experiences cannot be easily lumped into the single category of informal science education (cf., Falk et al., 2015; National Research Council, 2015). In general, both children and adults have opportunities to develop an interest in science beyond the classroom 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. In fact, evidence exists suggesting all of these sources actually do contribute to both science interest and understanding (cf., Falk & Needham, 2013; National Research Council, 2009, 2015).

Evidence for positive influences on science interest have been reported for school (Bulunuz & Jarrett, 2010; Maltese & Tai, 2010; Trumper, 2006), science centers (e.g., Bulunuz & Jarrett, 2010; Falk, Dierking, Swanger, et al., 2016; 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, 2016), the internet (e.g., Horrigan, 2006; National Science Board, 2016; Takahashi & Tandoc, 2016), 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 although is that despite evidence that all of these various sources likely contribute to the short and potentially long-term science interests of the public, comprehensive data supporting these claims, let alone comparisons between these various sources on the basis of the quality of the experience are relatively scarce. 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 measure 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; Renninger & Hidi, 2016) and Krapp (2002) who conceptualized interest as a complex, multidimensional construct, as 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 a person's values and cognitive predispositions toward science as a subject, 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. [NOTE: All three of these dimensions of interest have at times been considered constituents of "science identity" (cf., Archer et al., 2010; Calabrese Barton et al., 2012; Carlone & Johnson, 2007).]

Equally poorly understood is the role that the actual experience an individual has while engaged in learning science plays in supporting that person's science 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). Mindful of these challenges we opted to create and validate a new measure of science experience.

This article examines 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 adults' self-reported interest in science. We asked adults to report both current experiences and recalled experiences—specifically several years earlier while they were in middle/junior high school. By necessity, this article should be viewed as a preliminary, coarse-grained effort to determine the relative contributions that each of these five types of experiences makes to the public'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 research questions:

- What is the relationship between adults' current science interest values and cognitive predispositions and the frequency of adults 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 adults' current science interest values and cognitive predispositions and their self-perceptions of the quality of their current and prior experiences as part of science classes in school, visiting science centers, watching science television and/or reading science-related books and magazines (not for school)?

As noted above, 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. 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.

3 | METHODS

3.1 | Data collection

To examine the five types of science education experiences and their relative contribution to adult interest in science, data for this article were obtained in 2015 from telephone surveys collected by a third party survey company (BRC) under the direction of the research team. Data was collected in three U.S. metropolitan areas: Los Angeles (LA), California, Phoenix, Arizona, and Philadelphia, Pennsylvania.

Participants over the age of 18 were drawn from random samples of residents in each of the three communities: LA, Phoenix, and Philadelphia. Household selection for this project was accomplished via a computer-generated, unweighted, random digit dial telephone sample which selects households on the basis of telephone prefix. This method was used because it ensures a randomly selected sample of area households proportionately allocated throughout the sample universe. This method also ensures that all unlisted and newly listed telephone households are included in the sample. A preidentification screening process was also utilized on this project. This computer procedure screens the sample to remove known business and commercial phone prefixes in addition to disconnected lines, faxes, and computers. This process helps limit contacts to residential phones. Both landlines and cell telephones were included in this research.

All of the interviewers who worked on this project were professional interviewers. Each had prior experience and received a thorough briefing on the particulars of this study. During the briefing, the interviewers were trained on: (a) the purpose of the study; (b) sampling procedures; (c) administration of the questionnaire; and (d) other project-related factors. In addition, each interviewer completed a set of practice interviews to ensure that all procedures were understood and followed.

Interviewing on this study was conducted during an approximately equal cross-section of late afternoon, evening, and weekend hours. This procedure was followed to further ensure that all households were equally represented regardless of work schedules. Furthermore, during the interview segment of this study, up to six separate attempts (on different days and during different times of day) were made to contact each selected household. Only after six unsuccessful attempts was a selected household substituted in the sample. The full sample was completed using this methodology; partially completed interviews were not counted toward fulfillment of the total sample quota.

All of the interviewing on this project was conducted at a central location telephone facility located in Phoenix by means of Computer-Assisted Telephone Interviewing (CATI). The CATI system is a computer-generated interview that uses a tightly integrated branching pattern to control cuing and display of contingent questions. This system allows for a more relaxed interview environment, while reducing the risks of coding error. The system also performs internal consistency checks on survey variables and prompts interviewer staff to ask probing or clarify answers.

The CATI software maintains a record of call disposition. When a residential contact was established, the interviewer introduced her/himself and the study, selected the appropriate household member, and attempted to complete the interview with the designated respondent. If the designated respondent was not at home or if the call was at an inconvenient time, the interview was rescheduled.

One hundred percent of the completed interviews were edited and any containing errors of administration were pulled, the respondent re-called, and the errors corrected. In addition, 15% of each interviewer's work was randomly selected for validation to ensure its authenticity and correctness. No problems were encountered during this phase of interviewing quality control.

In total, 3,001 adult residents completed the telephone survey (response rate = 21.7%) with 6% completing it in Spanish and 94% in English. This response rate is consistent with most telephone surveys conducted recently in the United States (see Connelly, Brown, & Decker, 2003; Dillman, 2000; Vaske, 2008 for reviews). A planned missing data design was utilized to help alleviate concerns of participant fatigue due to questionnaire length (Graham, Taylor, Olchowski, & Cumsille, 2006; Rathod & LaBruna, 2005). An effort was made to include cellular telephones, but they still represented less than 30% of the sample. To minimize any potential sampling bias, the results were weighted by current U.S. Census data to be comparable to demographics from each of the three jurisdictions: greater LA, Phoenix, and Philadelphia (Table 1).

3.2 | Analysis variables

The survey assessed current levels of multiple dimensions of science interest, 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 relevant parts of survey is included as a Supporting Information.

3.3 | 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, Dierking, Staus, et al. (2016). 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 previous research on the California Science Center use and impact conducted by the authors (e.g., Falk & Amin, 1997; Falk, Brooks, & Amin, 2001; Falk, Dierking, Swanger, et al., 2016; Falk & Needham, 2011). All items used 4-point Likert-like response scales, ranging from "agree a lot" to "disagree a lot." Our goal was to capture the multiple dimensionality of interest outlined by Renninger and Hidi (2016).

Using the collected, weighted 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 15 items represented at least three distinct dimensions of science-related interest, which we labeled—values and cognitive predispositions, social relationships, and self-efficacy. These three dimensions were consistent with Renninger and Hidi's (2006, 2016) conceptualization of interest, including their assertion that interest includes both cognitive and affective perceptions of value and disposition as well as self-perceptions of the emotional, social and identity-related feelings associated with the ability to "do" science. These three dimensions were also consistent with the prior research described above that also showed that interest and interest development were multifaceted. Given that all three dimensions of interest were potentially independent, and thus, would require that each be treated as an 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—values and cognitive predispositions. 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. Although not necessarily more or less important than the other two, this dimension arguably represents an important and critical aspect of public science interest. Based on the factor loadings with the original 15 items, we believe this subset of seven items adequately captured the aspects of science interest that is specifically related to how individuals generically value, both personally and societally, science as field, as well as how

TABLE 1 Adult sample demographics

Demographic	Category	Actual/Un- Los Angeles (%)	Weighted Philadelphia (%)	Percentages Phoenix (%)	Weighted Los Angeles (%)	Percentages Philadelphia (%)	Phoenix (%)
Gender	Male	44.9	37.6	41.2	45.7	36.5	40.4
	Female	55.1	62.4	58.8	54.3	63.5	59.6
Ethnicity	White	53.6	46.9	70.9	28.2	36.2	45.1
	Hispanic	19.6	5.2	15.7	49.3	13.3	41.3
	Black/African American	15.0	39.9	7.7	8.6	41.8	6.6
	Asian	6.2	2.0	1.0	11.2	6.7	2.9
	Other	5.5	5.9	4.6	2.7	2.0	4.1
Education	Less Than High School Graduate	5.0	7.5	5.1	6.6	8.4	6.9
	High School Graduate	14.5	25.7	17.7	20.5	26.9	20.5
	Two Years or less of College	29.3	31.0	38.5	29.2	31.6	37.9
	Bachelor's Degree	26.0	17.3	20.8	26.0	16.9	19.7
	Master's Degree	13.5	11.3	11.9	9.4	10.6	10.5
	Professional Degree	9.7	4.5	3.4	7.6	3.7	2.9
	Something Else/Don't Know/No Answer	2.0	2.7	2.6	0.8	2.0	1.6
2014 Household Income	Below Median Income	22.9	36.6	34.8	33.6	37.8	37.2
	Above Median Income	53.5	43.6	40.9	49.7	43.7	40.5
	Refused to Answer/Missing	16.6	19.8	24.4	16.6	18.5	22.3

TABLE 2 Single factor PCA results for subset of science interest items

Item	Factor loadings
Q1 Science will be useful in my future.	.738
Q2 I will need to know science to get a good job.	.602
Q3 It will be useful to me in the future to know some science.	.755
Q9 Science tells us about how people think and behave.	.776
Q10 Science helps me understand the world around me.	.833
Q11 I use science ideas in my everyday life.	.819
Q12 Science has improved the quality of human life.	.876
Eigenvalues	4.211
% of variance	60.158
Cronbach's α	.884

individuals perceived that their own science knowledge might or might not benefit them now and in the future.

The final PCA results for these seven "values and cognitive predisposition" items are shown in Table 2. Factor loadings ranged from 0.602 to 0.876 and the single factor solution for the seven items explained over 60% of the variance in item responses. Internal consistency was high, with a Cronbach's alpha values of 0.884.

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 values and cognitive predispositional science interest. As stated above, we recognize that this measure represents only one of several potential dimensions of the interest construct. We also recognize that "science" too is a broad domain and that adults may be interested in some areas of science but not others (cf., Falk, 2017; Falk, Dierking, Swanger, et al., 2016). Thus, in the introduction to the survey, participants were encouraged to think about the topic of science broadly and were provided a number of examples, including space exploration, nutrition and cooking, bird watching, and psychology. In the survey, all science learning experiences were described to participants as activities that help people stay current in or find out more about science.

3.4 | Current and retrospective self-reports

We utilized self-reports for both current and past indicators of frequency and quality of experience. As has been widely reported in the literature, self-reports are not always the most reliable 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; Schwarz, 2007), particularly given how challenging information about past events can be to collect.

3.5 | Frequency of science experiences

One of the major independent, or more accurately "criterion" variables[1] 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 sixth/seventh grade. Building off earlier studies (e.g., Falk & Amin, 1997; Falk, Dierking, Swanger, et al., 2016; Falk & Needham, 2011; Falk et al., 2001; 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."

3.6 | Perception of science experience

The other major independent/criterion 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.

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, 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 4-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"). Participants were not asked about their prior, early adolescent experiences with the Internet, given that the Internet did not exist for many of these adults when they were children. Similarly, participants, all of whom were adults, were not asked about their current school classroom experiences since the vast majority was not currently enrolled in any type of formal education.

Using the data collected (weighted by city), 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. However, 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 eight learning contexts (four retrospective and four current) are shown in Table 3. Factor loadings were high, ranging from 0.628 to 0.936, with the

TABLE 3 Single factor PCA results for perceived experience by learning context

Item	Factor loadings							
	Current science center	Current reading	Current T.V.	Current internet	Younger school	Younger science center	Younger reading	Younger T.V.
Q20 …I am able to explore ideas that are interesting to me.	.785	.782	.800	.732	.817	.821	.809	.815
Q21 …makes me think in new ways.	.780	.756	.724	.718	.822	.806	.827	.799
Q22 My family enjoys *doing this*.	.628	.874	.886	.889	.932	.929	.914	.917
Q23 …helps me understand the world around me.	.788	.734	.795	.791	.821	.803	.753	.774
Q24 I think my friends would enjoy *this*.	.673	.874	.882	.883	.930	.924	.916	.905
Q26 …makes me feel excited.	.764	.808	.823	.838	.832	.879	.810	.864
Q27 …keeps me interested.	.816	.888	.880	.868	.934	.932	.930	.929
Q28 … *do it* again.	.800	.908	.877	.875	.936	.930	.933	.913
Q29 …makes me feel good about myself.	.738	.888	.865	.891	.906	.896	.929	.924
Eigenvalues	5.128	6.303	6.327	6.263	7.013	6.997	6.835	6.860
% of variance	56.981	70.034	70.301	69.594	77.923	77.741	75.949	76.227
Cronbach's α	.903	.943	.944	.942	.963	.962	.958	.958

nine items explaining between 56% and 78% of the variance for the different learning contexts. Cronbach's alpha internal consistency values were also high, ranging from 0.903 to 0.963. 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.

3.7 | Demographic variables

All respondents were asked to report their gender and age, how long they had lived in the city in which the data were collected, their race/ethnicity (U.S. census categories), and what languages were spoken at home. In addition, participants were asked "what is the highest grade of school that you have completed;" responses were coded on a close-ended 10-point scale from "no schooling completed" to "doctoral degree." Respondents were also asked to indicate whether their family income was greater or lesser than the median income of the city (as determined by U.S. Department of Commerce data) in which data was collected.

3.8 | 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).

A nonresponse bias check was conducted with a random sample of individuals who refused to initially respond to the telephone survey. This nonresponse check was conducted to examine any potential differences between respondents and nonrespondents of the initial telephone survey and whether data needed to be weighted to ensure that the sample was representative of and generalizable to the larger target population of the study area. A sample of 75 individuals who declined participation in the initial telephone survey was telephoned a second time and asked a smaller subset of survey questions. No statistical evidence ($p > .05$) of differences between respondents to the initial telephone survey and this nonresponse bias check was found.

4 | RESULTS

4.1 | Independent measures

The key independent measures investigated were use of science-rich 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, income, and race/ethnicity. Figure 1 summarizes self-reported current adult use/nonuse of each of the four relevant science rich educational resources. All four media were used by large majorities of the public to learn about science. Overall, watching science-related television was the most utilized medium, with roughly 80% of all adults engaging in this activity at least annually, while visiting science center was the least utilized with roughly two-thirds of adults visiting at least annually. Based on frequency of use, Internet use and science reading predominated, with roughly one-fifth of all adults engaging in these activities on a daily basis. Roughly two-fifths of adults self-reported engaging in science-related Internet use, reading, and television viewing multiple times per week.

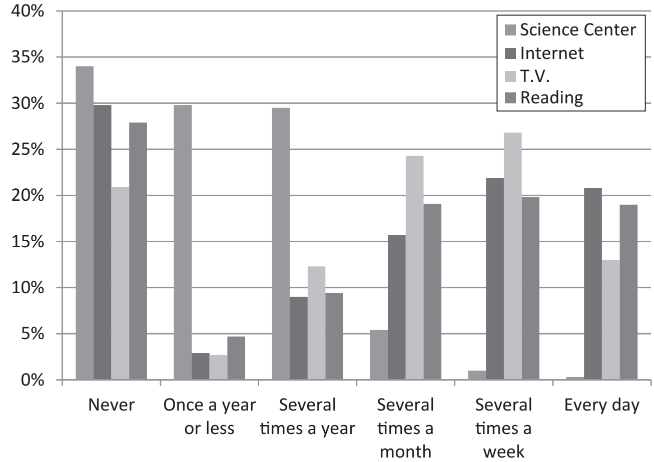

FIGURE 1 Current percent use of science rich media [Color figure can be viewed at wileyonlinelibrary.com]

Figure 2 summarizes adults' self-reported use/non-use of each of the four relevant science rich experiences when they were early adolescents. Given that Internet use was not an option for many adults during their youth, since widespread use only began about 10 to 15 years ago, these results were not included. Use of the remaining three science-rich educational resources were self-reported as relatively frequently utilized; although not as frequently as during adulthood. Fifty percent of adults 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 and 15% saying they watched several times per week. Comparable numbers of adults indicated that they did science-related reading on a regular basis during their youth, although the total number of adults claiming to have read science-related material at this point in their life was only about 40% of the sample. Similarly about 40% of the sample indicated visiting a science center during sixth and seventh grades, with most doing so once a year or at most several times a year.

Perhaps not surprisingly, there were strong positive correlations between all of the utilization and experience data (Table 4). Individuals who currently used the various science-related media most frequently were also most likely to have had positive experiences with these media. Also, individuals

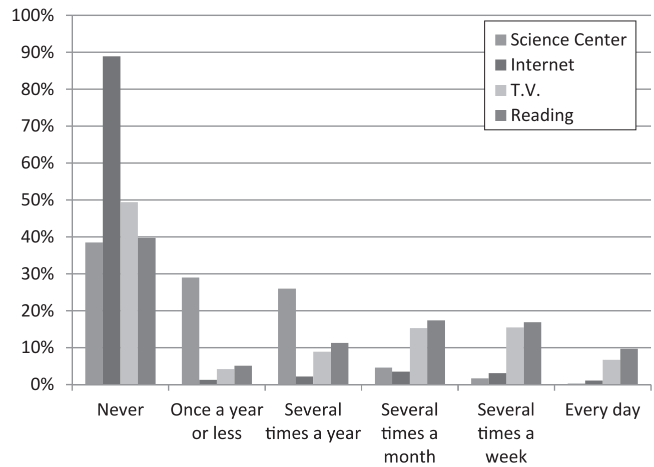

FIGURE 2 Younger percent use of science rich media [Color figure can be viewed at wileyonlinelibrary.com]

Note. Internet "Never" frequency is an aggregation of "Never" and "Never/Not Yet Invented" responses

TABLE 4 Rank-order correlations between current use and current experience variables

Variable	*1.*	*2.*	*3.*	*4.*	*5.*	*6.*	*7.*
1. U-Center							
2. U-Reading	.28***						
3. U-T.V.	.25***	.28***					
4. U-Internet	.39***	.45***	.34***				
5. E-Center	.26***	.19***	.18***	.20***			
6. E-Reading	.14***	.15***	.12***	.20***	.55***		
7. E-T.V.	.18***	.24***	.15***	.23***	.59***	.72***	
8. E-Internet	.16***	.21***	.13***	.23***	.61***	.67***	.68***

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

who used one form of science-related media were also likely to utilize other forms of science-related media.

4.2 | Relationship between independent and dependent measures

Table 5 summarizes the correlations between the eight measures of science experience and adult current science interest values and cognitive predispositions, all of which were significant and positive. These correlations ranged in strength from .28 for adults' recalled perceptions of their early adolescent experiences with science in school to .49 for adults' perceptions of their current science experiences using the internet. Current experiences were consistently more highly correlated with current science interest values and predispositions than were recalled past experiences.

A linear multiple regression model was used for determining the contributions of self-reported quality of adults' current experiences visiting science centers, watching science-related television, reading science-related books and magazines, and using the internet for science-related purposes on respondent current values and cognitive dispositional interest in science; age, race/ethnicity, and gender were included in the model as control variables (Table 6). A significant regression equation was found ($F(10, 1040) = 35.668$, $p < .001$), with an R^2 of .255. Current science center visitation, reading, and internet science usage experiences were found to be significant predictors of science value and cognitive predispositional interest, controlling for all other predictor variables; the relation with science-related television watching was not significant. Among the control variables, Hispanic/Latino/a and African American race/ethnicities were found to be significantly related to current science value and cognitive predispositional interest, while Asian and other non-white race/ethnicities, age, and gender were not significantly related to current adult science interest values and predispositions. Having an income above the median had a very small and positive association with science interest values and predispositions.

A second linear multiple regression model was used for determining the contributions of self-reported quality of adults' retrospective experiences as early adolescents when visiting science centers, watching science-related television, reading science-related books and magazines, and participating in

TABLE 5 Weighted means, standard deviations, and rank-order correlations between study experience and interest variables

Variable	*M*	*SD*	*1.*	*2.*	*3.*	*4.*	*5.*	*6.*	*7.*	*8.*	*9.*
1. C-Center	3.15	.41	(.90)								
2. C-Reading	3.08	.42	.55***	(.94)							
3. C-T.V.	3.09	.41	.59***	.72***	(.94)						
4. C-Internet	3.12	.41	.61***	.67***	.68***	(.94)					
5. Y-Center	3.10	.45	.52***	.54***	.57***	.54***	(.96)				
6. Y-Reading	3.02	.46	.50***	.56***	.58***	.53***	.71***	(.96)			
7. Y-T.V.	3.08	.45	.53***	.59***	.60***	.55***	.72***	.76***	(.96)		
8. Y-School	2.93	.50	.43***	.49***	.50***	.45***	.70***	.66***	.62***	(.96)	
9. Interest	3.33	.45	.44***	.46***	.47***	.49***	.36***	.33***	.38***	.28***	(.88)

Note. Values on the diagonal represent Cronbach's alpha for the measures. C-Center = Current Science Center Science Experiences. C-Reading = Current Reading Science Experiences. C-T.V. = Current T.V. Science Experiences. C-Internet = Current Internet Science Experiences. Y-Center = Younger Science Center Science Experiences. Y-Reading = Younger Reading Science Experiences. Y-T.V. = Younger Reading Science Experiences. Y-School = Younger School Science Experiences. Interest = Science Interest.
$^*p < .05$, $^{**}p < .01$, $^{***}p < .001$.

science-related schools classes on respondent current value and cognitive predispositional interest in science; age, race/ethnicity, and gender were again included in the model as control variables (Table 7). A significant regression equation was found ($F(10, 779) = 18.236$, $p < .001$), with an R^2 of .190. Recalled

TABLE 6 Multiple regression of current science experiences predicting science interest

Predictor variables	**B**	**95% CI**
Science centers	.134***	[.063, .204]
Reading	.136**	[.053, .220]
T.V.	.062	[–.026, .150]
Internet	.202***	[.114, .290]
Control Variables	**B**	**95% CI**
Age	–.001	[–.003, .000]
Ethnicity (Hispanic)	–.089**	[–.146, –.031]
Ethnicity (African American)	–.070	[–.144, .004]
Ethnicity (Asian)	.005	[–.083, .092]
Ethnicity (Other Non-White)	.014	[–.125, .153]
Gender (Male)	.037	[–.011, .084]
Income (Above)	.083**	[.034, .132]
R^2	.256	
F	28.432***	
N	922	

Note. Ethnicity reference variable is White. Gender reference variable is Female. Income reference variable is Below.
$p < .05$, $^{**}p < .01$, $^{***}p < .001$.

TABLE 7 Weighted multiple regression of younger science experiences predicting science interest

Predictor Variables	B	95% CI
Science Centers	.168**	[.054, .281]
Reading	.077	[–.042, .196]
T.V.	.155**	[.039, .271]
School	–.068	[–.156, .020]
Control Variables	**B**	**95% CI**
Age	–.001	[–.003, .001]
Ethnicity (Hispanic)	–.193***	[–.268, –.117]
Ethnicity (African American)	–.165***	[–.254, –.077]
Ethnicity (Asian)	.011	[–.108, .131]
Ethnicity (Other Non-White)	–.080	[–.252, .091]
Gender (Male)	.021	[–.038, .081]
Income (Above)	.075*	[.015, .134]
R^2	.181	
F	13.702***	
N	692	

Note. Ethnicity reference variable is White. Gender reference variable is Female. Income reference variable is Below.
*$p < .05$, **$p < .01$, ***$p < .001$.

early adolescent science center visit and television viewing science experiences were found to be significant predictors of science interest values and predispositions; reading science-related books and magazines (not for school) and school science classroom experiences were not significant, controlling for all other predictor variables. Among the control variables, as above, Hispanic/Latino/a and African American race/ethnicities were found to significantly relate to science interest values and predispositions, while Asian and other non-white race/ethnicities, age, and gender were not significantly related to current adult science interest values and predispositions. Also as above, having an income above the median had a very small and positive association with science interest values and predispositions.

5 | DISCUSSION

Data from this study show that overall, a broad and representative cross-section of adults living in three American cities engage in a wide array of science-related activities and that large majorities do so frequently; with likely much of the variability in use between media sources due to the nature and accessibility of the resource, for example, for most people the Internet and television are more readily accessible resources in space, time, and money than are science centers. Nearly two-thirds of all Americans self-report currently participating in some kind of science-related activity every week and nearly half do so daily. Only about one in five Americans indicated that they never do any of the various science-related activities included in the study. Consistent with other sources (e.g., Horrigan, 2006; National Science Board, 2016), the internet and science-related television were the most frequently used resources, and science centers the least utilized, although even the latter were claimed to have been visited by roughly two-thirds of the public at least once per year. Individuals also indicated that they utilized a wide array of science-related resources in their youth, although they reported participating at considerably lower rates during their middle school years than what they do currently. Roughly half of all adults indicated that they watched science related television as an early adolescent and slightly less than half reporting some use of science centers and reading science-related books not for school. Use of the Internet during current adults' youth was limited, presumably because of its relatively recent emergence as a viable option.

Also consistent with previous data (Falk & Needham, 2013; National Science Board, 2016), individuals who utilized any one of these various science rich media were also likely to have utilized other science rich media as well. In addition, the 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 free-choice learning situations (Falk & Dierking, 2014; Renninger & Hidi, 2016). That said, it is a variable that needs to be accounted for and understood since arguably creating experiences that motivate individuals to self-select to be engaged with future science experiences is the whole point of science education.

Following from this argument, one of the key findings from this study was that that having frequent, positive science-related experiences in- and out-of-school, both early and later in life, correlated with having a strong value and cognitive predispositional interest in science as an adult. Although a diversity of positive science-related experiences correlated with current adult value and cognitive predispositional interest in science, only some of these experiences were uniquely predictive of adult interest after controlling for other variables in the models. Specifically, positive current adult free-choice learning experiences, such as visiting a science center, reading books and magazines about science, and using the internet to learn more about science, significantly predicted current adult science interest values and predispositions, while positive experiences watching science related television or other types of broadcast media did not. Similarly, positive experiences visiting a science center and watching science-related television as an early adolescent significantly and uniquely predicted adult current science interest values and predispositions, early adolescent positive experiences reading science-related books and science classroom experiences did not.

One conclusion suggested by the data is that all these media are important, but that some, for example, science-related television, are more important early in life and others, for example, books and magazines, are more important later in life. The interesting exception to this general trend was the significant contribution to adult science interest values and predispositions made by positive experiences visiting a science center both during early adolescence and adulthood. Although fewer adults visited science centers as adults than participated in other types of science-related activities such as watching science television or reading science-related books and magazines, the impact of a positive science visit on science interest values and predispositions was greater. Given the relatively recent emergence of the internet as a media for supporting science interest and learning, the current study could not determine whether or not early use would or would not have contributed to long-term science interest values and predispositions; certainly positive current use among adults did significantly contribute to adults' current science interest values and predispositions.

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 media for promoting the public's long-term interest in science—in particular the role of formal education/schooling. Results showed that although many individuals indicated having positive classroom science experiences, these school-based experiences did not significantly contribute to most adults' long-term science interest values and predispositions after controlling for other factors. Comparably, reading of science-related books and magazines outside school was an overall positive experience for most youth, but insufficiently so to affect long-term science interest values and predispositions. Whereas out-of-school experiences during youth, such as visiting a science center or watching science-related television, were significant predictors of adult science interest values and predispositions. These results also highlight the importance of continued participation in science rich experiences—the greater the long-term involvement, the greater the interest (or perhaps the other way around).

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 some classroom teachers certainly work hard at making science fun and exciting and emphasize 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 cognitive outcomes. This may apply to the role of reading, as well. For those working within a school context, these findings are clearly disappointing since as discussed earlier, research continues to show that interest is a central motivator of human behavior (Hidi & Renninger, 2006; Renninger, Nieswandt, & Hidi, 2015; Silvia, 2006) and a significant predictor of the career and life choices made by youth and adults (Eccles, 2005; Jones, Corin, Andre, Childers, & Stevens, 2017; Maltese & Tai, 2010; Tai et al., 2006; Wigfield & Eccles, 2000); plus we can assume that all science teachers seek to inspire and motivate their students to become lifelong science learners.

The findings from this study do not allow direct inferences about exactly how these various experiences influence or interact with current adult science interest values and predispositions, 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 values and predispositions, or is the reverse true? Do individuals with positive science center or television experiences during early adolescence self-select to further engage in science-related activities, which results in long-term science interest values and predispositions? Do out-of-school science-related activities pre-dispose individuals to be more engaged with school science, which in turn results in adults more inclined to participate in free-choice science learning experiences, or does 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., Falk, Storksdieck, & Dierking, 2007; National Research Council, 2015). As with any complex system, these relationships likely exist and played some kind of mutually reinforcing influence. Regardless of these complexities, there is no escaping the fact that it appears that free-choice/informal experiences, both in early adolescence and adulthood emerged as the most significant predictors of adult science interest values and predispositions.

The findings also appear to support the contention that social inequalities continue to exist in the United States. The data in particular suggest a small but significant influence of race/ethnicity and income on science interest values and predispositions. Given that White respondents and those with higher incomes were more likely to report higher value and cognitive predispositional interest in science than did Hispanic/Latino/a and Black respondents and those with lower incomes, particular attention and concerted effort are needed to ensure that future formal and informal science education efforts actively promote equitable opportunity for all individuals. Contrary to a number of other reported studies (e.g., Alexander et al., 2012; Babarović, Gracin, Burušić, Dević, & Velić, 2016; Osborne et al., 2003; Staus et al., Submitted for Publication), there was no evidence that males self-reported higher value and cognitive predispositional interest in science than females. Similarly, age showed no evidence of influencing adult self-reported science interest values and predispositions. This finding too deviates from some earlier research suggesting an age-related bias in adult science interest values and predispositions (e.g., Miller, 2010).

5.1 | Limitations

Clearly, these results cannot be taken as the definitive case for what factors contribute to adult value and cognitive predispositional interest in science 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 the Methods, a number of studies from various disciplines have established that self-report data, although not perfect are actually reasonable surrogates for more direct measures, especially when using survey data (Chan, 2009; Gonyea, 2005; Vaske, 2008). Similar challenges arise due to the use of retrospective data as a surrogate for actual early adolescent experiences, although as above, several investigators have found such approaches yield quite acceptable results (Lam & Bengo, 2003; Mueller & Gaus, 2015; Schwarz, 2007).

The finding that formal schooling was not a unique predictor of adult value and cognitive dispositional science interest can be argued to have arisen from the fact that results were generic to all school experiences and it is well known that the quality of school science varies considerably as a function of district and teacher quality. This criticism could be countered, however, by pointing out that the school classroom measure in this study was exactly comparable to all of the other measures, as all variables were course grained, summative indicators of quality rather than fine grained measures of specific quality. In other words, science center exhibitions and programs as well as the print, broadcast and digital media all also vary 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, e.g., individual science center experiences see Falk & Dierking, 2014). It is possible although, that greater variability exists within the classroom realm. If so, that could 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, for example, in 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 between all these experiences. For example, many science centers experiences now incorporate formal presentations, broadcast media, and Internet experiences, while many classrooms now include a range of traditionally informal education delivery vehicles. Also, school-aged children are regularly assigned science-related books to read and media to watch. And adults typically utilize any number of media in pursuit of their interests, and may not always reliably discriminate between them. 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 two aspects of science education: interest and experience. We believe that the dimensions of interest and experience that we selected are robust and that heightened science interest values and cognitive predispositions as well as positive science experiences are indisputably reasonable and important science education goals. We do not argue that they are the only or even necessarily the most science education goals. Thus, whether or not the specific dimensions of interest and 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 with our current data set. Based on the literature cited above, it is presumed that such correlations were highly likely, but fully answering that question remains something that will need to be explored in subsequent research.

Finally, there is an issue of generalizability of findings. Although data was collected in only three localities—Los Angeles, Phoenix, and Philadelphia—and we are quite confident that findings reliably reflect these areas of the United States, we cannot be equally confident that the findings fully generalize to other parts of the United States, 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 representation of all individuals and socioeconomic categories within those locales, there is no obvious reason to assume that the results are not more broadly generalizable. 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 adult interest in science generally and science interest values and predispositions 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 the 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. Although findings from this or any study are certainly not a sufficient basis for changing policy, it is hoped that these results coupled with findings from a growing body of other research might be sufficient impetus to justify serious debate about the wisdom of current science education policies, including and particularly the current privileging of formal schooling over other forms of science education when considering how best to advance the public's knowledge, participation, and interest in science.

6 | CONCLUSIONS

This study highlights the complex and synergistic nature of the science learning ecosystem; an ecosystem that we only somewhat understand. More research is needed on the cumulative and complementary influences of all science resources across an individual's lifetime and real progress in public education will require such an ecosystem-wide approach. However, the primary take-home message of this article is that the data broadly support the contention made in the introduction that public science education is supported not by a single major resource (e.g., formal schooling), but rather by a vast array of resources that includes schools and free-choice learning experiences, both in childhood and adulthood. Data presented here suggest that all of these sources contribute to adults' science interest values and cognitive predispositions with a range of different modalities of out-of-school experiences being particularly important. These findings, along with evidence that free-choice experiences appear to contribute more to adult science literacy than schooling (Falk & Needham, 2013), provide additional support for the argument that the overwhelming tilt in current science education policy and financial support toward school-based science at the expense of out-of-school science is potentially misplaced. At a minimum the results argue for the need to give greater attention and potentially greater support to free-choice learning.

The results also reinforce societal concerns about equity and access. Although it has long been argued that schools are the great levelers in terms of social inequalities, the fact that the most important contributors to adult science interest values and predispositions were non-school experiences raises important policy issues. Given that there is a world-wide concern for increasing the long-term public interest and engagement in science by all citizens, independent of means and background, these and other recent studies cited about (above?) suggest that the goal of enhancing science equity might best be achieved through increased public support for free-choice learning. Given the evidence that only two types of youth science learning experiences—visiting a science center and viewing science-related television—were uniquely predictive of long-term adult science interest values and predispositions, one might conclude from this study that the most cost-effective approach to broadening access to science for minorities and low income individuals would be to invest in these two specific types of experiences. A more conservative conclusion would be that at a minimum, results from the current study suggests that school-based solutions are certainly not the only nor even arguably the best vehicle for enhancing the public's lifelong interest in science

Although the data tilt in the direction of free-choice learning experiences, in general it also reinforces the synergistic and cumulative nature of science interest development and learning; individuals having positive science-related experiences both in youth and adulthood are more likely to persist in pursuing future science-related experiences. 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. A large majority of Americans engage in some kind of science-related experience throughout their lives and to the degree these experiences are positive, they appear to support strong science interest. Thus, it appears that a sound science education policy would want to support not a single type of science resource but multiple sources. Over an individual's lifetime, quality classroom experiences, science television, science books and magazines, the internet and particularly science centers and museums all individually and collectively contribute to the public's science interest, and by extension, their knowledge and general literacy.

There has been increasing rhetorical acknowledgement amongst policy makers about the importance of this kind of broad, multisector strategy (e.g., National Research Council, 2015; President's Council of Advisors on Science and Technology, 2010; Traphagen & Traill, 2014), 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, and there appear to be no significant proposals to distribute more equitably any resources related to support of science education beyond schools; in fact the policies of the current U. S. government are poised to significantly reverse 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 policy for addressing the need for a scientifically interested, engaged, and literate society remain mired in the past, research such as this suggests that the solution to these challenges will require an openness to embracing the changing realities of when and where the public's science education occurs.

ENDNOTE

[1] The variables that it is assumed to influence an outcome.

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SUPPORTING INFORMATION

Additional Supporting Information may be found online in the supporting information tab for this article.

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