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Education

# Correlating Science Center Use With Adult Science Literacy: An International, Cross-Institutional Study

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**ABSTRACT:** This international investigation was designed to determine if, and under what circumstances experiences at science centers, significantly correlated with a range of adult general public science and technology literacy measures. Given the complex and cumulative nature of science and technology learning, and the highly variable and free-choice nature of science center experiences, an epidemiological research approach was used. Quantitative surveys were administered to 6,089 adults living in 17 communities located in 13 countries; all with active science centers. Data collection and analysis protocols ensured a representative sampling based on age, education, and income from each of the 17 participating communities. Results showed that individuals who used science centers had significantly higher understanding, interest and curiosity, participation in free-choice leisure activities, and identity relative to science and technology than did individuals who did not visit; even when potential self-selection biases such as income, education level, and prior interest were taken into consideration. These findings significantly strengthen the argument that the presence of one or more healthy and active science centers within a community, region, or country represents a vital investment for fostering and maintaining a scientifically and technologically informed, engaged, and literate public. *Sci Ed* **100:**849–876, 2016

## INTRODUCTION

A range of studies have documented that individuals pursue lifelong science interest and understanding in and out of school using a variety of community resources (e.g., libraries, science centers, aquariums and zoos, broadcast and print media and the Internet) (Barron, 2006; Bevan et al., 2010; Falk & Dierking, 2010; Lemke, Lecusay, Cole, & Michalchik, 2012; National Research Council [NRC], 2009; Organization for Economic Cooperation and Development [OECD], 2012; Russell, Knutsen, & Crowley, 2013; Stocklmayer, Rennie, & Gilbert, 2010). For example, every year hundreds of millions of adults of all backgrounds visit science centers across Europe, Asia, North America, Latin America, Australia, and other regions. Science-center programming is diverse, offering visitors of all ages, both short- and longer-term experiences and programs in science. The science-center field has long argued that these institutions make science accessible to a broad range of people in innovative, engaging, and enjoyable ways, thus playing a critical role in supporting the science learning of the public. But comprehensive data supporting this claim are limited. Although evidence showing the contribution of science centers to public science learning certainly exists (e.g., ASDC (as Ecsite-uk), 2008; ASTC, n.d.; Falk, Brooks, & Amin, 2001; Falk & Needham, 2011; Falk & Storksdieck, 2005, 2010; NRC, 2009; Salmi, 2002), most investigations have involved single sites and self-selected populations under conditions of limited generalizability. Robust evidence is sparse, and little comprehensive international data exist.

There are many ways to define the "contributions" science-center experiences might make to the science and technology literacy of adults in the public. Most experts agree (e.g., Bauer, 2009; Layton, Davey, & Jenkins, 1986; Miller, 2007) that a measure of successful science and technology education impact for adults is their meaningful participation in science and technology-related activities in society, again either through vocations or avocations. However, traditionally the default measure of success has been how much science centers contribute to adults' civic science and technology literacy as measured by selected close-ended science and technology knowledge questions (e.g., Miller, 2002, 2007). Although science-center contributions can be measured in this manner, this may not be the best way to document the contribution of science centers to public science literacy, nor the outcome on which to focus. For example, the U.S. NRC (2012) argued strongly that measures of knowledge, particularly measures based on what everyone "needs to know," are unduly narrow and restrictive, even when measuring the impacts of school experiences (see also, Falk, Storksdieck, & Dierking, 2007; Wagner, 2007). Osborne and Dillon (2008) called for a new vision of science education that not only tries to support what learners know and how they know it, but also the kinds of careers and avocations that science and technology educational experiences afford and why these careers and avocations are personally fulfilling, worthwhile, and rewarding. A committee of experts assembled by the U.S. NRC (2009) identified six interwoven strands of outcomes supported by informal venues like science centers, including supporting curiosity and other scientific habits of mind, as well as identity building as it relates to science. And, as Falk and Storksdieck (2005, 2010) discovered when attempting to understand visitor experiences at the California Science Center in the United States, multiple measures were required to sufficiently capture the full extent, breadth, and depth of changes in visitors' conceptual understanding of a single science concept. Collectively, these findings suggest the need for a broad set of metrics to capture the ways that science-center experiences may contribute to public understanding and appreciation of science.

Accordingly, the research undertaken in this study with 17 institutions in 13 countries was designed to determine whether, how, and under what circumstances experiences at science centers may be associated with a range of possible science and technology outcomes for the adult general public. Another aspect of the study investigated these same relationships for 14- and 15-year old youth; these findings will be reported in a subsequent paper. Working collaboratively with research partners, the team identified a set of dependent variables of interest and sought to determine empirically whether there was evidence that experiences at science centers correlated with the adult publics':

- knowledge and understanding of science and technology,
- participation in free-choice science and technology-related leisure experiences (e.g., reading science and technology–related books and articles or watching science and technology-related media),
- interest in science and technology,
- creativity and problem solving,
- participation in science and technology–related avocations and hobbies,
- participation in science and technology–related vocations, and
- identifying as a science and technology–confident individual.

## LITERATURE REVIEW

### Understanding the Contribution of Science-Center Experiences to Adult Learning

Learning in general, and science learning in particular, is rarely, if ever, immediate. Most individuals develop interest, understanding, and an identity related to science through an accumulation of experiences from different sources at different times (e.g., Barron, 2006; Falk & Dierking, 2010; Ito et al., 2013; Lemke et al., 2012; OECD, 2012; NRC, 2009; Renninger & Riley, 2013; Stocklmayer et al., 2010). For instance, an adult science and technology learner experiences a range of different science-and-technology learning opportunities in a variety of contexts including watching television; reading books, magazines, or the newspaper; visiting a local science center, zoo, or aquarium; solving every-day problems; talking with friends or relatives; and, increasingly, from forays on the internet. From the perspective of the learner, the context in which he or she encounters science and technology may change moment to moment, but all of these experiences seamlessly contribute to stimulating and sustaining interests and motivation in a topic (Hidi & Renninger, 2006).

In other words, it is extremely difficult in any educational experience, but particularly within an adult science-center context, to completely define and, in particular, delimit either the educational "interventions," the criterion variables, or the possible "outcomes" (the dependent variables) sufficiently to ascribe causality. In the case of a science-center visit, all visitors enter the experience with partially to well-formed interests, knowledge, opinions, and motivations that directly influence learning (Falk & Dierking, 2000, 2014; NRC, 2009), and, as shown from research across several contexts, learners build their understanding and appreciation for science over time utilizing multiple sources (e.g., Barron, 2006; Bronfenbrenner, 1977; Falk & Needham, 2013; Ito et al., 2013). Thus, it is imprudent to assume that any one individual or group of individuals has a singular, clear, or consistent "beginning state." One also cannot presume any degree of homogeneity with regard to science-center audiences; unlike in schooling, one cannot say, "Well, they are all in third grade, so they should know this." The reality is that these simplified views of learning rarely, if ever, occur either in or out of school (NRC, 2000).

Additional challenges in measurement are exacerbated by several interrelated factors, all related to choice and some measure of self-selection bias. First, all learners enter an institution like a science center with different identity-related motivations that directly influence what they choose to do and why they choose to learn (Falk, 2009; Falk & Storksdieck, 2010). Second, because of the "free-choice" nature of science centers, most visitors, but particularly adult visitors, choose whether to visit or not (Falk, 2001). Furthermore, learners themselves almost always exercise considerable choice in determining what topics or exhibitions to pay attention to and what to learn predicated on what they think is personally important and interesting (Falk & Dierking, 2014). Clearly, the free-choice nature of science-center learning experiences complicates any efforts to control all variables and entering predispositions. Any effort to "randomly" assign a science-center experience to one group, but not to another, runs the risk of not accurately reflecting the true nature of these experiences. Consequently, results of such research designs open up the possibility of creating a raft of logistical, ecological-validity, and ethical issues that potentially undermine the credibility of findings.

Although considered the "gold standard" by many researchers (Institute of Educational Sciences & National Science Foundation, 2013), more than two decades of research has shown that standard randomized-control-treatment (RCT) research designs using traditional pre-and posttest assessments do not always result in the kinds of definitive results typically claimed for such methods (Christ, 2014; Clay, 2010; Williams, 2014) or just may not be possible or ethical to conduct. For example, RCTs were not used to establish the link between smoking and lung cancer since it would have required unethical procedures over a significant period of time. Instead, researchers utilized epidemiological research approaches to establish a significant relationship between smoking and lung cancer that did not require using an RCT (Hill, 1965).

There are also situations in which conducting an RCT study distorts important aspects of what is being studied; this is definitely the case when trying to understand the impacts of visiting settings, such as science centers. The free-choice nature of first choosing whether or not to visit such a setting and then which elements within the science center to attend to, are arguably key to making these effective learning institutions (Falk, 2001; NRC, 2009); the free-choice nature of these experiences are not confounding "noise," that needs to be controlled for or eliminated to support more accurate measurement. To attempt to measure learning by removing such an essential aspect of the process is not appropriate. This is particularly true of studies attempting to understand the long-term impacts of these experiences (Falk & Dierking, 2000; Falk, Scott, Dierking, Rennie, & Cohen Jones, 2004; McCreedy & Dierking, 2013). As the smoking studies referenced to above attest, RCT studies are not the only research methods that allow for the identification of critical relationships (Williams, 2014).

### Measuring Relationships/Contributions

In research contexts in which complexity, interconnections between criterion and dependent variables, and the cumulative nature of the phenomenon being studied present methodological challenges, researchers have advocated for "epidemiological" research approaches (e.g., Buck, Llopis, Nájera, & Terris, 1998; Checkoway, Pearce, & Kriebel, 2004; McNeil, 1996; Morabia, 2004; Rothman, 2002). Epidemiology is the science that studies the incidence, distribution, patterns, sources, effects, and control of health and disease conditions in defined populations. It is the cornerstone of public health and informs policy decisions and evidence-based practice by identifying risk factors for disease and targets for preventive healthcare (Blankenberg et al., 2003; Morabia, 2004; Porta,2014).

Epidemiologists long ago determined that there were far too many interconnected factors that interact over time to generate valid predictive models of human health and well being using exclusively RCT methods, even for something as seemingly concrete as a disease such as tuberculosis or the flu. For example, factors such as the initial state of physical health, exposure details, genetics, stress levels, and other mental characteristics at the time of exposure can significantly influence whether someone gets a disease and if they recover (Buck et al., 1998). The presence of these interconnected and correlated criterion variables typically invalidates the assumptions required to establish clearly definable "treatment" and "control" groups. And this is just the case for models related to "simple" communicable diseases. More complicated models have been required to study diseases such as coronary heart disease and cancer given that they have many more complicating, interacting, and often congenital factors (e.g., Erkkilä et al., 2008; Jaquish, 2007; Wahrendorf, 1996).

To address the challenges involved in fully isolating singular "cause-and-effect" variables, epidemiological research designs have been employed. These approaches utilize correlational as well as traditional parametric statistics to parse relationships and effects (Blankenberg et al., 2003; Checkoway et al., 2004; McNeil, 1996; Rothman, 2002; Sullivan & Knutson, 2000). These approaches allow investigators to say with specific statistical certainty that certain vectors do or do not influence a disease. For example, this approach was used to successfully understand how smoking, exercise, diet, and genetics collectively and synergistically interacted to contribute to heart disease (Jaquish, 2007). None of these factors alone accounted for why someone had a heart attack and none could be validly isolated in ways required in a typical, randomized pre-/posttest design. A major use of epidemiological approaches has been to analyze associations or hypothesized relationships between known factors. Often epidemiological research combines large data sets across populations of varying demographic characteristics with the singular goal of revealing relationships between various "dosages" (e.g., none, low, or high) of "exposure" (e.g., alcohol use or environmental contamination) to known "consequences" (e.g., incidence of cancer or reduced lifespan). In such studies, the focus is on population-level effects, rather than individual effects, that is, distribution and patterns across varied demographics, rather than determining differences across and between individuals.

## METHODS

Given the complex and cumulative nature of science-and-technology learning and the highly variable and free-choice nature of science-center experiences, an epidemiological research approach is appropriate. This study was designed to determine whether there was evidence that "exposure" to a science-center experience that could include visiting exhibitions, participating in an in-depth program and/or watching a science demonstration, to name a few possible experiences, with a range of "dosages," from an hour or two to continuously for many hours, resulted in a variety of science literacy "consequences," defined for the purposes of this study as: (1) knowledge and understanding of science and technology, (2) participation in free-choice science and technology–related leisure experiences (e.g., reading science and technology–related books and articles or watching science and technology–related media) ,(3) interest in science and technology ,(4) creativity and problem solving, (5) participation in science and technology–related avocations and hobbies, (6) participation in science and technology–related vocations, and (7) identifying as a science and technology–confident individual.

## Research Design

Following an epidemiological research framework, this investigation analyzed the effects of science-center experiences by determining relationships between specific criterion variables related to the science-center experience and a range of long-term dependent variables focusing on desired outcomes such as public understanding, attitudes, and behaviors associated with science and technology. As is standard in such research designs (e.g., Morabia, 2004), redundancy and independent mechanisms for computing reliability were built into the design, particularly given that all of the data relied on self-reports. It is also important to note that data were collected *outside* the science center, thus not all research participants were science-center users.

The research involved a large-scale, multinational survey of adults (18 years of age and above) from 17 communities distributed across 13 countries. Each community possessed an active science center: Heureka (Finland), Universeum (Sweden), Swedish Museum of Technology (Sweden), VilVite (Norway), Technopolis, the Flemish Science Center (Belgium), Center for Life (UK), Ciencia Viva (Portugal), Science Center Singapore (Singapore), National Museum of Natural Science (Taiwan), Patricia and Phillip Frost Museum of Science (United States),[1] Questacon (Australia), MIDE, Museo Interactivo de Economía (Mexico), Maloka Science Center (Colombia), Science North (Canada), Ontario Science Center (Canada), Canada Technology Museums Corporation (Canada), and TELUS Spark (Canada). Selection of these 17 communities was not based upon a random selection process, rather convenience sampling was used since support for this research was generated internally by participating institutions. As a consequence, the participating communities were not evenly distributed globally nor were they selected to be specifically representative of either the global distribution of science centers or the distribution of population globally. Despite this nonrandomized selection process, a representative sample of primarily urban but also rural communities across five continents participated in the study, including communities located in both developed and developing countries; within each community, individuals representative of all socioeconomic circumstances were included proportional to their presence in that community. Also included in the study was a representative sampling of individuals of diverse race/ethnicities residing within these 17 communities. However, because of the challenges of distinguishing and accurately accommodating these differences across the 17 sites, except in the most reductive stereotypical manner, e.g., majority/minority population, no specific effort was made to account for this variable. The science centers in the study also were representative in terms of their size, geographic reach (some are the only science center or museum in the country or region, others are located in

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[1] Formerly the Miami Science Museum.

cities with many competing cultural institutions/organizations), and relationship between the organization and its publics (cf. Feinstein & Meshoulam, 2014).

## Instrument Development

Project researchers, working in collaboration with cooperating science centers, developed and pilot-tested the instrument. Items were carefully selected and as many as possible were drawn from existing instruments with an effort to identify items from highly reliable and valid international questionnaires such as Program for International Student Assessment (PISA; OECD, 2011) and Relevance of Science Education (ROSE; Schreiner & Sjøberg, 2004). Given that this was a paper-and-pencil instrument, we assumed only literate individuals would participate in the study. It was piloted with 14–15-year olds for comprehension of language and the validity of science concepts and processes included; the same instrument that worked for youth was used with adults so the instrument's reading and comprehension levels were at approximately those of a 14-year old or lower.

The key-dependent measures in the study were a series of questions related to each of the seven outcome variables: (1) knowledge and understanding of science and technology, (2) participation in free-choice science and technology–related leisure experiences (e.g., reading science and technology–related books and articles or watching science and technology–related media), (3) interest in science and technology, (4) creativity and problem solving, (5) participation in science and technology–related avocations and hobbies, (6) participation in science and technology–related vocations, and (7) identity as a science and technology–confident individual. With the exception of vocations, multiple items were developed, piloted, and included for each measure. For all questions, participants were encouraged to think about science and technology not only within canonical topic areas such as physics, chemistry, and biology, but also from the perspective of everyday science activities such as automechanics, cooking, and the science of pet or houseplant care.

The key criterion measures whether or not individuals had visited the science center in their community, and if so, the nature of the experience. For those who had visited the science center, important variables were how recently the science center had been visited and the frequency of visits (overall and within the previous 12 months). In addition, an effort was made to determine the kind of experience an individual had when visiting the science center, including a wide range of possible experiences from intensive classes to passive viewing of films or exhibitions. Also queried was the extent or "dosage" of the visit, from 1 hour or two to many hours continuously. A final section asked respondents to describe the free-choice science and technology–related experiences they had as a child of 12 years old or younger, as well as report on basic demographic data such as gender, age, income (above or below local median family income), and education level.

Each institution's questionnaire was modified as necessary by collaborating institutions to ensure cultural relevance and appropriateness and then was translated into the major local languages/dialects. Cultural relevance was particularly important for the examples given and items that designated where a person lived in the community, national annual median household income (which we determined using the most recent census data available for each community), and the name of the science-center people were to indicate whether they had visited or not. Each institution also provided digital image(s) of people engaged with experiences at their institution that were used to personalize the front page of the questionnaire.[2]

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[2] Each institution was allowed to add 1–3 items of specific interest to them (either institution-specific or shared among a few institutions, e.g., the four Canadian institutions included items specific to Canada).

## Sample

Unlike many science-center studies, data for this study were not collected inside the institution, but outside the institution within the community in which each institution resided. Data were collected in places in which people representative of the community, not necessarily museum users would be found, in workplaces, public parks, and libraries. The goal was to build a sample for each institution that was as representative as possible of the full diversity of the institution's community; one that would include both individuals who had visited the science center, as well those who had not. Although the differing financial and cultural circumstances of the collaborating 17 science centers prevented use of a single, random sampling data collection procedure, census data were used to identify appropriate characteristics for each community sample, and all data were collected in ways that, as close as possible, approximated a random, yet representative sample of the adults living within each community area.[3] Each of the resulting 17 sampling protocols was designed to build a representative sample that included individuals reflective of the current distributions of individuals living within that community as determined by the most recent local census data on age, income, educational level, and geographical distribution. In deference to financial constraints, it was decided that the minimum target sample size would be 300 adults per institution, based on achieving the commonly accepted standard for representative sampling of a population at about ±5% margin of error at the 95% confidence level (i.e., confident in sampling 19 times out of 20), assuming a 60/40% split in responses (cf. Dillman, 1978, 1991).

In an effort to ensure as much data comparability as possible, detailed data-collection and data-entry protocols were developed and in-depth training conducted for all staff and contractors (and/or volunteers) involved in data collection and entry through a series of specially developed training webinars. Two separate, 2-hour webinars were held, and each was scheduled at two different times of day to accommodate the various time zones of participants. The first training was targeted at the person at each institution who would serve as the project research coordinator. This session focused on an overview of the study, study preparation guidelines, and what one needed to know to successfully recruit and manage data collectors and data-entry specialists with the appropriate skill sets.

The second webinar was targeted at those actually conducting data collection and entry or those who would be responsible for training these individuals. The first half of the webinar concentrated on data collection, providing specific details about planning for how each institution would identify their samples, schedule data collection, and assemble materials (e.g., questionnaires, clipboards, pencils, tables). Participants were also guided through the data-collection protocol, including how to systematically invite people to participate, tips for getting complete data, and how to manage data. The goal was for these procedures to be as uniform across all 17 communities as possible. The second portion of the training presented a sample form for data entry created by the research team, discussed getting started, and provided concrete examples and troubleshooting tips to ensure accurate data input.

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[3] The financial resources available to each participating institution for this study varied. Some institutions were able to afford to subcontract with professional survey research companies and collected their data using traditional, randomized telephone survey procedures. Other institutions, either due to the nature of the communities served (e.g., inappropriateness of telephone surveys) or limited resources opted to collect data using in-person surveys where staff or volunteers contacting individuals in public settings as diverse as shopping malls and factories. As appropriate in the community, in-person surveys were conducted by individuals fluent in the local language/dialect of the sampled population. In all cases, the most recently available local census data were used to create sampling procedures that closely mirrored the local population.

All instrumentation for data collection, entry, and analysis; training; and data analysis was developed and implemented by the project research team with input from participating institutional partners. All data were collected and entered by institution staff, volunteers, or contractors. Individual questions were handled by the project research team. Data were collected from January through April of 2013. A standard Microsoft Excel database was developed by the research team, and all data were compiled and entered into this database by institution staff and then sent to the research team for analysis.

### Data Analysis

To ensure that all collected data were representative of the larger global population in the study, samples for each of the participating institutions were weighted appropriately and combined, that is, data from each of the communities were statistically weighted by age, sex, and population statistics utilizing census data from each of the 13 countries, a procedure used by the U.S. Census Bureau when it combines data across individual census blocks to discuss trends in the U.S. population (U.S. Census Bureau, 2014).

These aggregated data were analyzed using parametric and nonparametric univariate (e.g., frequencies, percentages) and bivariate (e.g., t tests, ANOVA, cross-tabulations, chi square) inferential statistics. If warranted, items were combined to create a set of dependent-measure scales related to science and technology: knowledge and understanding, interest and curiosity, engagement in free-choice leisure activities, avocation, vocation, and identity and confidence. Cronbach's alpha and exploratory factor analyses were used to assess the internal consistency across items, that is, how closely related a set of items were as a group and construct validity of the scales. Cronbach's alpha is considered a measure of scale reliability, though a "high" value for the alpha does not imply that the measure is unidimensional. Analysis was conducted in an iterative way, beginning with general comparisons and cross-tabulations, followed by more fine-grained analyses.

As with all analysis of this kind, inferential statistical tests (i.e., $p$ values) reveal relationships or differences among variables, but limited information about the strength or magnitude of these relationships or differences. Effect-size statistics measure the strength of these relationships and differences to help address this issue. Corresponding effect–size analyses include Cramer's $V$ for chi-square tests, eta for analysis of variance ($F$) tests, and point–biserial correlation ($r_{\text{pb}}$) for independent samples $t$ tests ($t$) (see Vaske, 2008 for a review). Using guidelines from Cohen (1988) and Vaske (2008), Cramer's $V$ values of 0.10, 0.30, and 0.50, and eta and point–biserial correlation values of .10, are considered "small," .24 "minimal," "medium" or "typical," and .37 or greater "large" or "substantial."

## RESULTS

A total of 6,089 adults across the 17 sites were sampled with most institutions exceeding the proscribed minimum sample size of 300 individuals; four institutions fell short of this number (Table 1). Fewer than half of all residents in the entire sample had visited the science center in their community (44%), with a slight majority indicating that they had never visited or were unsure of whether or not they had ever visited their local science center at some point in their life.

Although the subpopulation visiting science centers was broadly comparable in age and gender to the subpopulation of individuals who had not visited a science center, individuals who had visited the local science center differed on two key demographic variables. As shown in Table 2, individuals with higher levels of education and household incomes were significantly more likely to have visited their local science center than were individuals

**TABLE 1**
**Sample Sizes for Each Institution**

| Institution | Country | Adult |
|---|---|---|
| Canada Science & Technology Museum | Canada | 250 |
| Centre for Life | England, UK | 424 |
| Ciencia Viva | Portugal | 321 |
| Heureka | Finland | 379 |
| Maloka Science Center | Colombia | 406 |
| Patricia and Phillip Frost Museum of Science | USA | 256 |
| Museo Interactivo de Economia (MIDE) | Mexico | 384 |
| National Museum of Natural Science | Taiwan | 521 |
| Swedish National Museum of Science & Technology | Sweden | 287 |
| Ontario Science Center | Canada | 250 |
| Questacon National Science & Technology Centre | Australia | 381 |
| Science Centre Singapore | Singapore | 412 |
| Science North | Canada | 385 |
| Technopolis | Belgium | 388 |
| Telus Spark | Canada | 392 |
| Universeum | Sweden | 258 |
| VilVite – Bergen Science Centre | Norway | 395 |
| Total | | 6,089 |

**TABLE 2**
**Relationship Between Science Center Visitation and Demographics**[a]

| | Not Visited or Unsure (56%) | Visited (44%) | Total | $\chi^2$ or *t* Value | *p* Value | Effect Size ($\phi$, *V*, or $r_{\mathrm{pb}}$) |
|---|---|---|---|---|---|---|
| Sex | | | | 0.31 | .578 | .01 |
| Males | 49 | 50 | 49 | | | |
| Females | 51 | 50 | 51 | | | |
| Average age (mean years of age) | 45 | 46 | 45 | 0.15 | .881 | .01 |
| Highest education level | | | | 356.08 | <.001 | .25 |
| Less than high school/O levels | 15 | 6 | 11 | | | |
| High school or equivalent/A levels | 24 | 16 | 21 | | | |
| Vocational or technical certificate | 20 | 15 | 18 | | | |
| Associates, polytechnic, foundation degree | 14 | 18 | 16 | | | |
| Bachelor's degree | 19 | 28 | 23 | | | |
| Master's degree | 7 | 14 | 10 | | | |
| Doctoral or professional degree | 2 | 4 | 3 | | | |
| Household income | | | | 139.30 | <.001 | .16 |
| Below median | 62 | 46 | 54 | | | |
| Above median | 38 | 54 | 46 | | | |

[a] Cell entries are percent (%) unless specified as means/averages.

with less education and lower incomes. The effect sizes for these relationships were within the typical range.

## Dependent Measures

Tables 3–8 show internal consistencies for the multiple dependent measures to determine whether these multiple items could be reliably grouped into single composite indices. There was high internal consistency for composite measures of science and technology: knowledge and understanding (Table 3), interest and curiosity (Table 4), engagement in free-choice leisure activities (one item removed; few individuals indicated they engaged in this activity) (Table 5), avocation (Table 6), and identity and confidence (Table 8; given that this was framed around the science-center experience, data are only available for those who actually visited a science center). Given that there was only one vocational item, it represents its own individual concept. With the exception of creativity and problem solving (Table 7), all Cronbach alphas were high indicating that the items grouped well together and justified creating single indices for each.

As indicated above, the items measuring creativity and problem solving (Table 7) did not group together—at a minimum they were each measuring slightly different things, more likely they were not individually or collectively measuring the domain intended. Accordingly, an internally consistent creativity and problem solving scale could not be created. Of equal if not greater concern was the fact that the patterns of responses seen in these items raised questions about validity. Because of concerns about both validity and reliability, these items were excluded from further analyses.

## Contributions Made by Science-Center Visits

Tables 9–12 show what correlations, if any, visits to a science center had with adult understanding, interest and curiosity, engagement in science-and-technology avocations and hobbies, vocations, and confidence as a science and technology learner. Note that the dependent outcome measures are all the combined scales described above with the exception of the vocation measure, which was a single item.

Table 9 shows that the more frequently a person visited the science center, the stronger the correlation with most of the dependent measures. For knowledge and understanding, interest and curiosity, free-choice engagement, avocations and science confidence, the strongest correlations consistently were observed for those individuals who visited most frequently. However, there was no clear evidence that visiting a science center correlated with choosing a science and/or technology vocation, and significant correlations with science and technology–related avocations and hobbies were only seen after multiple visits. Overall, effect sizes were typical, except for vocations and avocations, which were minimal. For knowledge and understanding associations significantly increased between no visits and 1–2 visits, leveled off between 1–2 and 3–10 visits and then increased significantly again for 11+ visits. For free-choice engagement, associations significantly increased between no visits and 1–2 visits and 3–10 visits but then leveled off for 11+ visits. Interest and curiosity showed regular increases with increasing frequency.

As Table 10 shows, there was a consistent association between visiting and the other dependent variables, and generally the more recent a visit, the stronger the relationship. In general, even several year-old experiences (e.g., before 2010) seemed to correlate with the dependent measures, but the strongest correlations were seen among adults who had visited within the previous year. The degree to which the criterion variable of how recently a person visited influenced the six dependent variables varied. The effect sizes were typical.

**TABLE 3**
**Internal Consistency of Science Knowledge and Understanding Measures**

| | Mean | Standard Deviation | Item Total Correlation | Alpha if Item Deleted[c] |
|---|---|---|---|---|
| Compared to the average person, how much do you know about science or technology[a] | 2.24 | 0.92 | .53 | .92 |
| How much do you know about topics in physics[b] | 2.33 | 0.81 | .64 | .92 |
| How much do you know about topics in chemistry[b] | 2.44 | 0.83 | .55 | .92 |
| How much do you know about biology of plans or animals[b] | 2.55 | 0.80 | .46 | .92 |
| How much do you know about human biology[b] | 2.80 | 0.78 | .52 | .92 |
| How much do you know about space or astronomy[b] | 2.16 | 0.83 | .61 | .92 |
| How much do you know about geology[b] | 2.18 | 0.81 | .59 | .92 |
| How much do you know about topics in technology[b] | 2.35 | 0.94 | .46 | .92 |
| How much do you know about topics in math[b] | 2.52 | 0.87 | .48 | .92 |
| How much do you know about topics related to the environment[b] | 2.61 | 0.82 | .65 | .91 |
| How much do you know about ways that scientists design experiments[b] | 2.12 | 0.91 | .64 | .92 |
| How easily could you recognize a science or technology question in a newspaper report on a health issue[b] | 2.70 | 0.89 | .67 | .91 |
| How easily could you explain why earthquakes occur more frequently in some areas than others[b] | 2.61 | 0.95 | .68 | .91 |
| How easily could you describe the role of antibiotics in treatment of disease[b] | 2.53 | 0.95 | .63 | .92 |
| How easily could you identify a science or technology question associated with disposal of garbage[b] | 2.57 | 0.91 | .67 | .91 |
| How easily could you predict how changes to an environment will affect survival of some species[b] | 2.60 | 0.95 | .68 | .91 |
| How easily could you interpret scientific information provided on labels of food items[b] | 2.62 | 0.92 | .63 | .92 |
| How easily could you discuss how evidence can lead to changing understanding about possibility of life on Mars[b] | 2.18 | 0.97 | .66 | .91 |
| How easily could you identify the better of two explanations for the formation of acid rain[b] | 2.24 | 0.97 | .68 | .91 |

[a] Measured on recoded scale of 1 “much or a bit less,” 2 “about the same,” 3 “a bit more,” and 4 “much more.”

[b] Measured on scale of 1 “nothing,” 2 “a little,” 3 “a moderate amount,” and 4 “a lot.”

[c] Overall scale reliability Cronbach alpha = .92.

TABLE 4
Internal Consistency of Science and Technology Interest and Curiosity Measures

| | Mean | Standard Deviation | Item Total Correlation | Alpha if Item Deleted[d] |
|---|---|---|---|---|
| I generally have fun when I am learning science or technology topics[a] | 4.60 | 1.33 | .76 | .85 |
| I like reading or hearing about science or technology[a] | 4.64 | 1.34 | .79 | .84 |
| I am happy doing science or technology problems[a] | 4.11 | 1.48 | .71 | .85 |
| I enjoy learning about or acquiring new knowledge in science or technology[a] | 4.66 | 1.35 | .80 | .84 |
| Compared to the average person, how curious are you about science or technology[b] | 3.43 | 0.99 | .59 | .88 |
| Do you seem to have more questions about science or technology things than most other people you know[c] | 2.69 | 0.77 | .50 | .88 |

[a] Measured on scale of 1 “strongly disagree” to 6 “strongly agree.”

[b] Measured on scale of 1 “much less,” 2 “a bit less,” 3 “about the same,” 4 “a bit more,” and 5 “much more.”

[c] Measured on scale of 1 “never,” 2 “usually not,” 3 “sometimes,” and 4 “always.”

[d] Overall scale reliability standardized Cronbach alpha = .88.

Note: The combined scale was created using standardized *z* scores because the variables were measured on different scales.

TABLE 5
Internal Consistency of Free-Choice Science and Technology Leisure Engagement[a]

| | Mean | Standard Deviation | Item Total Correlation | Alpha if Item Deleted[b] |
|---|---|---|---|---|
| Read books, magazines, newspaper articles about science or technology not including reading for school or work | 4.13 | 1.58 | .59 | .73 |
| Use the internet to search for or learn about science or technology related topics during free time | 4.06 | 1.65 | .65 | .70 |
| Watch or listen to science or technology educational programs on TV, video, podcast, or radio during free time | 4.08 | 1.41 | .60 | .73 |
| Talk about science or technology with friends or family during free time | 3.53 | 1.53 | .52 | .76 |

[a] Measured on recoded scale of 1 “never,” 2 “1-2 times every 5 years,” 3 “several times a year,” 4 “monthly,” 5 “weekly,” and 6 “daily.”

[b] Overall scale reliability Cronbach alpha = .78.

**TABLE 6**
**Internal Consistency of Science and Technology–Related Avocations and Hobbies Measures[a]**

| | Mean | Standard Deviation | Item Total Correlation | Alpha if Item Deleted |
|---|---|---|---|---|
| Avocations[b,c] | | | | |
| I would like to or currently pursue a hobby involving science or technology | 3.59 | 1.66 | .72 | – |
| I would like to find out more about some area of science or technology | 4.24 | 1.51 | .72 | – |

[a] Cell entries are means on scale of 1 "strongly disagree" to 6 "strongly agree."
[b] Overall scale reliability for "avocations" Cronbach alpha = .83.
[c] Cannot calculate alpha if deleted for these because if deleted, there would only be a single item left, so no scale.

**TABLE 7**
**Internal Consistency of Creativity and Problem-Solving Measures[a]**

| | Mean | Standard Deviation | Item Total Correlation | Alpha if Item Deleted[b] |
|---|---|---|---|---|
| Are you the kind of person who likes there to be just one right answer when faced with a problem | 2.62 | 0.84 | .03 | .44 |
| When a problem comes up, do you tend to come up with solutions that are different than most people | 2.90 | 0.63 | .20 | .05 |
| When a problem comes up, do you try to see how others have solved similar problems in the past | 3.03 | 0.73 | .19 | .04 |

[a] Cell entries are means on scale of 1 "never," 2 "usually not," 3 "sometimes," and 4 "always."
[b] Overall scale reliability Cronbach alpha = .24.

Although all correlations with dependent measures shown in Table 11 increased as a function of increases in the number of science-center visits within the previous 12 months, there were clear increases between Nnever, 0, 1, and 2–4 visits with a distinct "flattening" out of effects after 2–4 visits. In other words, there appeared to be a threshold effect with incremental change occurring between never and 2–4 visits, but not after that. This pattern was apparent for all variables. In general, the effect sizes were typical.

As above, the general patterns in Table 12 were clear, with the major change in association generally occurring between no time and 1–2 hours of visiting. However, as above, there appeared to be a threshold effect with little change in association occurring after 1–2 hours spent on the last visit to the science center. The only variable showing a stronger association for very long visits, 5+ hours, was self-reported science confidence. There appeared to be no significant correlations between length of visit and science and technology–related vocations and avocations. The effect sizes for significant items were minimal to typical.

**TABLE 8**
**Internal Consistency of Science Center Influence on Perceived Confidence in Science and Technology Measures[a]**

| After Visiting the Science Center | Mean | Standard Deviation | Item Total Correlation | Alpha if Item Deleted[b] |
|---|---|---|---|---|
| I learned at least one thing about science or technology I never knew before. | 4.69 | 1.24 | .58 | .95 |
| I discovered things about science or technology I never knew before. | 4.64 | 1.22 | .63 | .95 |
| My understanding of science or technology was strengthened or extended. | 4.43 | 1.17 | .75 | .95 |
| My appreciation of science or technology increased. | 4.36 | 1.27 | .78 | .95 |
| I got new ideas or techniques that have been useful to me in my work or hobbies. | 3.61 | 1.43 | .77 | .95 |
| My interest in a specific area of science or technology increased. | 3.92 | 1.34 | .83 | .95 |
| My curiosity about science or technology increased. | 4.06 | 1.35 | .86 | .95 |
| I found myself thinking about some aspect of science or technology. | 4.12 | 1.33 | .80 | .95 |
| My behavior regarding science or technology changed because of my visit. | 3.61 | 1.41 | .82 | .95 |
| My visit inspired me to learn more about science or technology. | 3.92 | 1.35 | .85 | .95 |
| I discovered or learned new ways to do things. | 3.90 | 1.33 | .83 | .95 |
| My curiosity was ignited. | 4.20 | 1.31 | .80 | .95 |
| My understanding of myself increased. | 3.54 | 1.39 | .78 | .95 |
| I became more confident to question things. | 3.60 | 1.41 | .78 | .95 |
| I found myself thinking about pursuing courses or a career in science or technology. | 2.96 | 1.55 | .68 | .95 |
| My visit inspired me to get involved in a project in the community related to science or technology. | 2.90 | 1.48 | .64 | .95 |
| I realized that someone in my group had knowledge, interest, or skills that I did not know about. | 3.52 | 1.55 | .61 | .95 |

[a] Measured on scale of 1 “strongly disagree,” 2 “moderately disagree,” 3 “slightly disagree,” 4 “slightly agree,” 5 “moderately agree,” and 6 “strongly agree.”
[b] Overall scale reliability Cronbach alpha = .96.

## Role of Education and Income on Relationships

Since as shown in Table 2 individuals with more education and higher incomes were more likely to visit science centers than were individuals with less education and lower incomes, it seemed important to further explore this relationship relative to the investigated outcomes. Tables 13 and 14 summarize the whole-population relationship between education level and income respectively and five of the dependent measures (the dependent

**TABLE 9**
**Relationship Between the Number of Previous Science Center Visits and Dependent Scales[a]**

| | Never Visited (53%) | 1–2 Visits (17%) | 3–10 Visits (24%) | 11+ Visits (7%) | *F* Value | *p* Value | Eta |
|---|---|---|---|---|---|---|---|
| Knowledge and understanding[a] | $2.32^{1}$ | $2.56^{2}$ | $2.58^{23}$ | $2.65^{3}$ | 106.94 | <.001 | .23 |
| Interest and curiosity[c] | $0.05^{1}$ | $0.16^{2}$ | $0.25^{3}$ | $0.33^{3}$ | 35.56 | <.001 | .14 |
| Free-choice engagement[b] | $3.77^{1}$ | $4.04^{2}$ | $4.23^{23}$ | $4.41^{3}$ | 72.01 | <.001 | .19 |
| Vocations[d] | 3.37 | 3.30 | 3.45 | 3.36 | 1.17 | .319 | .03 |
| Avocation[d] | $3.90^{1}$ | $3.77^{2}$ | $3.99^{13}$ | $4.02^{13}$ | 4.40 | .004 | .05 |
| Science confidence[d] | – | $3.77^{1}$ | $3.83^{1}$ | $4.10^{2}$ | 13.30 | <.001 | .10 |

[a] Most variables in index measured on scale of 1 “nothing,” 2 “a little,” 3 “a moderate amount,” and 4 “a lot.”

[b] Variables in index measured on recoded scale of 1 “never,” 2 “1–2 times every 5 years,” 3 “several times a year,” 4 “monthly,” 5 “weekly,” and 6 “daily.”

[c] Variables in index measured on various different scales. Cell entries, therefore, represent standardized *z* scores.

[d] Variables in index measured on scale of 1 “strongly disagree” to 6 “strongly agree.”

Note: Means with different superscripts are significantly different at $p < .05$ based on Tamhane’s post hoc tests for unequal variances.

**TABLE 10**
**Relationship Between Year of Most Recent Science Center Visit and Dependent Scales[a]**

| | Never Visited (53%) | Before 2010 (11%) | 2010–2011 (14%) | 2012 (14%) | 2013 (7%) | *F* Value | *p* Value | Eta |
|---|---|---|---|---|---|---|---|---|
| Knowledge and understanding[a] | $2.32^{1}$ | $2.52^{2}$ | $2.61^{3}$ | $2.62^{3}$ | $2.74^{4}$ | 89.93 | <.001 | .25 |
| Interest and curiosity[c] | $0.05^{1}$ | $0.20^{2}$ | $0.22^{2}$ | $0.27^{2}$ | $0.49^{3}$ | 29.78 | <.001 | .14 |
| Free-choice engagement[b] | $3.77^{1}$ | $4.09^{2}$ | $4.11^{2}$ | $4.34^{3}$ | $4.55^{4}$ | 60.41 | <.001 | .20 |
| Vocations[d] | $3.37^{13}$ | $3.21^{2}$ | $3.24^{12}$ | $3.58^{3}$ | $4.01^{4}$ | 13.82 | <.001 | .10 |
| Avocation[d] | $3.90^{1}$ | $3.73^{2}$ | $3.86^{123}$ | $4.12^{3}$ | $4.44^{4}$ | 16.76 | <.001 | .11 |
| Science confidence[d] | – | $3.71^{1}$ | $3.84^{12}$ | $3.92^{2}$ | $4.32^{3}$ | 27.17 | <.001 | .18 |

[a] Most variables in index measured on scale of 1 “nothing,” 2 “a little,” 3 “a moderate amount,” and 4 “a lot.”

[b] Variables in index measured on recoded scale of 1 “never,” 2 “1–2 times every 5 years,” 3 “several times a year,” 4 “monthly,” 5 “weekly,” and 6 “daily.”

[c] Variables in index measured on various different scales. Cell entries, therefore, represent standardized *z* scores.

[d] Variables in index measured on scale of 1 “strongly disagree” to 6 “strongly agree.”

Note: Means with different superscripts are significantly different at $p < .05$ based on Tamhane’s post hoc tests for unequal variances.

**TABLE 11**
**Relationship Between Number of Visits in Last 12 Months and Dependent Scales[a]**

| | Never Visited (53%) | 0 Visits (24%) | 1 Visit (13%) | 2–4 Visits (7%) | 5+ Visits (2%) | *F* Value | *p* Value | Eta |
|---|---|---|---|---|---|---|---|---|
| Knowledge and understanding[a] | $2.32^{1}$ | $2.54^{2}$ | $2.58^{2}$ | $2.70^{3}$ | $2.74^{3}$ | 83.01 | <.001 | .24 |
| Interest and curiosity[c] | $0.05^{1}$ | $0.20^{2}$ | $0.21^{2}$ | $0.34^{3}$ | $0.38^{23}$ | 27.75 | <.001 | .14 |
| Free-choice engagement[b] | $3.77^{1}$ | $4.06^{2}$ | $4.34^{3}$ | $4.41^{3}$ | $4.44^{3}$ | 55.05 | <.001 | .19 |
| Vocations[d] | $3.37^{1}$ | $3.17^{2}$ | $3.48^{1}$ | $3.86^{3}$ | $3.90^{13}$ | 14.95 | <.001 | .10 |
| Avocation[d] | $3.90^{1}$ | $3.70^{2}$ | $4.01^{1}$ | $4.38^{3}$ | $4.46^{3}$ | 20.97 | <.001 | .12 |
| Science confidence[d] | – | $3.71^{1}$ | $3.86^{2}$ | $4.11^{3}$ | $4.19^{3}$ | 19.22 | <.001 | .15 |

[a] Most variables in index measured on scale of 1 “nothing,” 2 “a little,” 3 “a moderate amount,” and 4 “a lot.”

[b] Variables in index measured on recoded scale of 1 “never,” 2 “1-2 times every 5 years,” 3 “several times a year,” 4 “monthly,” 5 “weekly,” and 6 “daily.”

[c] Variables in index measured on various different scales. Cell entries, therefore, represent standardized *z* scores.

[d] Variables in index measured on scale of 1 “strongly disagree” to 6 “strongly agree.”

Note: Means with different superscripts are significantly different at $p < .05$ based on Tamhane’s post hoc tests for unequal variances.

**TABLE 12**
**Relationship Between Hours Visited on Last Visit and Dependent Scales[a]**

| | Never Visited (53%) | 1–2 Hours (11%) | 3–4 Hours (20%) | 5+ Hours (16%) | *F* Value | *p* Value | Eta |
|---|---|---|---|---|---|---|---|
| Knowledge and understanding[a] | $2.32^{1}$ | $2.57^{2}$ | $2.59^{2}$ | $2.61^{2}$ | 106.45 | <.001 | .23 |
| Interest and curiosity[c] | $0.05^{1}$ | $0.22^{2}$ | $0.23^{2}$ | $0.30^{2}$ | 32.25 | <.001 | .13 |
| Free-choice engagement[b] | $3.77^{1}$ | $4.19^{2}$ | $4.20^{2}$ | $4.26^{2}$ | 64.34 | <.001 | .18 |
| Vocations[d] | 3.37 | 3.35 | 3.37 | 3.54 | 1.33 | .264 | .03 |
| Avocation[d] | 3.90 | 3.88 | 3.92 | 4.06 | 1.91 | .126 | .03 |
| Science confidence[d] | – | $3.76^{1}$ | $3.78^{1}$ | $4.17^{2}$ | 27.93 | <.001 | .15 |

[a] Most variables in index measured on scale of 1 “nothing,” 2 “a little,” 3 “a moderate amount,” and 4 “a lot.”

[b] Variables in index measured on recoded scale of 1 “never,” 2 “1–2 times every 5 years,” 3 “several times a year,” 4 “monthly,” 5 “weekly,” and 6 “daily.”

[c] Variables in index measured on various different scales. Cell entries, therefore, represent standardized *z* scores.

[d] Variables in index measured on scale of 1 “strongly disagree” to 6 “strongly agree.”

Note: Means with different superscripts are significantly different at $p < .05$ based on Tamhane’s post hoc tests for unequal variances.

**TABLE 13**
**Relationship Between Median Household Income and the Dependent Scales**

| | Below Median | Above Median | $t$ Value | $p$ Value | $r_{pb}$ |
|---|---|---|---|---|---|
| Knowledge and understanding[a] | 2.39 | 2.51 | 8.32 | $<.001$ | .11 |
| Out of school engagement[b] | 3.85 | 4.13 | 8.96 | $<.001$ | .12 |
| Interest and curiosity[c] | –0.07 | 0.96 | 7.77 | $<.001$ | .10 |
| Vocations[d] | 3.41 | 3.41 | 0.10 | .924 | .00 |
| Avocation[d] | 3.93 | 3.95 | 0.54 | .591 | .01 |

[a] Most variables in index measured on scale of 1 “nothing,” 2 “a little,” 3 “a moderate amount,” and 4 “a lot.”

[b] Variables in index measured on recoded scale of 1 “never,” 2 “1-2 times every 5 years,” 3 “several times a year,” 4 “monthly,” 5 “weekly,” and 6 “daily.”

[c] Variables in index measured on various different scales. Cell entries, therefore, represent standardized $z$ scores.

[d] Variables in index measured on scale of 1 “strongly disagree” to 6 “strongly agree.”

measure identity and science and technology confidence was excluded because it was only measured for those individuals who had visited the science center). The level of education was correlated with the measured science-and-technology outcomes, the more schooling an individual had, generally the stronger the correlation for all dependent measures. Effect sizes were strongest for science and technology–related knowledge and understanding, interest and curiosity, and free-choice leisure engagement with minimal effect sizes for science and technology–related vocations and avocations. Individuals with family incomes above the community median showed significantly greater correlations with science and technology–related knowledge and understanding, interest and curiosity, and free-choice leisure engagement than did individuals with family incomes below the community median; however, effect sizes were minimal. There were no statistical differences for family income as a function of science and technology–related avocations or vocations.

## The Role of Self-Selection on Relationships

Given that there are parallel correlations between education and income and the various dependent measures and science-center visitation and the various dependent measures, these data were further analyzed to determine whether the observed associations with visiting a science center could have been disproportionately caused by some kind of education and/or income self-selection bias. In other words, perhaps the overall positive correlations for use of science centers reported above were merely an artifact of a self-selection bias; results were not caused by the science-center experience itself but rather because they disproportionately attracted individuals with higher education and income. An additional source of self-selection bias beyond education and income could have been science-and-technology interest and engagement. In other words, given the high likelihood that the most science and technology-interested and engaged individuals would also be the most likely individuals to visit the science center, this too could have skewed the positive correlations reported above. Using science-and-technology understanding, vocations and avocations as dependent variables, these three possible areas of self-selection bias were considered—bias due to education, bias due to income, and bias due to prior interest and engagement.

Tables 15 and 16 compare the relationship between the first two potential areas of self-selection bias—education and income—as a function of visit/not visit and the three

**TABLE 14**
**Relationship Between Education Level and the Dependent Scales[a]**

| | Level of Education | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Less Than High School | High School or Equivalent | Vocational or Technical Certificate | AA Degree | BA Degree | MA Degree | Doctoral Degree | *F* Value | *p* Value | Eta |
| Knowledge and understanding[a] | $2.10^{1}$ | $2.33^{2}$ | $2.39^{23}$ | $2.43^{3}$ | $2.62^{4}$ | $2.66^{4}$ | $2.76^{4}$ | 94.29 | $<.001$ | .30 |
| Interest and curiosity[c] | $-0.42^{1}$ | $-0.13^{2}$ | $0.02^{3}$ | $0.03^{3\delta}$ | $0.19^{5}$ | $0.15^{45}$ | | | | |
| Free-choice engagement[b] | $3.25^{1}$ | $3.76^{2}$ | $3.98^{3}$ | $4.09^{3}$ | $4.25^{4}$ | $4.26^{4}$ | $4.23^{34}$ | 65.97 | $<.001$ | .25 |
| Vocations[d] | $3.07^{1}$ | $3.13^{1}$ | $3.42^{2}$ | $3.25^{12}$ | $3.69^{3}$ | $3.59^{23}$ | $3.77^{23}$ | 16.01 | $<.001$ | .13 |
| Avocation[e] | $3.59^{1}$ | $3.71^{12}$ | $3.91^{2\gamma}$ | $3.83^{12}$ | $4.20^{4}$ | $4.11^{34}$ | $4.26^{34}$ | 20.18 | $<.001$ | .14 |

[a] Most variables in index measured on scale of 1 “nothing,” 2 “a little,” 3 “a moderate amount,” and 4 “a lot.”

[b] Variables in index measured on recoded scale of 1 “never,” 2 “1–2 times every 5 years,” 3 “several times a year,” 4 “monthly,” 5 “weekly,” and 6 “daily.”

[c] Variables in index measured on various different scales. Cell entries, therefore, represent standardized $z$ scores.

[d] Variables in index measured on scale of 1 “never,” 2 “usually not,” 3 “sometimes,” and 4 “always.”

[e] Variables in index measured on scale of 1 “strongly disagree” to 6 “strongly agree.”

Note: Cell entries with different superscripts are significantly different at $p < .05$ level based on Tamhane’s post hoc test for unequal variances

**TABLE 15**
**Relationship Between Education/Visit Types and Dependent Variable Scales**

| | College Degree, visit | College Degree, Do Not Visit | No College Degree, Visit | No College Degree, Do Not Visit | *F* Value | *p* Value | Eta |
|---|---|---|---|---|---|---|---|
| Knowledge and understanding[a] | 2.72[1] | 2.54[2] | 2.48[3] | 2.25[4] | 206.67 | $<.001$ | .31 |
| Vocations[b] | 3.62[1] | 3.72[1] | 3.19[2] | 3.25[2] | 25.51 | $<.001$ | .12 |
| Avocation[b] | 4.16[1] | 4.17[1] | 3.73[2] | 3.80[2] | 31.45 | $<.001$ | .13 |

[a] Most variables in index measured on scale of 1 “nothing,” 2 “a little,” 3 “a moderate amount,” and 4 “a lot.”

[b] Variables in index measured on scale of 1 “strongly disagree” to 6 “strongly agree.”

Note: Cell entries with different superscripts are significantly different at $p < .05$ level based on Tamhane’s post hoc test for unequal variances

**TABLE 16**
**Relationship Between Income/Visit Types and Dependent Variable Scales**

| | Above Median, Visit | Above Median, Do Not Visit | Below Median, Visit | Below Median, Do Not Visit | *F* Value | *p* Value | Eta |
|---|---|---|---|---|---|---|---|
| Knowledge and understanding[a] | 2.62[1] | 2.39[2] | 2.55[3] | 2.29[4] | 107.41 | $<.001$ | .24 |
| Vocations[b] | 3.44 | 3.37 | 3.33 | 3.46 | 1.49 | .215 | .03 |
| Avocation[b] | 3.97 | 3.91 | 3.89 | 3.95 | 0.79 | .499 | .02 |

[a] Most variables in index measured on scale of 1 “nothing,” 2 “a little,” 3 “a moderate amount,” and 4 “a lot.”

[b] Variables in index measured on scale of 1 “strongly disagree” to 6 “strongly agree.”

Note: Cell entries with different superscripts are significantly different at $p < .05$ level based on Tamhane’s post hoc test for unequal variances.

dependent variable scales. In all cases, individuals who visited science centers showed significantly higher science-and-technology understanding than did those who had not visited a science center. Effect sizes were moderate to substantial. Low-income individuals who visited the science center showed significantly higher science-and-technology understanding than did high-income individuals who had not visited a science center. Results for avocations and vocations did not follow this pattern; there were no significant differences between visit and not visit. Effect sizes were minimal.

As for possible self-selection related to prior interest and engagement, we used *K*-means cluster analysis to determine the similarity of adult participants based upon the following science interest-and-engagement items: frequency of participation in science and technology–related out-of-school activities, science interest, enjoyment or curiosity about science and technology, and favorite school subject. We chose these items because they broadly and collectively captured the suite of attributes one would expect from a science-interested and engaged versus uninterested or disengaged individual. This cluster analysis revealed three distinct groups within the population: (a) a large group of individuals that

**TABLE 17**
**Results of K-Means Cluster Analysis for Interest and Engagement[a]**

| | Science Interest and Engagement Type | | | | | |
|---|---|---|---|---|---|---|
| | Really Like Science ($N = 2541$) | Like Science ($N = 1988$) | Dislike Science ($N = 771$) | $\chi^2$ or $F$ Value | $p$ Value | Eta or $\phi$ |
| Read books, magazines, or newspaper articles | $4.75^1$ | $4.51^2$ | $2.11^3$ | 2173.04 | <.001 | .66 |
| Use the Internet | $4.90^1$ | $4.19^2$ | $1.95^3$ | 2656.24 | <.001 | .70 |
| Watch/listen TV, videos, podcasts, or radio | $4.72^1$ | $4.10^2$ | $2.48^3$ | 1691.80 | <.001 | .62 |
| Talk with friends or family | $4.25^1$ | $3.40^2$ | $2.01^3$ | 1338.72 | <.001 | .58 |
| Have fun when I learning science or technological topics | $5.43^1$ | $3.85^2$ | $3.54^3$ | 2023.13 | <.001 | .65 |
| Like reading or hearing about sci. or technology | $5.51^1$ | $3.92^2$ | $3.50^3$ | 2249.92 | <.001 | .67 |
| Happy doing science or technology problems | $5.04^1$ | $3.29^2$ | $2.88^3$ | 2088.88 | <.001 | .66 |
| I enjoy learning about science or technology | $5.53^1$ | $3.92^2$ | $3.55^3$ | 2142.89 | <.001 | .67 |
| Favorite topic in school was mathematics or science[b] | 50.8 | 34.6 | 21.4 | 334.75 | <.001 | .24 |

[a] Cell entries are means on scale of 1 “strongly disagree,” 2 “moderately disagree,” 3 “slightly disagree,” 4 “slightly agree,” 5 “moderately agree,” and 6 “strongly agree” unless otherwise specified.

[b] Cell entries are percentages.

Note: Cell entries with different superscripts are significantly different at $p < .05$ level based on Tamhane’s post hoc test for unequal variances.

really liked science and technology (48%); another large group that generally liked science and technology (38%); and a small group of individuals that strongly disliked science and technology (14%) (Table 17). Participants who really liked science and technology were significantly more likely to participate in out-of-school science activities, showed more interest and curiosity toward science, and were more likely to report mathematics or science as their favorite school topic than the other two identity groups.

As expected, individuals who “strongly liked” science and technology group were significantly more likely than those who merely “liked” science and technology to visit a science center, and those who “liked” science and technology were significantly more likely than the “dislike” group to do so ($X^2 = 116.06$, $p < .000$, effect size = 0.15). However, science-center utilization was limited in all cases. Only half of the “really like” science-and-technology population had ever visited a science center (1271/2541). Forty percent of those who fell within the “like” science-and-technology group had visited a science center (795/1988) and only 29% of “dislike” science-and-technology group (224/771) had visited. More importantly, although interest and engagement in science and technology as expected significantly correlated with science-and-technology knowledge, and science-and-technology vocations and avocations (Table 18) there was a strong science center-use association with substantial effect sizes. For all three groups, individuals who had visited a

**TABLE 18**
**Relationship Between Science Interest and Engagement by Science Center Visit and Dependent Variable Scales**

| | Really Like Science, Visit | Really Like Science, Do Not Visit | Like Science, Visit | Like Science, Do not Visit | Dislike Science, Visit | Dislike Science, Do Not Visit | *F* Value | *p* Value | Eta |
|---|---|---|---|---|---|---|---|---|---|
| Knowledge and understanding[a] | 2.81$^{1}$ | 2.61$^{2}$ | 2.41$^{3}$ | 2.27$^{4}$ | 2.12$^{4}$ | 1.86$^{5}$ | 488.89 | $<$.001 | .56 |
| Vocations[b] | 4.09$^{1}$ | 4.28$^{1}$ | 2.64$^{2}$ | 3.02$^{3}$ | 2.13$^{4}$ | 2.23$^{4}$ | 298.96 | $<$.001 | .47 |
| Avocation[b] | 4.54$^{1}$ | 4.75$^{2}$ | 3.39$^{3}$ | 3.62$^{4}$ | 2.67$^{5}$ | 2.81$^{5}$ | 432.82 | $<$.001 | .54 |

[a] Most variables in index measured on scale of 1 “nothing,” 2 “a little,” 3 “a moderate amount,” and 4 “a lot.”

[b] Variables in index measured on scale of 1 “strongly disagree” to 6 “strongly agree.”

Note: Cell entries with different superscripts are significantly different at $p < .05$ level based on Tamhane’s post hoc test for unequal variances.

science center showed higher science-and-technology knowledge as compared with those in the population with similar interest and engagement not visiting a science center. Table 17 also shows that the relationship between science-center use and science-and-technology vocations and avocations was more complex. Relative to vocations, use of science centers was positively correlated only for those who liked science and technology; there was no effect for those who really liked or disliked science and technology. With regard to avocations, use of science centers was negatively correlated for the two most science and technology-positive groups and trending in the same direction for the dislike group. Effect sizes for all three relationships were substantial.

## CONCLUSIONS

Overall, the results consistently showed that adult science-center experiences positively correlated with science and technology–related outcomes. In particular, visiting a science center significantly correlated with

- science-and-technology knowledge and understanding,
- interest and curiosity in science and technology,
- participation in free-choice science and technology–related leisure activities, and
- confidence in and identification with science and technology.

Although more equivocal, there was also evidence that science-center experiences positively correlated with whether individuals had science and technology–related vocations and avocations (e.g., hobbies, habits of mind).

In general, the more frequent, the longer in duration, and the more recent an experience, the greater was the correlation with all six of the outcome measures (creativity and problem solving was excluded from analysis). This is not a surprising finding, but is important nonetheless, because it reinforces the potential role that cumulative, as well as more recent, science-center experiences might have.

However, there was evidence that correlations were not entirely linear. For example, there appeared to be a threshold phenomenon related to both the number of visits and hours spent on a visit. Although correlations strengthened as the number of science-center visits within a year increased, there was a clear "flattening" out of the effect after about two to four visits. Similarly, strong correlations were observed between no visit and a visit lasting 1–2 hours, although there was no evidence that relationships significantly increased across outcomes as visit times increased. These results are important because historically science centers have had no solid evidence on which to base decisions related to how intensively, and over what time periods, interventions should be planned. It was always generally assumed that "more was better." These findings suggest that there may be limitations to "more" and there could be a "sweet spot" for achieving desired effects. These conclusions will be important to verify through future research since findings suggest some initial hypotheses which now can be tested under more controlled conditions, with an eye for whom and under what circumstances these results might or might not apply.

As discussed in the outset of this paper, using a science center almost always involves a degree of self-selection, particularly among adults, who nearly always have a choice of whether to visit or not. Thus the strong positive correlations observed for adults utilizing science centers and a wide range of science-and-technology outcomes might have been reflective of some overall self-selection bias, with likely bias candidates being socioeconomic and educational privilege. Considerable data, collected over many years, has shown that museums in general attract wealthier, better educated individuals (cf. Falk, 2009 for review). In other words, the positive observed relationships could be explained potentially as yet another example of the “rich getting richer, and the poor getting poorer.” Although the data certainly suggest that greater education and family income correlated with science-center use, such differences did not appear to be the only, let alone the primary, reason that science-center experiences positively correlated with many of the science-and-technology outcomes. As shown in Tables 15 and 16, independent of education or income, individuals who visited science centers showed higher levels of knowledge and understanding. In fact, low-income individuals who visited a science center actually showed significantly higher science-and-technology understanding than did high-income individuals who had not visited a science center.

A potentially more problematic bias would be that the positive correlations seen above might be primarily due to the fact that individuals already predisposed to benefit from a science-center experience, i.e., those with strong preexisting science-and-technology interests and engagement, would be sufficiently over-represented in the science-center visiting population so as to skew results towards the positive. However, the evidence in this study does not support this conclusion. As expected, although science-and-technology knowledge positively correlated with science-and-technology interest and engagement; as shown in Table 18, within group comparisons between those who did and did not visit a science center showed significantly higher knowledge and understanding for those who utilized science centers. This was true with very high effect sizes for all three levels of interest and engagement.

Extrapolating from these results, self-selection bias for visiting a science center, including biases related to education, income and interest, and engagement, did likely influence the observed correlations, but these biases were almost certainly not the only nor potentially the primary reason that science-center experiences positively correlated with the overall science-and-technology outcomes presented above. In fact, the data, at least based on one key measure—science-and-technology understanding—suggest the opposite. It appears that utilizing a science center positively influences science literacy outcomes independent of prior education, income or interests, and experiences. However, fully disentangling the relationships between these variables is not possible from this data set and will require further investigation.

In addition to these overall findings, the self-selection analysis revealed other interesting findings. First, consistent with previous research (e.g., Falk & Needham, 2013; National Science Board, 2012, 2014), study data suggest that a large majority of individuals worldwide consider themselves to be science and technology-interested and engaged. Since there were three times as many highly interested and engaged individuals as science-and-technology uninterested and disengaged, it was not surprising that the former group were better represented among the science-center visiting public. However, this relationship was not as extreme as one would suppose. Nearly 30% of those possessing little interest in and engagement with science and technology visited science centers as compared with half of those who “really liked” science and technology and 40% of those who generally liked science and technology. Although there are obviously many ways to satisfy a science-and-technology interest beyond visiting a science center, the lack of use by those expressing strong interest represents an interest finding. Collectively these data suggest interesting opportunities and challenges for the science-center community. In particular, it will be important for the community to better understand why individuals do or do not perceive value in a science-center experience and then act upon those understandings. Although issues like education and income no doubt played a role in these patterns, findings suggest that other factors were likely at play; perhaps things like the desire to facilitate the learning of children and/or issues related to identity (cf. Doering & Pekarik, 1996; Falk, 2009; Moussouri, 1997; Packer & Ballantyne, 2002).

Equally interesting was the self-selection data related to vocations and avocations. Specifically, although as expected, interest and engagement in science and technology generally correlated with vocations and avocations in these areas (unlike knowledge and understanding), there were no clear patterns of correlation between interest and engagement in science and technology, vocations and avocations, and science-center use. In general, visiting science centers appeared to be negatively correlated with vocations and avocations in science and technology. One interpretation of these results is that adults who are sufficiently interested and engaged in science and technology to pursue science and technology–related jobs and/or hobbies do not utilize science centers, or at least do not use them in ways that connect to their vocations or avocations. If this hypothesis is true, it would be consistent with the widely held public assumption that interactive science centers are primarily perceived by the public as being for children (and families), rather than for "serious" adults. This too is a finding that needs to be further tested, but, if true, represents both an opportunity and a challenge for science centers.

It is important to note that as with all types of research designs, the epidemiological approach used had specific limitations. One major limitation is the dependence on and validity of self-report data for both the dependent and criterion measures. A number of studies from various disciplines have established that self-report data though not perfect, is a reasonable proxy for more direct measures, especially when using survey data (Chan, 2009; Gonyea, 2005; Vaske, 2008). Obviously, the other drawback was an inability to fully "control" variables. However, given the free-choice nature of science centers, covariance between variables as well as possible self-selection biases were inevitable. Finally, the size and scope of this international investigation limited our ability to explore fully potentially important variables like race/ethnicity (cf. Dawson, 2014) because of the extreme variability and nuances of this issue across the 13 countries sampled.

Despite these methodological challenges, these kinds of interrelationships between variables have an important "upside" when it comes to practice. We would expect that the free-choice nature of the experience would enable each individual using the science center to selectively pursue his or her unique prior interests, knowledge, and experiences. In turn, these interests, knowledge, and experiences would be reinforced by what happens at the science center, which would then lead to further science and technology–related interests, knowledge, and experiences. Arguably (cf. Falk & Dierking, 1992, 2014) it is the tendency of science centers to facilitate just these kinds of "cascading" experiences that make these settings such valuable educational resources and, at least theoretically, contributed to the positive correlations with outcomes observed.

In conclusion, we have been able to document the probability that significant relationships exist between science-center use and (1) science-and-technology knowledge and understanding, (2) interest and curiosity in science and technology, (3) engagement in out-of-school science and technology–related activities, and (4) confidence in and identification with science and technology. These findings are consistent with an abundance of short-term, pre- and postschool field trip and general-public-visit research showing that science-center experiences significantly enhance users' science literacy (see reviews by Falk & Dierking, 2014; NRC, 2009). Importantly, this research indicates that these positive associations were not solely the result of self-selection biases such as prior interest, engagement, or socioeconomic privilege. The results of this study strengthen the argument that the presence of one or more healthy and active science centers within a community, region, or country represents a vital investment for fostering and maintaining a scientifically and technologically informed, engaged, and literate public.

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