Measuring the Impact of a Science Center on Its Community

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Received 30 December 2009; Accepted 16 February 2010

Abstract: A range of sources support science learning, including the formal education system, libraries, museums, nature and Science Centers, aquariums and zoos, botanical gardens and arboretums, television programs, film and video, newspapers, radio, books and magazines, the Internet, community and health organizations, environmental organizations, and conversations with friends and family. This study examined the impact of one single part of this infrastructure, a Science Center. This study asked two questions. First, who in Los Angeles (L.A.) has visited the California Science Center and what factors best describe those who have and those who have not visited? Second, does visiting the California Science Center impact public science understanding, attitudes, and behaviors and if so, in what ways? Two random telephone surveys of L.A. county adults 18 years of age and over ($n = 832$; $n = 1{,}008$) were conducted; one in 2000, shortly after the opening of the totally redesigned and rebuilt Science Center and one in 2009, roughly a decade after opening. Samples were drawn from five racially, ethnically, and socio-economically diverse communities generally representative of greater L.A. Results suggest that the Science Center is having an important impact on the science literacy of greater L.A. More than half of residents have visited the Science Center since it opened in 1998 and self-report data indicate that those who have visited believe that the Science Center strongly influenced their science and technology understanding, attitudes, and behaviors. Importantly, Science Center visitors are broadly representative of the general population of greater L.A. including individuals from all races and ethnicities, ages, education, and income levels with some of the strongest beliefs of impact expressed by minority and low-income individuals. The use of a conceptual ‘‘marker’’ substantiates these conclusions and suggests that the impact of the Science Center might even be greater than indicated by the mostly self-report data reported here. © 2010 Wiley Periodicals, Inc. J Res Sci Teach 48: 1–12, 2011
Keywords: Science Center; free-choice learning; informal; science literacy; infrastructure

A range of sources support science learning, including the formal education system, libraries, museums, nature and Science Centers, aquariums and zoos, botanical gardens and arboretums, television programs, film and video, newspapers, radio, books and magazines, the Internet, community and health organizations (e.g., YWCA, Scouts, 4-H), environmental organizations, and conversations with friends and family (Falk, Randol, & Dierking, 2008; Falk, Storksdieck, & Dierking, 2007). Each of these institutions contributes to science learning. This study examined the particular contribution of a Science Center to public understanding of science.

In 1996, research began at the California Science Center (Science Center) in Los Angeles (L.A.), California to answer questions such as: (a) What contribution does this Science Center make to public understanding of science? (b) How successfully has the Science Center accomplished its educational mission of enhancing public understanding, attitudes, and behaviors toward science and technology? and (c) Does the Science Center facilitate long-term science learning, and if so, what is the nature of this learning? Assessing impacts of an institution such as the Science Center is not trivial. This institution is open free of charge and has more than a century of influence in the L.A. area, most in its previous incarnation when it was known as the

Contract grant sponsor: Noyce Foundation; Contract grant sponsor: California Science Center.
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DOI 10.1002/tea.20394
Published online 23 November 2010 in Wiley Online Library (wileyonlinelibrary.com).

California Museum of Science and Industry. L.A. is also a community where the impact of a single institution is diluted by population size (i.e., over 10 million people) and transience (e.g., some L.A. schools have turnover rates in excess of 70% per year with district-wide rates in the range of 45%; Brooks, Mojica, & Land, 1998). However, it was assumed that the influence of this institution would measurably increase over the decade beginning in the late 1990s because of major changes to the institution. In 1993, the institution developed a new master plan that involved closing the old California Museum of Science and Industry and totally razing the existing buildings and eliminating all previous exhibitions. Built in its place was a totally new and redesigned museum with completely new exhibitions and programs; this new institution was also given a new name—the California Science Center. The new 22,760 m^2 (245,000 ft^2) California Science Center opened in 1998 with the expectation that the major investments made in improving the quality of exhibitions, public programs, and marketing would result in a marked increase in its impact on public science understanding, interest, and behavior.

It was envisioned that two approaches were needed to track the influence of the Science Center on the L.A. public; these two approaches were termed *inside-out* and *outside-in*. The *inside-out* approach was designed to identify visitors to the institution and assess the short- and long-term effects that various projects, activities, and exhibitions had on these visitors; the vast majority of research on free-choice science learning is of this form. Examples of Science Center *inside-out* research are the recently completed longitudinal investigation of a cohort of 200 randomly selected Science Center visitors (Falk & Storksdieck, 2005, 2010) and a study on the role of emotion in visitor learning (Falk & Gillespie, 2009). By contrast, the *outside-in* approach was designed to investigate through face-to-face interviews and large-scale random telephone surveys the science understanding, awareness, and attitudes of individuals within the broader community to determine any impact the Science Center was having on these individuals; this type of investigation is relatively rare. Collectively, these research approaches represent a decade of snapshots of the changes in L.A. residents' science-related knowledge, attitudes, and behaviors, as well as their perceptions of the role of the Science Center in facilitating those changes. This article presents results from one particular set of "*outside-in*" studies.

Background

It has long been assumed that formal schooling is the primary mechanism by which the public learns science, but in recent years there has been a growing appreciation for the fundamental role played by the vast array of non-school science education institutions (Falk & Dierking, 2010). Although Science Centers and other similar institutions have long asserted that they play a critical role in supporting public understanding of science, comprehensive supporting data is limited. As summarized in a recent national report (Bell, Lewenstein, Shouse, & Fedler, 2009), a growing body of data demonstrates that Science Centers and similar institutions have an educational impact. Most research in support of these assertions, however, is limited in scope and "*inside-out*" in approach. In other words, data demonstrates that a self-selected population has benefited from such experiences, but little research has used the "*outside-in*" approach to demonstrate that large numbers of the general public have benefited.

A number of major challenges limit valid and reliable documentation of impacts that Science Centers have on communities. The biggest challenges are created by two interrelated factors—the complex nature of learning itself and the multi-dimensional and interactive nature of the science-learning infrastructure. It was once assumed that science and other learning was a linear process that primarily occurred through directed instruction. If this is the case, which many people still believe, measuring science learning is relatively straightforward. This approach has led to a widespread misperception that the public is generally science illiterate and that the number of years of schooling is the best predictor of science knowledge (Falk et al., 2007; Layton, Davey, & Jenkins, 1986; Turner, 2008).

Science learning is rarely, if ever, instantaneous. Individuals typically acquire an understanding of scientific concepts through an accumulation of experiences from different sources at different times (e.g., Anderson, Lucas, Ginns, & Dierking, 2000; Bransford, Brown, & Cocking, 2000; Caillot & Nguyen-Xuan, 1995; Korpan, Bisanz, Boehme, & Lynch, 1997; Medrich, 1991; Miller, 2001, 2004; National Science Board, 2006; Rogoff & Lave, 1984; Wagner, 2007). An individual's understanding of the physics of flight, for example, might represent the cumulative experiences of completing a classroom assignment on Bernouli's principle, reading a book on the Wright brothers, visiting a Science Center exhibit on lift and drag, and watching a television program on birds. All of these experiences are combined, often seamlessly, to construct a personal understanding of flight; no one source is sufficient to create understanding, nor one single institution solely responsible. In the above scenario, when did this individual learn about flight, what experiences most contributed to learning, and how could one specifically identify the piece learned in a Science Center, for example, as opposed to school, reading, or television?

Not only is learning incremental, but a variety of institutions continuously contribute to public science learning. St. John and Perry (1993) argued that both formal and informal education institutions need to be viewed as comprising parts of a single large educational infrastructure. They defined infrastructure as something that lies below the surface and provides critically important support to a range of economic and social activities. Infrastructure represents the essential under-girding for other activities (e.g., highway infrastructure facilitates transportation and community services such as fire and police departments). Infrastructure investments help provide structures, create conditions, and develop capacities prerequisite to the functioning of daily life. Given that all parts of the infrastructure are at some level intertwined, disentangling the impact of one piece from another is complex. The only way to measure the impact of a piece of infrastructure is to examine what happens if it is removed (e.g., temporary closure of a bridge) or by capturing impact prior to it being put in place and then monitoring events as that piece of infrastructure becomes more important.

The series of *outside-in* investigations in this research were designed to compensate for these impediments to measuring specific impacts of the Science Center. The first challenge related to the inherently incremental and distributed nature of science learning. Although individuals were asked about science they knew and their interest in science, this knowledge and interest could have derived from many sources. As a first approach, the public was asked to ascribe a source of their knowledge and interest in science. This approach, however, was insufficient since the cumulative nature of learning makes attribution challenging, even for the most thoughtful and reflective individuals. An innovation of this research, therefore, was to create a "marker" for the Science Center experience. The idea was to find a learning equivalent of a radioactive tracer; something that in and of itself may or may not be highly important, but which could be considered an indicator of something greater that was meaningful. The goal was to find a concept, idea, or word for which understanding could be mostly attributed to this Science Center. The concept of "homeostasis" was chosen for this purpose. The concept of homeostasis is fundamental in physiology, but is not a term with which most people are familiar, despite it being addressed in most high school biology courses. However, one of the iconic new exhibits in the redesigned Science Center was an auditorium show featuring a 15 m (50 foot) animatronic woman named *Tess* and her animated sidekick *Walt*. A 10-minute show describes how the human body has variables such as core body temperature and oxygen levels that it needs to keep relatively constant to stay healthy, and that when faced with physiological challenges, the body works to keep these variables fairly constant by all of the body's organs working together in a process called homeostasis. In short, the exhibit was expressly designed to tangibly and engagingly teach visitors this important, but relatively poorly understood scientific concept.

The second challenge to measuring the impact of a Science Center on its community arises from the infrastructural nature of science education—the presence of a myriad of sources contributing to science learning and how to measure the role of particular parts of this infrastructure. To address this challenge, longitudinal data were collected across multiple years, including shortly after the totally rebuilt Science Center reopened and again a decade after this opening. It was hoped that this approach would make it possible to see change over time in both science knowledge and interest, and thus indirectly allow one to ascribe some of this change to the presence of this new piece of infrastructure. The research described in this article builds on two previous studies: (a) a 1996 qualitative investigation ($n = 200$) conducted in shopping malls, libraries, and parks throughout greater L.A. (Falk & Amin, 1997); and (b) a 1997 telephone survey in greater L.A. ($n = 1{,}007$; Falk, Brooks, & Amin, 2001).

Two large overarching research questions were posed:

(1) Who in L.A. has visited the California Science Center and what factors best describe those who have and those who have not visited?

(2) Does visiting the California Science Center impact public science understanding, attitudes, and behaviors, and if so, in what ways?

Methods

In 2000, a random sample of L.A. county adults 18 years of age and over ($n = 832$) was interviewed by telephone. Interviewees were drawn from five racially, ethnically, and socio-economically different communities—Canoga Park, El Monte, Santa Monica, Torrance, and South Central L.A. These communities were selected to be generally representative of the diversity of greater L.A. residents (Falk et al., 2001). A similar population was contacted by telephone in 2009 using a comparable instrument ($n = 1{,}008$). Fourteen percent of the 2000 survey respondents were interviewed in Spanish; 8% of the 2009 interviews were in Spanish. All remaining individuals were interviewed in English.

Questions relevant to this article were embedded within a larger interview protocol that was broadly designed to assess public use of community resources for learning science in general and those of the California Science Center in particular. Telephone surveys took an average of 19 minutes to complete and were conducted in the late morning and early evening hours, usually between 10:30 a.m. and 09:30 p.m. (Pacific Time) seven days a week over 6-week periods (February 23–April 16, 2000; January 28–March 9, 2009). The most productive times to conduct surveys were weekends and evenings. The survey instruments mostly consisted of close-ended items, with a few open-ended questions. The two instruments contained mostly comparable items, but there were some differences, as the 2009 instrument was modified to reflect evolving insights into how to assess issues being investigated. Open-ended responses were recorded verbatim in lists, phrases, and short sentences. Order of questions in the interviews was randomly rotated to avoid order effects and set patterns in responses. All questions were randomly monitored for interviewer quality. Only results of questions directly related to impacts of the Science Center are reported here.

Demographics of the two samples were not totally comparable. Although an effort was made in 2009 to include cellular telephones in the sample, they still represented less than 10% of the sample. It was assumed that demographic differences between the samples were partly a consequence of the significant decline in use of telephone landlines over the past decade, so to ensure comparability and representativeness, both the 2000 and 2009 sample data were weighted by U.S. Census data. The weighted samples were comparable to both U.S. Census data and to each other, with the exception that the 2009 sample included slightly higher percentages of respondents with higher incomes and undergraduate and/or graduate college degrees (Table 1).

Results

Who Visits the Science Center?

Since the Science Center reopened in 1998, it has recorded in excess of 1 million visitors per year. Approximately 2 years after reopening, slightly more than 23% of the L.A. adult population sampled self-reported that they had visited the Science Center. Ten years after opening, 45% of L.A. adults self-reported that they had visited the Science Center, 12% within the last 12 months. In addition, 37% of 2009 respondents indicated that they had children under the age of 18 years, 49% of whom had visited the Science Center. This could be extrapolated to suggest that roughly half of the 30% of L.A. residents who are children have also visited the Science Center. Collectively then, as of 2009 more than half (approximately 60%) of L.A. residents had visited the Science Center. In 2009, among those who indicated that they had visited the Science Center, the average number of visits per individual was 3. Visitors were drawn from all segments of society. In both 2000 and 2009, age and gender did not correlate with those who did or did not visit this center. There were, however, significant relationships between visitation and education, income, and length of time living in southern California, $\chi^2 = 3.83–45.66, p = 0.05$ to <0.001. Individuals with more education, longer length of residence in southern California, and higher income were more likely to have visited this center. The effect sizes (e.g., Cramer's *V*, point-biserial correlation or r_{pb}), however, ranged from only 0.10 to 0.22, suggesting that these relationships between visitation and sociodemographic characteristics were relatively "weak" (Cohen, 1988) or "minimal" (Vaske, 2008).

A range of questions were asked about respondents' current and early childhood leisure, science and technology related activities, and experiences. Most adult activities significantly declined between 2000 and

Table 1
*Demographic distributions of samples**

	2000	2009
Gender		
Male	41	44
Female	59	56
Mean age (years)	43	43
Race/ethnicity		
White/Caucasian	46	46
Black/African American	13	16
Latino/Hispanic	29	25
Asian American	7	8
Other	5	5
Household income		
<$50,000/year	56	38
> $50,000/year	44	62
Education level achieved		
High school or less	35	28
Some college or technical school	27	24
College degree	22	28
Graduate degree	16	19
Mean length living in L.A. (years)	31	30

*Cell entries are percentages unless specified as means.

2009 except Internet use, watching educational programs on television, and listening to educational programs on radio, tapes, or compact disks, which significantly increased. Self-reported visitation to museums, Science Centers, aquariums, or zoos did not change across years. Table 2 summarizes 2009 respondents' current leisure activities as a function of visiting or not visiting the Science Center and Table 3 summarizes 2009 respondents' childhood leisure activities as a function of visiting or not visiting the center. Adults visiting the center were significantly more likely than non-visitors to participate in all of the educationally oriented leisure activities, except taking science or technology related classes. Adults visiting the Science Center were also significantly more likely than non-visitors to participate in all but two of the childhood activities. The exceptions were attending science or technology related classes and listening to educational radio programs, audio tapes, or compact disks.

Impact of Visiting the Science Center

Beginning with self-reports about their children's learning, adults were quite positive about the impact of the Science Center experience on their children. Given that there were no substantive differences between 2000 and 2009 adult opinions about impacts of the Science Center on their children, only 2009 data are reported here. Nearly all adults (87%) who indicated that their children had visited the Science Center reported that the visit increased their children's science or technology understanding, with 45% believing that the experience increased their children's understanding "a lot." Similarly, a high percentage agreed that the center increased their child's appreciation for (80%) and interest in (78%) science or technology. Most adult respondents (79%) also believed that visiting the Science Center increased their child's curiosity about science or technology, with 44% believing that the experience increased their children's curiosity "a lot." In total, 79% of adults reported that their child's experiences at the Science Center provided an opportunity for them to talk with their child about some aspect of science and/or technology. The lowest perceived impact was that the Science Center experience changed their child's science-related behaviors, as 53% of adults indicated that visiting the center changed their child's behavior and only 21% believed that visiting changed their child's behavior "a lot."

Most adult respondents (74%) believed that the Science Center experience inspired their children to learn more about some aspect of science or technology after the visit, with 44% believing that visiting the center inspired their child "a lot." Parents of minority groups (e.g., African American, Asian, Latino/a) were significantly more likely than white parents to agree with this statement, $F = 4.33$, $p = 0.002$, eta (η) effect

Table 2
Differences in 2009 activities for those who did and did not visit the Science Center

Activity	Ever Visited California Science Center[1] No (55%)	Ever Visited California Science Center[1] Yes (45%)	t-Value	p-Value	Effect Size (r_{pb})
Read books, magazines, or newspapers	4.31	4.56	3.59	<0.001	0.11
Read books, magazines, or newspaper articles about science or technology	2.65	3.28	5.67	<0.001	0.18
Do hobbies or participate in a hobby club or group that involves science or technology	0.81	1.10	2.80	0.005	0.09
Use the Internet	3.63	4.41	6.95	<0.001	0.21
Use the Internet to search for or learn about science or technology	2.19	2.93	6.31	<0.001	0.20
Take classes	1.20	1.44	2.13	0.034	0.07
Take science or technology related classes	0.60	0.70	1.16	0.247	0.04
Do activities with an organized club, church, or religious group	1.66	2.10	3.82	<0.001	0.12
Watch educational programs on TV, or cable TV channels	3.53	3.89	3.93	<0.001	0.13
Listen to educational radio programs, audio tapes, or CDs	1.84	2.20	2.75	0.006	0.09
Go to libraries	1.82	2.17	3.45	0.001	0.11
Go to museums, Science Centers, aquariums, or zoos	1.33	1.81	7.34	<0.001	0.23
Go on family trips or outings	1.85	2.36	6.07	<0.001	0.19
Participate in a science or technology related club or group like an astronomy club, birding club, or hobby airplane group	0.33	0.49	2.43	0.015	0.08

[1]Cell entries are means on 6-point scale: 0 = never; 1 = once a year; 2 = several times a year; 3 = monthly; 4 = weekly; 5 = daily.

size = 0.31; and lower income parents were also more likely to agree, $t = 4.66$, $p < 0.001$, $r_{pb} = 0.31$. Over 79% of adult respondents also believed that their child's visit to the center enhanced their child's chances of future success in life, with 46% believing that visiting enhanced their success "a lot." Minority parents were significantly more likely to agree with this statement, $F = 3.95$, $p = 0.004$, $\eta = 0.30$; and lower income parents were also more likely to agree, $t = 3.54$, $p = 0.001$, $r_{pb} = 0.24$. These effect sizes suggest that

Table 3
Differences in 2009 childhood activities for those who did and did not visit the Science Center

Childhood Activity	Ever Visited California Science Center[1] No (55%)	Ever Visited California Science Center[1] Yes (45%)	t-Value	p-Value	Effect Size (r_{pb})
Read books, magazines, or newspaper articles about science or technology	1.45	1.78	4.66	<0.001	0.15
Did hobbies or participated in a hobby club or group that involved science or technology	0.81	0.96	2.05	0.040	0.07
Took science or technology related classes outside of school	0.47	0.42	1.04	0.297	0.03
Watched educational programs on TV, or cable TV channels	1.09	1.41	4.14	<0.001	0.13
Listened to educational radio programs, audio tapes, or CDs	0.50	0.59	1.61	0.108	0.05
Went to libraries	1.96	2.36	6.31	<0.001	0.20
Visited museums, Science Centers, aquariums, or zoos	1.55	1.87	4.91	<0.001	0.16
Went on extended family trips or outings to national parks or other learning sites	1.32	1.62	4.21	<0.001	0.14
Participated in scouts, clubs, or other organized groups	1.26	1.60	4.26	<0.001	0.14

[1]Cell entries are means on 4-point scale: 0 = not at all; 1 = a little; 2 = some; 3 = a lot.

relationships among income, minority status, and impacts of the Science Center on children were ''medium'' (Cohen, 1988) or ''typical'' (Vaske, 2008).

When talking about themselves, adults also self-reported a range of positive outcomes from their visit(s) to the Science Center. Four core outcome statements were common to both the 2000 and 2009 surveys and an additional 14 items were added to the 2009 survey to capture more possible outcomes. Table 4 provides mean responses for the four common questions across each of the 2 years. In 2009, respondents were significantly more likely to agree that as a result of visiting the Science Center, they learned one or more things that they did not know before, their understanding of things that they already knew was strengthened, and their attitudes or behaviors were more positive toward science or technology. Respondents in 2009, however, were significantly less likely to agree that visiting the center gave them a stronger interest in some aspect of science. Responses to the 18 items asked in the 2009 survey showed that virtually all adults (95%) agreed (56% strongly) with the statement ''my understanding of science or technology was strengthened or extended by my visit to the California Science Center''; 92% agreed (65% strongly) that their appreciation for science and technology increased because of their visit; and 94% agreed (70% strongly) with ''I learned at least one thing about science or technology that I never knew before.'' Similarly, 85% agreed (45% strongly) with the statement ''my curiosity about science or technology was increased by visits to the California Science Center''; 81% agreed (51% strongly) that their visit reminded them of something about science or technology that they had forgotten or not thought about in a while; and 83% agreed (44% strongly) with the statement ''after visiting the California Science Center, I found myself thinking about some aspect of science or technology.'' Furthermore, 63% agreed (29% strongly) that their visit stimulated their interest in science and technology; 46% agreed (19% strongly) that the visit changed their behavior regarding science and technology; and 49% agreed (23% strongly) that their visit gave them some new ideas or techniques that they could use in their work or hobbies. Minorities were significantly more likely to agree with statements about the Science Center providing new ideas or techniques for work or hobbies, changing attitudes toward being more positive about science or technology, and changing behavior regarding science or technology, $F = 7.15–17.77, p < 0.001, \eta = 0.26–0.39$. Lower income respondents were also significantly more likely to agree with most statements, especially about the Science Center providing new ideas or techniques, changing attitudes about science or technology, and changing behavior regarding science or technology, $t = 4.19–5.49$, $p < 0.001$, $r_{pb} = 0.19–0.27$.

In addition to these quantitative questions, respondents were also given an opportunity to describe in their own words examples of what they believed they learned as a consequence of visiting the Science Center. Answers came from all areas of science covered at this particular Science Center and there were no responses that could be construed as covering topics not addressed at this Science Center. In the 2009 sample, the distribution of responses was: human body (51%), physics (11%), earth science (9%), particular animals (7%), new technology (5%), electricity (4%), environment (4%), and transportation (2%). Example responses included: ''DNA stands for Deoxyribonucleic Acid''; ''...about electricity, about how current flows, that was pretty interesting''; ''something about the way cars were built that helps add velocity that helps a car be more aerodynamic''; ''the digestive system and how food is broken [down] in your system'';

Table 4
Agreement with impact statements by year

Impact Statements	Year[1]		*t*-Value	*p*-Value	Effect Size (r_{pb})
	2000	2009			
I learned one or more things that I never knew before	4.36	4.60	3.27	0.001	0.14
My understanding of things I already knew was strengthened or extended	4.23	4.48	3.61	<0.001	0.15
I came away with a stronger interest in some area of science or technology	3.97	3.55	3.91	<0.001	0.15
It changed my attitudes or behaviors to be more positive toward science or technology	3.48	3.84	3.84	0.003	0.13

[1]Cell entries are means on 5-point scale: 1 = strongly disagree; 2 = somewhat disagree; 3 = neither; 4 = somewhat agree; 5 = strongly agree.

"exhibit of Tess (human body) shows the interrelationship of body parts and how things are balanced"; "one particular thing I remember, whatever you drop on the street, it will go to the ocean and affect the whole ecosystem, the fish and everything else"; and "I learned about eating better. I should know that for myself. My son knows that, but I guess I didn't. The importance of eating well, and also the importance of recycling. How much garbage American's have."

To confirm that much of what is learned at a Science Center is "what people, sort of already know" (Falk & Dierking, 2000), respondents in 2009 were asked after providing their example "how much did you know about what you learned before visiting the California Science Center?" Only 7% of respondents answered "a lot" and 24% indicated "nothing at all," whereas over two-thirds (69%) indicated "some" or "a little."

Science Knowledge and Science Center Use

Individuals were asked to self-report how knowledgeable, in general, they were about science and technology. In total, 41% of the 2009 sample said "yes" to the question "is there an area of science or technology in which you consider yourself particularly well informed or knowledgeable?" When asked to give examples of their knowledge, responses fell into several major categories: computers (27%), biology (16%), medicine/health (16%), electronics (12%), environmental issues (10%), astronomy (8%), aerospace/aviation (5%), physics/chemistry (5%), and engineering (5%). There were significant positive relationships between those who self-reported being well informed about science and technology, and visits to the Science Center (Table 5). In addition, the more frequently an individual visited this Science Center, the greater their self-reported perception that they were well-informed about science, $F = 11.75$, $p < 0.001$, $\eta = 0.15$.

Homeostasis Marker

These learning data are based on self-reports and raise questions about accuracy and attribution. Knowledge of the concept of homeostasis, therefore, was used as a "marker" to provide a more direct gauge of whether actual learning did or did not occur, and whether it could be considered a consequence of visiting the Science Center. Although no true baseline was collected through a comparable telephone survey prior to the opening of the new Science Center, a useable baseline was created by randomly sampling visitors during the first 3 months that the new Science Center was open (i.e., "*inside out*" study). This visitor population consisted almost exclusively of first time visitors to the new Science Center and thus it was reasonably assumed that any entering understanding they possessed of the concept of homeostasis derived from learning that occurred outside the Science Center. Further, since Science Center visitors in general are more likely to be knowledgeable of science than the general public given their self-selected interest in visiting a Science Center, this should represent a conservative estimate of the baseline L.A. publics' understanding of the concept of homeostasis. Five human physiology professionals were polled and asked to define homeostasis; the final single agreed upon definition was—homeostasis is the balance or equilibrium that organisms or cells strive to maintain. In this 1998 study, only 7% of visitors entering the Science Center could provide an acceptable definition of homeostasis, but 57% could do so upon exiting. These findings were consistent with other data showing that 72% of all first-time visitors to the center went to the show where *Tess*, the 50 foot animatronic woman and her sidekick *Walt* explained homeostasis, and 85% of these individuals were able to provide an acceptable definition of this concept after the show (Falk & Amin, 1999). Thus, the baseline

Table 5
Differences in amount informed about science and technology based on whether respondents had visited the Science Center

	Ever Visited California Science Center[1]				
	No	Yes	t-Value	p-Value	Effect Size (r_{pb})
2000	1.82	2.20	3.73	<0.001	0.18
2009	2.13	2.52	5.53	<0.001	0.17
Total	2.04	2.49	9.12	<0.001	0.20

[1]Cell entries are means on 5-point scale: 0 = not informed at all; 1 = only somewhat informed; 2 = informed about average; 3 = reasonably well informed; 4 = very well informed.

percentage of those in the L.A. area able to correctly identify homeostasis prior to opening of the Science Center can be assumed to have been 7% or less.

Two years after reopening of the Science Center, nearly half of the public said they had heard of homeostasis (44%) and 10% of respondents could give an acceptable definition of the word. This represented a significant increase from 1998, $\chi^2 = 5.46, p = 0.02$. As of 2009, the overall number of individuals in the L.A. area claiming to have heard of homeostasis had not changed much (41%), but those who could correctly define the word had doubled to 20%, which was significantly greater than in 2000, $\chi^2 = 20.85$, $p < 0.001$. Individuals able to correctly define homeostasis were significantly more likely to have visited this Science Center both in 2000 where 75% of those able to correctly define homeostasis had visited the Science Center and in 2009 where 61% of individuals able to define homeostasis had visited the Science Center, $\chi^2 = 11.76$–35.93, $p \leq 0.001$. Interestingly, among those individuals able to correctly define homeostasis, only 2% of respondents in 2000 and 14% in 2009 claimed that they learned the concept at the Science Center; large majorities in both years attributed their knowledge of homeostasis to schooling. Regardless of attribution, however, there was a significant relationship between being able to correctly define homeostasis and having visited the Science Center.

Discussion

Taken together, these results suggest that the Science Center is having an impact on the L.A. community. Close to half (45%) of L.A. adults have visited this Science Center since it reopened in 1998. Visitors are broadly representative of the general population of greater L.A. including individuals from all races and ethnicities, ages, and income levels, although individuals with slightly higher incomes and education are more likely to visit. Given that the Science Center estimates that approximately half of all its visitors are children, the actual percentage of the L.A. public who has visited this Science Center is likely in the neighborhood of 60% of residents.

Although demographic variables were relatively weak indicators of whether an individual did or did not visit the Science Center, participation in educationally oriented leisure activities as an adult and as a child was highly indicative. People who participated in leisure free-choice learning activities were significantly more likely to visit this Science Center. Two demographic variables that correlated with visitation are income and education, and this finding is not surprising because a determinant of participation in free-choice learning experiences is a belief in the importance of life-long learning and a willingness and financial ability to engage in leisure for that purpose (Falk & Heimlich, 2009).

Although responses of parents about their children's experiences at the Science Center are second hand and thus need to be viewed with some caution, they were overwhelmingly positive. Most adults perceived that their children derived significant benefit from their experiences at the Science Center. Between 70% and 80% of adults with children reported that their children learned new science, were inspired by their visit to extend their science learning, and that the Science Center increased their child's interest, curiosity, and attentiveness to science. Adults also reported that a visit to this Science Center resulted in their children engaging in science-related activities following their visit. There was an indication, although weaker, that a visit to the Science Center also changed children's behaviors related to science or technology. An important finding was that adults strongly agreed that the Science Center created opportunities for them to talk with their children about science or technology, and that it gave their child opportunities in life not supported by other organizations or institutions in the community. Some of these perceptions of the value of this Science Center were particularly strong among lower income and minority adults in L.A. In this regard, it could be suggested that the Science Center added to the "funds of knowledge" (González, Moll, & Amanti, 2005) of minority and low income adults and children, and were perceived as representing meaningful and important repertoires of practice. The Science Center was perceived as a gateway experience to future success. Given that there is evidence that traditional classroom practices have been found to privilege majority and upper income children (Cobern & Aikenhead, 1998; Kurth, Anderson, & Palincsar, 2002; Lee & Fradd, 1998; Moje, Collazo, Carillo, & Marx, 2001), these findings are particularly interesting and encouraging and worth further study; particularly given the dearth of confirmatory data in the literature.

Almost every adult community member surveyed who had previously visited the Science Center agreed that their visits to this institution resulted in an increase in their science and technology knowledge and understanding, and respondents were able to back up their self-reports with specific examples of things they learned. These examples of increased understanding spanned the range of topics and content areas covered at the Science Center. Most of these respondents also reported increases in other dimensions of science and technology learning, including increases in the affective dimensions of curiosity, interest, and appreciation, as well as in their science and technology behaviors and capabilities. These results are supported by dozens of summative Science Center exhibition evaluations that have been conducted showing that adult visitors learn from their experiences as well as show positive changes in science affect (Bell et al., 2009). However, the strength and relatively unique ''*outside-in*'' nature of this particular data set represent a singularly strong endorsement of the value and durability of these ephemeral free-choice learning experiences on the public's science literacy. Except for interest in science, strength of this agreement increased significantly across the decade since the new California Science Center was opened. It is not clear why interest in science declined.

In general, self reported impacts were slightly higher for cognitive outcomes (e.g., increased understanding, learning, and thinking about science or technology) than for affective outcomes (e.g., increased appreciation and curiosity). This finding is interesting because it runs counter to the longstanding assertion made by many in the Science Center profession that a primary outcome of these centers and other such ''designed spaces'' is enhancing affect (Bell et al., 2009). One possible explanation for the higher reported levels of cognition versus affect is that the self-selected group who visited the Science Center already possessed high interest, curiosity, and appreciation for science and technology. These existing high levels would tend to diminish the chances of further increases in affect and at the same time enhance the chances of increases in cognition. However, insufficient evidence exists to fully explain this outcome and findings suggest that this too is an important area for future research.

The homeostasis marker allowed this research to move beyond some of the problems with self-report data and show that a visit to this Science Center directly contributed to public understanding of science. The change over a decade in the L.A. public's understanding of the concept of homeostasis provides strong evidence that the Science Center was responsible for improving public long-term science knowledge and understanding. It is reasonable to believe that learning of science and technology went far beyond just learning this single concept. As shown by reported outcomes from a visit, changes in science understanding, attitudes, and behaviors occurred across a range of topics. In fact, learning about homeostasis was only rarely singled out as one of the specific learning outcomes of a visit.

Another important finding revealed by the homeostasis ''marker'' was that despite evidence that for most people the ability to accurately define the concept of homeostasis was directly tied to their experiences at the Science Center, most attributed their understanding of homeostasis to their initial exposure, which was school. These results raise the provocative possibility that the overwhelmingly positive self-reports of Science Center impact may actually represent underreports of impact.

Directly tied to the attribution findings of the homeostasis marker was the finding that the Science Center appeared to be primarily reinforcing and extending visitors' previous knowledge rather than adding ''new'' knowledge. Adults in this study reported that the majority of what they learned was content that they ''sort of already knew.'' Although hypothesized nearly a decade ago (Falk & Dierking, 2000), data from this study provide an empirical basis for this conclusion. This finding has real implications for the ability of the Science Center and other comparable institutions to take credit for the educational value that they provide to society. Our culture has developed strong and arguably misplaced conceptions about the nature of learning. Although ''learning'' is both a process of gaining ''new'' knowledge as well as equally a process of ''building and strengthening'' existing knowledge (Bransford et al., 2000), our society tends to privilege only the former. Accordingly, we tend to place greater value on educational experiences that provided first exposure to a topic than we do to experiences that provided essential support and understanding that allows a topic to become deeply known. Since schools tend to be places where most science concepts are first presented, this societal bias represents a particular challenge to free-choice learning institutions such as the California Science Center that appear to particularly support the building and strengthening of knowledge.

Findings also demonstrated a relationship between public perceptions of science understanding and visits to the Science Center. Individuals who had visited this Science Center were more likely to feel informed about science, and this relationship increased with frequency of visitation. Although the data reveal that the Science Center is just one of many sources in L.A. that the public uses to learn about science and technology, the data also show that it is an important part of the public science learning infrastructure, making a measurable contribution to the science literacy of a large number of citizens. This result is reinforced by the fact that a large number of adults who visited this Science Center, including minority and lower income adults, believed that the Science Center provided them and their children with important learning opportunities. In fact, minority and lower income adults not only shared these beliefs, but believed this to be true for several important outcomes in significantly greater numbers than their majority and more affluent counterparts.

In summary, findings from this research provide strong evidence that the California Science Center directly and significantly contributes to science learning, interests, and behaviors of a large subset of the L.A. community. Over the course of a decade, over half of the population of L.A. has visited this center and apparently a large percentage of those who have visited have been impacted positively. The homeostasis marker and other data suggest that self-reports of impact are unlikely to be over-reporting impact; if anything, the impact of this Science Center on science and technology learning, interest, and behavior might actually be even greater than indicated by the data reported here. It is reasonable to assume that over time, the percentage of the L.A. population that is being impacted by this Science Center will continue to grow, and of course these data do not account for the hundreds of thousands of individuals from beyond the L.A. area who have also visited this center.

So how generalizable are these findings to other institutions in other communities? Clearly, each institution and community is unique. The California Science Center, for example, is notable among science centers in the United States for the demographic diversity of its visitor population; a diversity that closely mirrors the demographic profile of the general population that it serves. This may be due to several factors including its free admission policy, integration within a multiethnic neighborhood of L.A., and location within an ethnically diverse metropolitan area. It is unclear how this diversity impacted findings for its visitors in general and most significantly for those visitors who have been traditionally underserved by other free-choice learning institutions. Although it is not possible to directly generalize findings from this one institution to all Science Centers and other comparable free-choice learning institutions, it is reasonable to assume that other similar institutions are also having positive impacts on their communities. To really understand these impacts, other institutions will need to conduct this kind of research. If and when such research is conducted, it is likely that variability across institutions and cities would be observed. Regardless, this comprehensive multi-year investigation of the impact of a single Science Center on its community provides initial support for the contention that free-choice science learning institutions make important contributions to their community's public education in general and science education in particular.

The authors thank the Noyce Foundation and California Science Center for supporting this series of studies. Special thanks to Dr. David Bibas and Mr. Jeff Rudolph for their support over the years and Dr. Ann Muscat for helping launch this project in the first place. Earlier versions of this article were presented at the Annual Meetings of the Visitor Studies Association and Association of Science Technology Centers.

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