International Science Centre Impact Study

Final Report

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EXECUTIVE SUMMARY

Hundreds of millions of youth and adults visit science centers across the world. Although science centers have long asserted that these visits play a critical role in supporting the science learning of the public, robust and unequivocal evidence is limited. The International Science Centre Impact Study, a consortium of 17 science centers in 13 countries under the direction of John H. Falk Research, was designed to empirically determine whether experiences at science centres correlated with a range of critical public science and technology literacy outcomes.

Because of the complex and cumulative nature of science and technology learning, an epidemiological research approach was used. Epidemiological approaches are designed to demonstrate, with specific statistical certainty whether certain factors do or do not correlate with an outcome. A questionnaire was developed, pilot tested and administered in each of the 17 communities to a representative sample of: 1) all youth ages 14–15 (n=5,792); and 2) all adults ages 18 and over (n=6,089) living within the target communities. Roughly half of all 14- to 15-year-old youth (47%) and less than half of all adults (44%) in the combined sample had visited one of the science centers at least once during their lifetime.

Results strongly supported the contention that individuals who used science centres were significantly more likely to be science and technology literate and engaged citizens.

- For both youth and adults, visiting a science centre significantly correlated with increased: Science and technology knowledge and understanding; Science and technology interest and curiosity; Engagement with and interest in science as a school subject (youth); Engagement with science and technology-related activities out-of-school; and Personal identity and confidence in science and technology.
- Although correlations were significant for both youth ages 14-15 and adults ages 18 and above, the effect sizes were almost universally stronger for adults.
- The more frequent, the longer, and the more recent the science centre experience, the stronger the correlation for all outcomes.
- For adults in general and youth relative to interest and curiosity, there appeared to be a threshold effect with greatest incremental change seen when individuals visited between two and four times a year, but not more. Similarly, correlations were relatively flat for visits lasting up to four hours, but then increased markedly after five or more hours.
- In general, visiting a science centre resulted in significant correlations regardless of the specific nature of the experience. An important exception was adults who said their typical science centre experience was a school field trip.

Results enable the participating science centres, and by extension others within the science centre community to state with much greater confidence that the presence of one or more healthy and active science centres within a community, region, or country represents a vital mechanism for creating and maintaining a scientifically and technologically informed, engaged and literate public.

INTRODUCTION

A range of studies have documented that children and adults pursue lifelong science interest and understanding in and out of school using a variety of community resources (e.g., libraries, science centres, aquariums and zoos, broadcast and print media and the Internet) (Baron, 2006; Bervan, 2010; Bell, Lewenstein, Shouse, & Feder, 2009; Falk & Dierking, 2010; Lemke, Lecuse, Cole & Michalchik, 2012; OECD, 2012; Stocklmayer, Rennie, & Gilbert, 2010). 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; Falk & Needham, 2013; Ito et al., 2013; Korpan, Bisanz, Boehme, & Lynch, 1997; NSB, 2012). Although it is increasingly appreciated that many institutions and forms of media significantly contribute to science learning, formal education still garners most of the recognition and resources (Falk & Dierking, 2010; Falk, Osborne, Dierking, Dawson, Wenger, & Wong, 2012).

Every year, hundreds of millions of youth and adults of all backgrounds visit science centres across Europe, Asia, North America, Latin America, Australia, and other regions. Science centres have long argued that they make science accessible to a broad range of people in innovative, engaging and enjoyable ways. Science centre programming is diverse and involves visitors of all ages in science through short-term school and family excursion experiences, as well as through intensive long-term programs and courses during and outside of school hours. Although science centres have long asserted that they play a critical role in supporting the science learning of the public, comprehensive supporting data are limited. Although evidence showing the contribution of science centres to public science learning certainly exists (e.g., ASDC, 2008; ASTC, ND; Bell et al., 2009; Dierking, 2012; Falk & Dierking, 2010; Falk & Needham, 2011; Falk & Storksdieck, 2010; McCreedy & Dierking, 2013; 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 exists.

This investigation of a large sample of the public across numerous contexts and countries (17 institutions in 13 countries) was designed to determine if, how, and under what circumstances experiences at science centres significantly contributed to the public's knowledge and understanding of science, interest in science, engagement with science both in and outside of formal education and the workplace, creativity and problem solving abilities, and adoption of science-related vocations and avocations.

BACKGROUND

Nature of Learning   Any study of learning must first clarify its epistemology – the assumptions it makes about the nature of learning. Learning in general and science learning in particular, is rarely, if ever, immediate. Most individuals develop interest, understanding and identity related to science through an accumulation of experiences from different sources at different times (e.g., Baron, 2006; Bell, Lewenstein, Shouse, & Feder, 2009; Falk & Dierking, 2010; Lemke, Lecuse, Cole ,& Michalchik, 2012; OECD, 2012; Stocklmayer, Rennie, & Gilbert, 2010; Renninger & Riley, 2013). For instance, a young science learner experiences a range of different science learning opportunities in a variety of contexts including his or her school classroom, after-school science program at school, holiday programs at local science centers, visits to botanic gardens and science festivals, weekend mornings spent at a local library and, of course, time at home. From the perspective of the science learner, the context in which he or she encounters science may change moment to moment, but all of these experiences seamlessly contribute to stimulating and sustaining interests and motivation in a topic (Hidi & Renniger, 2006). This understanding of learning has significant implications for how one measures learning.

Understanding the Contribution of Science Centres to Learning   Learning in general, and learning resulting from experiences at a science centre in particular, is almost always additive and frequently episodic. In other words, using a pharmaceutical metaphor, it is extremely difficult in any educational experience but particularly within a science centre context, to completely define and delimit either the educational "dosage" or possible "impact" of learning sufficiently to ensure that resulting outcomes are solely the result of that single educational experience. In the case of a science centre visit, all visitors enter the experience with partially to well-formed interests, knowledge, opinions and motivations that directly influence learning (Bell et al., 2009; Falk & Dierking, 2000; 2013). As shown from research at the California Science Center in Los Angeles and in a study of the long-term (5-20+years) impacts of gender-focused science programming, learners build their understanding and appreciation for science over time by utilizing multiple resources (e.g., Falk & Needham, 2011, Falk & Storksdieck, 2010; McCreedy & Dierking, 2013). There is also growing recognition that some impacts related to understanding of scientific practices reside within social groups in which people visit (e.g., families, school groups), not solely within any one individual's mind. It is imprudent to assume that any one individual or group of individuals has a singular, clear or consistent "beginning state." Thus, one cannot presume any degree of homogeneity with regard to science centre audiences; they do not, as is sometimes assumed in schooling, come in "ignorant" and leave "smart." The reality is that these simplified views of learning rarely, if ever, occur either in or out of school (Bransford, Brown, & Cocking, 2000).

Additional challenges in measurement are exacerbated by several interrelated factors, all related to choice; all of which involve some measure of self-selection bias. First, all learners, even school-aged children and youth, enter institutions 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 centres, most visitors, adult as well as youth and children, choose whether to visit or not. Further, even when visitation is not a matter of choice, e.g., during a school visit, learners almost always exercise considerable choice in determining what topics or exhibitions to pay attention to and what content to learn predicated on what they think is personally important and interesting. Clearly, the free-choice nature of science centre learning complicates any efforts to control variables and entering predispositions. Any effort to "randomly" assign a science centre experience to one group, but not to another consequently results in a raft of logistical, internal validity and ethical issues that potentially undermine the credibility of findings. More than two decades of research has shown that standard randomized-control-treatment (RCT) research designs using traditional pre-and post-test assessments result in inaccurate measures of learning in free-choice settings (e.g., Falk & Dierking, 2000) and this is particularly true of studies that have attempted to understand long-term impacts (Anderson, Storksdieck, & Spock, 2006; Falk, Scott, Dierking, Rennie & Cohen Jones, 2004). The reason this is true is because the free-choice nature of science centre learning is not an annoying variable or "noise" that can be eliminated to support more accurate measurement; it is arguably a *key* aspect of what makes science centres effective learning institutions (Falk, 2001). To remove such an essential aspect of the learning is not appropriate. Thus, the most valid approach is one that frames research questions in terms of the "contributions" that a specific science centre experience makes to learning (e.g., Falk, Storksdieck, & Dierking, 2007; Falk & Needham, 2011).

<u>Researching "Contributions" rather than "Causes"</u> Given the complex and cumulative nature of science learning, and the highly variable and free-choice nature of science centre experiences, an "epidemiological" research approach was used for this project (e.g., Checkoway, Pearce, & Kriebel 2004; McNeil, 1996; Rothman, 2002). The methodological challenges outlined above reflect the realities that epidemiologists have faced for decades (Buck et al., 1998; Morabia, 2004). Over time, epidemiologists have learned that life is too complex with far too many interconnected factors that interact over time to generate valid predictive models of human health and wellbeing using RCT methods, even for something as seemingly concrete as a disease such as tuberculosis or the flu. For example, factors such as initial state of physical health, exposure details, genetics and stress levels and other mental characteristics at the time of exposure can significantly impact whether someone gets a disease and if they recover (Buck et al., 1998). The presence of these interconnected and correlated variables typically invalidates assumptions required to establish clearly definable "treatment" and "control" groups. And, this is just the case for "simple" models such as 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 and interacting factors (e.g., Erkkilä et al., 2008; Jaquish, 2007; Wahrendorf, 1996).

To address these issues, research designs have been employed where it is impossible to fully isolate singular "cause and effect" variables, and instead the approach is to utilize correlational statistics to parse relationships and impacts (Checkoway, Pearce, & Kriebel, 2004; McNeil, 1996; Rothman, 2002). These approaches allow investigators to say with specific statistical certainty that certain vectors do or do not influence disease. This approach, for example, has successfully enabled development of current understanding of how smoking, exercise, diet, and genetics interact to collectively and synergistically contribute to heart disease (Jaquish, 2007). None of these factors alone account for why someone has a heart attack and cannot be isolated in ways demanded in typical pre-/post-test designs.

Measuring Impact There are many ways to define the "impact" of a science centre experience. Traditionally, the default measure of success has been how well science centres contribute to student success in school courses or on standardized tests measuring science facts and concepts. Although both of these approaches arguably make sense within a formal school context, these measures are not the only possible indicators of impact and may not be the best indicators of the contribution that science centres make to public science and technology literacy. The U.S. National Research Council (2012), for example, argued strongly that these types of measures are unduly narrow and restrictive, even when measuring the impacts of school experiences. Osborne and Dillon (2008) called for a new vision of science education that not only tries to support what we know and how we know it, but also the kinds of careers and avocations that science educational experiences afford, and why these careers and avocations are personally fulfilling, worthwhile and rewarding. Most experts agree (e.g., Layton, Davey, & Jenkins, 1986; Miller, 2007; Wagner, 2007) that a measure of successful science education impact for adults is their meaningful participation in science-related activities in society, again either vocations or avocations. Furthermore, as Falk and Storksdieck (2005, 2010) found at the California Science Centre, multiple measures of learning were required to sufficiently capture the full extent, breadth and depth of changes in visitor knowledge and understanding of science as a result of their experiences. Collectively, these findings suggest the need for a broad set of metrics to capture the impact that science centre experiences may contribute to public understanding and appreciation of science. Research undertaken in the present study attempted to broadly define and measure the relationship between science centres experiences and a wide range of possible outcomes. This report summarizes initial findings from this study's data.

RESEARCH OBJECTIVES

The research sought to empirically determine whether experiences at science centres significantly correlated with:

- Improved knowledge and understanding of science and technology.
- Increased engagement with science within the formal education system.
- Increased engagement with science and technology outside of formal education and the workplace (e.g., participation in clubs, hobbies, pro-science behaviors).
- Enhanced interest in science and technology.
- Greater creativity and problem solving abilities.
- Adoption of science and technology-related vocational and avocational trajectories.
- Greater identity as a science and technology-confident individual.

METHODS

Research Design Following an epidemiological research framework, this investigation analyzed the impact of science centres by determining relationships between specific independent variables related to the science centre experience and a range of long-term dependent variables focusing on desired outcomes such as public understanding, attitudes and behaviors associated with science. As is standard in epidemiological research (Morabia, 2004), and was used in recent studies at the California Science Centre (Falk & Needham, 2011, 2013), redundancy and independent tools for computing reliability were built into the design to ensure that self-reports were both valid and reliable.

The research involved surveys of youth (14-15 years of age) and adults (18 years of age and above) across 17 institutions in 13 countries (5 continents) having active science centre programs. Data were collected for: Heureka (Finland), Universeum (Sweden), Swedish Museum of Technology (Sweden), VilVite (Norway), Technopolis (Belgium), Centre for Life (UK), Ciencia Viva (Portugal), Singapore Science Centre (Singapore), National Museum of Natural Science (Taiwan), Patricia and Phillip Frost Museum of Science (U.S.)[1], Questacon (Australia), MIDE (Mexico), Maloka Science Center(Colombia), Science North (Canada), Ontario Science Centre (Canada), Canada Technology Museums Corporation (Canada) and TELUS Spark (Canada). All instrumentation for data collection, entry and analysis; training; and data analysis was implemented by the project research team. All data were collected and entered by institution staff, volunteers or contractors.

<u>Instrument Development</u> Project researchers, working in collaboration with cooperating science centres, developed and pilot-tested the instrument. Items were carefully selected and as many as possible were from existing instruments with an effort to identify items from highly reliable and valid international surveys such as PISA. The language of each institution's questionnaire was customized to be culturally relevant and appropriate, particularly items that clearly designated where a person lives, national annual median household income and the name of the science centre we were asking people to indicate whether or not they had visited. 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 and each institution could add 1-3 items of specific interest to them (either institution-specific or shared among a few institutions, e.g., Canadian institutions).

<u>Sampling</u> Each of the 17 participating science centres distributed surveys to two populations. The Population A sample was designed to be as close to a random sample of the science centre's community as limited resources and technologies allowed. In the absence of a single completely random sampling procedure, the project research team worked with each institution individually, using recent community-specific government census data compiled by institutions to create a sampling strategy that would approximate a random sample of youth

and adults within each community area.[2] Most Population A youth data was collected at schools, but occasionally individuals at community-based organizations were also sampled. For Population A adults, particular neighborhoods, shopping areas, parks, and other areas were identified to ensure that individuals broadly representative of all sectors of their population were included.[3] Each protocol was designed to create community-representative sampling that selected individuals from a pre-determined mix of geographies and venues to yield a final population reflective of the current distributions of individuals by age, income, educational level and other characteristics of those living within the community. Each centre was asked to target a sample size of 300 (14-15 year olds) youth and 300 adults, for a total minimum sample of approximately 600. Thus the target Population A sample size for the whole study was approximately 10,000 individuals.

For Population B, each science centre was tasked with collecting a convenience sample of 100 additional subjects comprised of at least 50 youth (14-15 year old) and 50 adults who were considered "best cases;" individuals who the institution knew were actively engaged science centre visitors for whom it could reasonably be assumed the science centre experience had been beneficial.[4] Institutions were instructed that Population B samples could be collected in any way and in any place that was convenient for them. The only requirements for inclusion in this sample were that individuals meet the "best case" criteria and that each participant complete the entire questionnaire (e.g., online, part of programs or classes, while someone is visiting the science centre). Population B samples included institutional members, youth and adult volunteers, and/or those who had participated in in-depth programming of some kind. The purpose of collecting this sample was to provide a best-case "control" group in the (hopefully unlikely) event that anticipated positive effects of the science centre experience were not immediately apparent within Population A. The target Population B sample size for the whole study was approximately 1,700 individuals.

Project researchers provided detailed directions on how to collect data, as well as conducted training for all staff (and/or volunteers) involved in data collection through a series of specially developed internet-based training webinars. Two separate two-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 each institution's ISCIS research coordinator and focused on an overview of the study and preparation guidelines. An overview of instrument development, Population A and B sampling, data collection and entry and skills/qualifications of those conducting data collection and entry was provided during this training.

The second webinar was targeted at those conducting the 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 Populations A and B 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 invite people to participate, tips for getting complete data, and how to manage data. The second portion of the training presented a sample form for data entry created by the research team, discussed getting started and provided some examples and troubleshooting tips.

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 data base by institution staff.

<u>Data Analysis</u> To ensure that the data represented the target populations from which they were drawn, the data were statistically weighted by age, sex (male, female), and population proportions based on the most recent Census data compiled from each of the 13 countries.

Data from the questionnaires were analyzed using parametric and non-parametric univariate (e.g., frequencies, percentages) and bivariate (e.g., t-tests, cross-tabulations, chi-square) inferential statistics. Reliability and construct validity of scales were examined using Cronbach alpha reliability analysis and exploratory factor analyses. 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_{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 .10, .30, and .50, and eta and point-biserial correlation values of .10, .24, and .37 are considered "small" or "minimal," "medium" or "typical," and "large" or "substantial," respectively.

Table 1 summarizes the final sample sizes for each of the 17 institutions

Table 1. Sample sizes for each institution.

		Population A (Representative)		Population B (Best Case)		
Institution	Country	Youth	Adult	Youth	Adult	Total
Canada Science & Technology Museum	Canada	250	250	28	0	528
Centre for Life	England	384	424	14	139	961
Ciencia Viva	Portugal	319	321	50	50	740
Heureka	Finland	336	379	50	50	815
Maloka Science Center	Colombia	469	406	51	52	978
Patricia and Phillip Frost Museum of Science	USA	253	256	50	50	609
Museo Interactivo de Economia (MIDE)	Mexico	384	384	50	50	868
National Museum of Natural Science	Taiwan	590	521	63	65	1239
Swedish National Museum of Science & Technology	Sweden	319	287	53	63	722
Ontario Science Center	Canada	250	250	42	99	641
Questacon National Science & Technology Centre	Australia	278	381	37	56	752
Science Centre Singapore	Singapore	333	412	30	30	805
Science North	Canada	322	385	16	60	783
Technopolis	Belgium	382	388	12	60	842
Telus Spark	Canada	253	392	40	66	751
Universeum	Sweden	308	258	51	50	667
VilVite – Bergen Science Centre	Norway	362	395	50	50	857
Total		5792	6089	687	990	13558

A total of 13,558 completed surveys were collected across the 17 communities – 5,792 Population A youth, 6,089 Population A adults for a total of 11,881 Population A subjects, and 687 Population B youth and 990 Population B adults for a total of 1,677 Population B subjects.

What follows are results by population, starting with Population A Youth and then Population A Adults. Based on a representative sampling of the general public collectively served across these 17 communities the analyses focused on the relationship between science centre experiences of varying frequency and intensity and the range of potential science and technology outcomes identified as important for this study. In addition to Population A results, a limited summary of Population B Youth and Population B Adults is also included. From the start, the major focus of this investigation was to determine whether experiences at science centres contributed to the overall science and technology literacy of a community, thus our concentration on Population A. That said, we do believe that comparisons between Populations A and B could yield interesting insights, but as of this writing that analysis has yet to be conducted.[5]

RESULTS

Population A Youth

Across the entire Population A Youth sample, visits to the science centre were roughly evenly divided between those indicating they had never visited or who were unsure of whether they had visited (53%) and those indicating that they had visited at some point in their life (47%).

As shown in Table 2, females were slightly more likely than males within this age group to have visited science centres. Although statistically significant, the effect size shows this to be a small or minimal effect. Visit by income was also skewed. Individuals from families with household incomes above the national median were significantly more likely to have visited a science centre than those from lower income families. Again effect size suggests that this too was not a strong effect.

To ensure reliability and construct validity, multiple variables for each dependent measures of impact were developed. Tables 3 to 8 show the reliability analysis for most of these sets of measure to determine if these multiple variables (i.e., survey questions) could be grouped into single composite indices. In general, for items to be grouped, there needed to be more than one measure, the item total correlations should be above .40, and the Cronbach alpha reliability should exceed .65 (maximum of 1.00) (Vaske, 2008). It is not uncommon when there are multiple measures for some to be unreliable; these questions would then be eliminated to ensure that the resulting composite index is consistent and reliable. There was very high reliability for the Knowledge and Understanding (Table 3), Interest and Curiosity (Table 4), Engagement Out-Of-School (one item removed; very few individuals indicated they engaged in this activity anyway) (Tables 5a & 5b), Avocation (Table 6) and Science Confidence (Table 8, given that this was framed around the science centre experience, data are only available for those who actually visited a science centre) composite measures. Creativity and Problem Solving measures (Table 7) did not reliably group together. Finally, since there was only one Vocational item and only one Engagement In-School variable, these two outcome measures were each represented by an individual item. With the exception of Creativity and Problem Solving, all alphas were extremely high indicating that the items grouped well together and justified creating single indices.

Table 2. Relationship between Youth's visitation and demographics. [a]

	Not Visited or Unsure (53%)	Visited (47%)	Total	χ^2 value	*p*-value	Effect size (*ϕ*, *V*)
Sex				4.55	.033	.03
Males	52	49	51			
Females	48	51	49			
Household income				59.67	< .001	.11
Below median or unsure	77	67	72			
Above median	23	33	28			

[a] Cell entries are percent (%).

Table 3. Reliability of Youth's science knowledge and understanding.

	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]	2.20	.86	.48	.90
How much do you know about topics in physics [b]	2.59	.74	.53	.89
How much do you know about topics in chemistry [b]	2.51	.80	.51	.90
How much do you know about biology of plans or animals [b]	2.74	.83	.48	.90
How much do you know about human biology [b]	2.79	.81	.46	.90
How much do you know about space or astronomy [b]	2.37	.85	.52	.89
How much do you know about geology [b]	2.35	.84	.51	.90
How much do you know about topics in technology [b]	2.50	.92	.39	.90
How much do you know about topics in math [b]	2.82	.88	.42	.90
How much do you know about topics related to the environment [b]	2.73	.82	.57	.89
How much do you know about ways that scientists design experiments [b]	2.22	.86	.57	.89
How easily could you recognize a science or technology question in a newspaper report on a health issue [b]	2.51	.81	.61	.89
How easily could you explain why earthquakes occur more frequently in some areas than others [b]	2.61	.88	.58	.89
How easily could you describe the role of antibiotics in treatment of disease [b]	2.35	.93	.61	.89
How easily could you identify a science or technology question associated with disposal of garbage [b]	2.47	.89	.59	.89
How easily could you predict how changes to an environment will affect survival of some species [b]	2.72	.88	.60	.89
How easily could you interpret scientific information provided on labels of food items [b]	2.48	.85	.58	.89
How easily could you discuss how evidence can lead to changing understanding about possibility of life on Mars [b]	2.30	.92	.59	.89
How easily could you identify the better of two explanations for the formation of acid rain [b]	2.35	.95	.58	.89

[a] Measured on recoded scale of 1 "much or a bit less," 2 "about the same," 3 "a bit more," 4 "much more."
[b] Measured on scale of 1 "nothing," 2 "a little," 3 "a moderate amount," 4 "a lot."
[c] Overall scale reliability Cronbach alpha = 0.90.

Table 4. Reliability of Youth's science or technology interest and curiosity.

	Mean	Standard Deviation	Item total correlation	Alpha if item deleted [d]
I generally have fun when I am learning science or technology topics [a]	4.29	1.39	.71	.83
I like reading or hearing about science or technology [a]	4.17	1.41	.74	.82
I am happy doing science or technology problems [a]	3.90	1.48	.70	.83
I enjoy learning about or acquiring new knowledge in science or technology [a]	4.38	1.43	.74	.82
Compared to the average person, how curious are you about science or technology [b]	3.31	1.02	.66	.85
Do you seem to have more questions about science or technology things than most other people you know [c]	2.60	0.74	.44	.86

[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," 5 "much more."
[c] Measured on scale of 1 "never," 2 "usually not," 3 "sometimes," 4 "always."
[d] Overall scale reliability standardized Cronbach alpha = 0.86. NOTE: The combined scale was created using standardized z-scores because the variables were measured on different scales.

Table 5a. Reliability of Youth's science or technology engagement *out of school.* [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	3.63	1.60	.59	.68
Use the internet to search for or learn about science or technology related topics during free time	4.20	1.53	.58	.69
Watch or listen to science or technology educational programs on TV, video, podcast, or radio during free time	3.93	1.52	.55	.70
Participate in science or technology related club or group during free time	1.66	1.30	.34	.77
Talk about science or technology with friends or family during free time	3.52	1.66	.54	.70

[a] Measured on recoded scale of 1 "never," 2 "1-2 times every 5 years," 3 "several times a year," 4 "monthly," 5 "weekly," 6 "daily."
[b] Overall scale reliability Cronbach alpha = 0.75.

Table 5b. Reliability of Youth's science or technology engagement *out of school.* [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	3.63	1.60	.59	.70
Use the internet to search for or learn about science or technology related topics during free time	4.20	1.53	.60	.69
Watch or listen to science or technology educational programs on TV, video, podcast, or radio during free time	3.93	1.52	.56	.71
Talk about science or technology with friends or family during free time	3.52	1.66	.52	.73

[a] Measured on recoded scale of 1 "never," 2 "1-2 times every 5 years," 3 "several times a year," 4 "monthly," 5 "weekly," 6 "daily."
[b] Overall scale reliability Cronbach alpha = 0.77.

Table 6. Reliability of Youth's science and technology related avocations. [a]

Avocations [b]	Mean	Standard Deviation	Item total correlation	Alpha if item deleted
I would like to or currently pursue a hobby involving science or technology	3.59	1.58	.71	-- [c]
I would like to find out more about some area of science or technology	4.20	1.52	.71	-- [c]

[a] Cell entries are means on scale of 1 "strongly disagree" to 6 "strongly agree."
[b] Overall scale reliability for "avocations" Cronbach alpha = 0.83.
[c] Cannot calculate alpha if deleted for these because if deleted, there would only be a single item left, so no scale.

Table 7. Reliability of Youth's creativity and problem solving.[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	2.85	.83	.12	.36
When a problem comes up, do you tend to come up with solutions that are different than most people	2.86	.68	.22	.15
When a problem comes up, do you try to see how others have solved similar problems in the past	2.86	.77	.19	.19

[a] Cell entries are means on scale of 1 "never," 2 "usually not," 3 "sometimes," 4 "always."
[b] Overall scale reliability Cronbach alpha = 0.31.

Table 8. Reliability of science centre influence on Youth's perceived confidence in science and technology.[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.	4.67	1.25	0.52	0.96
I discovered things about science or technology I never knew before.	4.58	1.23	0.60	0.96
My understanding of science or technology was strengthened or extended.	4.20	1.26	0.76	0.96
My appreciation of science or technology increased.	4.09	1.31	0.80	0.95
I got new ideas or techniques that have been useful to me in my work or hobbies.	3.64	1.39	0.79	0.95
My interest in a specific area of science or technology increased.	3.89	1.37	0.81	0.95
My curiosity about science or technology increased.	4.05	1.36	0.82	0.95
I found myself thinking about some aspect of science or technology.	3.97	1.38	0.78	0.96
My behavior regarding science or technology changed because of my visit.	3.64	1.37	0.79	0.95
My visit inspired me to learn more about science or technology.	3.87	1.37	0.82	0.95
I discovered or learned new ways to do things.	3.91	1.34	0.78	0.96
My curiosity was ignited.	4.07	1.37	0.80	0.95
My understanding of myself increased.	3.46	1.47	0.73	0.96
I became more confident to question things.	3.59	1.46	0.75	0.96
I found myself thinking about pursuing courses or a career in science or technology.	3.44	1.55	0.71	0.96
My visit inspired me to get involved in a project in the community related to science or technology.	3.07	1.49	0.68	0.96
I realized that someone in my group had knowledge, interest, or skills that I did not know about.	3.65	1.44	0.63	0.96

[a] Measured on scale of 1 "strongly disagree," 2 "moderately disagree," 3 "slightly disagree," 4 "slightly agree," 5 "moderately agree," 6 "strongly agree."
[b] Overall scale reliability Cronbach alpha = 0.96.

From the start, measures of Creativity and Problem Solving were challenging dimensions to measure. There is considerable disagreement within the literature on whether these dimensions are actually measurable with closed-ended questionnaire items (e.g., Brown, Collins & Duguid, 1989; CRELL, 2009; Kim, 2006; Zeng, Proctor & Salvendy, 2011), but certain members of the ISCIS community felt strongly that this was an important outcome of science centre experiences. The final items included in the instrument were all borrowed and/or adapted from existing instruments. However, 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, a reliable Creativity and Problem Solving scale could not be created. Of greater concern was that the patterns of responses seen in these items raised questions about validity as well. Given the concerns about both validity and reliability the decision was made to exclude these items from further analyses.

Tables 9 to 12 represent the heart of the analysis for youth, indicating what impact, if any, visits to a science centre made on the five remaining key outcomes. Note the dependent measures of impact are all combined scales except for the Vocation measure, which represents a single item.

Table 9. Relationship between Youth's number of previous 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]	2.45	2.50	2.56	2.72	39.42	< .001	.14
Interest and curiosity [c]	0.09	0.10	0.12	0.17	16.62	< .001	.09
Out of school engagement [b]	3.86	3.71	3.76	4.00	7.65	< .001	.06
Vocations [d]	3.63	3.45	3.59	4.20	18.47	< .001	.10
Avocation [d]	3.97	3.68	3.79	4.24	19.73	< .001	.10
Science confidence [d]	--	3.80	3.81	4.13	15.37	< .001	.11

[a] Most variables in index measured on scale of 1 "nothing," 2 "a little," 3 "a moderate amount," 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," 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."

The general patterns in Table 9 are clear, all outcome measures increased as the number of science centre visits increased, with the strongest outcomes consistently correlated with those individuals who visited most frequently. Although significant, effect sizes were minimal to typical. Generally, the strongest correlations were at very high numbers of visits such as 11+

times. This is particularly notable for youth's vocational interests, in which the only post-visit means that were higher than those who had never visited were for those who indicated they had visited 11+ times. In other words, this analysis would suggest that if a relationship between use of a science centre and these various outcomes exists, it takes many visits for there to be a strong effect; this was particularly true for youth future careers, avocations in science and technology and their identity related to science and technology.

Table 10. Relationship between year of Youth's most recent 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]	2.45	2.51	2.53	2.61	2.67	27.52	< .001	.14
Interest and curiosity [c]	0.09	0.11	0.12	0.14	0.17	12.41	< .001	.09
Out of school engagement [b]	3.86	3.61	3.73	3.90	4.00	9.52	< .001	.08
Vocations [d]	3.63	3.43	3.50	3.68	4.26	17.32	< .001	.11
Avocation [d]	3.97	3.67	3.72	3.90	4.22	13.66	< .001	.10
Science confidence [d]	--	3.72	3.74	4.01	4.13	21.22	< .001	.15

[a] Most variables in index measured on scale of 1 "nothing," 2 "a little," 3 "a moderate amount," 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," 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."

Table 11. Relationship between Youth's 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]	2.45	2.49	2.57	2.70	2.95	36.27	< .001	.16
Interest and curiosity [c]	0.09	0.09	0.12	0.18	0.08	14.45	< .001	.10
Out of school engagement [b]	3.86	3.61	3.84	4.02	4.34	16.32	< .001	.11
Vocations [d]	3.63	3.45	3.76	4.08	4.51	15.90	< .001	.11
Avocation [d]	3.97	3.63	3.90	4.18	4.48	19.57	< .001	.12
Science confidence [d]	--	3.66	3.96	4.22	4.25	34.94	< .001	.20

[a] Most variables in index measured on scale of 1 "nothing," 2 "a little," 3 "a moderate amount," 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," 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."

As shown in Table 10, the correlation between visits and outcomes increased as science centre visits become more recent, with greatest evidence of correlation consistently seen for those individuals who visited most recently. Also apparent is that correlations are minimal or non-existent in visits older than two years. The effect sizes for these measures were by and large tending toward the typical range for social science research.

The general patterns in Table 11 are also clear; all correlations increase as the number of science centre visits in the past 12 months increases, with the strongest correlations being for those individuals who visit most frequently. A notable exception is interest and curiosity, which strongly drops between 2-4 visits and 5+ visits. Of importance to note is the lack of difference between youth who have never visited and those who have visited before but not recently (0 visits in last 12 months) suggesting as with Table 10 that how recently a youth visits does matter. In general, effect sizes were tending toward the typical range for social science research.

Table 12. Relationship between hours Youth 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]	2.45	2.55	2.57	2.59	25.39	< .001	.12
Interest and curiosity [c]	0.09	0.12	0.17	0.22	6.15	< .001	.06
Out of school engagement [b]	3.86	3.82	3.67	3.89	7.35	< .001	.06
Vocations [d]	3.63	3.64	3.54	3.76	2.80	.038	.04
Avocation [d]	3.97	3.83	3.74	3.92	7.38	< .001	.06
Science confidence [d]	--	3.78	3.80	4.01	12.31	< .001	.10

[a] Most variables in index measured on scale of 1 "nothing," 2 "a little," 3 "a moderate amount," 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," 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."

The patterns in Table 12 show generally greater correlation as the number of hours spent on the last science centre visit increases, with the greatest correlations being for those individuals who spent the most time. Both Knowledge and Understanding and Interest and Curiosity rise linearly as a function of increased time spent, but the other four indices (Out-Of-School Engagement, Vocation, Avocation, Science Confidence) rise appreciably between 3-4 hours and 5+ hours (Vocation actually declines between 1-2 and 3-4 hours), suggesting the possibility of some kind of threshold phenomenon. All of the effect sizes were minimal.

Tables 13 to 15 explore the relationship between visiting a science centre and engagement in school subjects, in particular interest and engagement in science. Table 13 suggests that although there were significant differences for many of the research participants as a function of visiting a science centre, only engagement in school science significantly correlated with increased number of visits from “never” to “11+ visits”; all other differences, including for mathematics, had inconsistent or negative patterns. Tables 14 and 15 show similar results – visiting a science centre correlated with interest in science as a school subject, but not other subjects. Effect sizes were minimal.

Table 13. Relationship between number of previous visits and Youth’s engagement *in school*. [a]

	Never Visited (53%)	1-2 Visits (17%)	3-10 Visits (24%)	11+ Visits (7%)	χ^2-value	*p*-value	*V*
Writing	11	7	7	5	34.54	< .001	.08
History	13	9	10	11	12.30	.006	.05
Math	23	21	20	24	6.04	.110	.03
Science	19	16	20	25	13.80	.003	.05
Foreign Languages	6	7	5	2	14.27	.003	.05
Art	14	20	17	13	16.76	.001	.06

[a] Cell entries are the percent who said it was their favorite topic in school.

Table 14. Relationship between year of Child’s most recent visit and engagement *in school*. [a]

	Never Visited (53%)	Before 2010 (11%)	2010-2011 (14%)	2012 (14%)	2013 (7%)	χ^2-value	*p*-value	*V*
Writing	11	8	6	8	6	38.36	< .001	.08
History	13	11	11	9	9	13.39	.010	.05
Math	23	19	20	22	24	7.35	.118	.04
Science	19	16	18	20	26	17.84	.< .001	.06
Foreign Languages	6	5	5	6	7	1.81	.771	.02
Art	14	17	17	20	13	17.34	.002	.06

[a] Cell entries are the percent who said it was their favorite topic in school.

Table 15. Relationship between number of Child's visits in last 12 months and engagement *in school.*[a]

	Never Visited (53%)	0 Visits (24%)	1 Visit (13%)	2-4 Visits (7%)	5+ Visits (2%)	χ^2-value	*p*-value	*V*
Writing	11	6	8	7	2	40.67	< .001	.08
History	13	10	8	11	16	15.61	.004	.05
Math	23	20	21	25	24	8.23	.071	.04
Science	19	19	18	24	33	10.99	.027	.05
Foreign Languages	6	4	8	4	4	20.86	< .001	.06
Art	14	18	18	14	9	13.54	.009	.05

[a] Cell entries are the percent who said it was their favorite topic in school.

Table 16. Exploratory factor analysis of Youth's visitation experiences on a "typical visit".

	Factor loadings [a]		
Variables	Factor 1: Prolonged Participation	Factor 2: Active Engagement	Factor 3: Mediated Experiences
Attended a camp	.73		
Participated in a long-term special program	.80		
Volunteered at the institution	.79		
Participated in a school field trip	-- [b]		
I thought a lot about science or technology		.72	
I talked with someone about what I was seeing or doing		.72	
I explained or showed someone how or why something worked		.69	
Actively engaged in hands-on activities at exhibits		.66	
Walked around / saw exhibits		.51	
Asked a question to staff about something I saw or did		.58	
Saw a movie or film			.77
Attended a presentation or lecture by a scientist			.61
Attended a demonstration on the exhibit floor			.69
Participated in a non-exhibit public program			.56
Participated in a staff-led class			.42
Eigenvalue	2.68	2.89	2.34
Percent (%) of total variance explained	17.88	19.24	15.60
Cumulative percent (%) of variance	17.88	37.12	52.72

[a] Principal components factor analysis with Varimax rotation. Only factors with eigenvalues greater than 1 and items with factor loadings greater than .40 were retained in the final factor structure. Items coded on 4-point scales of 1 = "not at all" to 4 = "a lot."

[b] Item did not load on any factor, so it was retained as its own factor.

The data were also analyzed to determine whether the nature of the visit experience (i.e., what kinds of visit experiences a child had) made any difference across these various outcomes. Table 16 shows the results of a principal components exploratory factor analysis (with Varimax rotation) of types of activities engaged in during a "typical visit." Results indicated that all of the various activities factored into three major groupings: (a) Prolonged Participation, (b) Active Engagement, and (c) Mediated Experiences. School field trips did not load on any of the factors and was retained as its own factor. Collectively, these factors explained more than half (53%) of the variance around what youth did while at the science centre. Table 17 summarizes the reliability analysis for these factors; all three factors had acceptable reliability (i.e., above .65).

Table 17. Reliability analysis of factors describing Youth's visitation experiences on a "typical visit".

Factors and variables [a]	Mean	Percent "Moderate" or "A Lot"	Item total correlation	Alpha if deleted	Cronbach alpha
Factor 1: Prolonged Participation [b]					.78
Attended a camp	1.49	16	.58	.72	
Participated in a long-term special program	1.45	14	.65	.67	
Volunteered at the institution	1.33	10	.64	.69	
Factor 2: Active Engagement					.78
I thought a lot about science or technology	2.67	57	.55	.74	
I talked with someone about what I was seeing or doing	2.33	43	.61	.72	
I explained or showed someone how / why something worked	2.07	32	.57	.73	
Actively engaged in hands-on activities at exhibits	2.68	59	.53	.74	
Walked around / saw exhibits	3.24	83	.36	.78	
Asked a question to staff about something I saw or did	2.01	31	.50	.75	
Factor 3: Mediated Experiences					.75
Saw a movie or film	2.63	57	.46	.72	
Attended a presentation or lecture by a scientist	2.07	32	.54	.69	
Attended a demonstration on the exhibit floor	2.52	53	.55	.69	
Participated in a non-exhibit public program	1.95	29	.52	.70	
Participated in a staff-led class	1.97	31	.48	.71	

[a] Items coded on 4-point scales of 1 = "not at all" to 4 = "a lot."

[b] "Participated in a school field trip" did not load on any factor, so it was retained as its own factor. Mean for this variable = 2.73, percent "moderate" or "a lot" = 62%.

Table 18 compares the probability for a positive outcome on each of the key dependent measures as a function of how youth reported spending their time on a typical visit. Although clearly the nature of each set of experiences accommodated by these various visit factors were quite different, all resulted in significant correlations across all six outcome dimensions.

Table 18. Relationships between Youth's visitation experiences on a "typical visit" and dependent scales. [a]

	Independent scales [a]			
Dependent scales	Prolonged Participation	Active Engagement	Mediated Experiences	School Field Trip
Knowledge and understanding [a]	.26***	.50***	.40***	.10***
Interest and curiosity [c]	.06**	.45***	.24***	.07**
Out of school engagement [b]	.19***	.41***	.26***	.06**
Vocations [e]	.09***	.38***	.23***	.07**
Avocation [e]	.16***	.46***	.28***	.08***
Science confidence [d]	.22***	.57***	.41***	.12***

Cell entries are Pearson correlations. * $p < .05$, ** $p < .01$, *** $p < .001$. No asterisk = not significant ($p > .05$).
[a] Most variables in index measured on scale of 1 "nothing," 2 "a little," 3 "a moderate amount," 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," 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."

Table 19. Relationships between the two sampled Youth's populations and the dependent scales.[a]

	Population A (General Population) Not Visited or Unsure	Population B (Best Case Visitor) Visited	*t*-value	*p*-value	r_{pb}
Knowledge and understanding [a]	2.45	2.75	15.21	< .001	.23
Interest and curiosity [c]	0.09	0.34	14.56	< .001	.22
Out of school engagement [b]	3.86	4.21	7.70	< .001	.12
Vocations [d]	3.63	4.16	7.38	< .001	.12
Avocation [d]	3.97	4.44	7.85	< .001	.13

[a] Most variables in index measured on scale of 1 "nothing," 2 "a little," 3 "a moderate amount," 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," 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."

Although Population A data are primarily discussed in this report, Table 19 summarizes differences between Population A individuals who had not visited the science centre and

Population B individuals deemed "best case" visitors as a function of key dependent measures. As expected, Population B individuals had significantly higher scores on these measures and the effect sizes were typical.

Population A Adults

Across the entire Population A Adult sample, less than half of all residents had visited science centres (44%) with 56% indicating that they had never visited or were unsure of whether or not they had visited at some point in their life.

Although the subpopulation visiting science centers was broadly comparable in age and gender to the sub-population of individuals who had not visited a science centre, individuals who had visited a science centre differed on two key demographic variables. As shown in Table 20, individuals with higher levels of education and household incomes were significantly more likely to have visited a science centre than individuals with less education and lower income. The effect sizes for these outcomes were within the typical range.

Table 20. Relationship between Adult's visitation and demographics. [a]

	Not Visited or Unsure (56%)	Visited (44%)	Total	χ^2 or t value	p-value	Effect size (ϕ, V, or r_{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 or unsure	62	46	54			
Above median	38	54	46			

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

Table 21. Reliability of Adult's science knowledge and understanding.

	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	.92	.53	.92
How much do you know about topics in physics [b]	2.33	.81	.64	.92
How much do you know about topics in chemistry [b]	2.44	.83	.55	.92
How much do you know about biology of plans or animals [b]	2.55	.80	.46	.92
How much do you know about human biology [b]	2.80	.78	.52	.92
How much do you know about space or astronomy [b]	2.16	.83	.61	.92
How much do you know about geology [b]	2.18	.81	.59	.92
How much do you know about topics in technology [b]	2.35	.94	.46	.92
How much do you know about topics in math [b]	2.52	.87	.48	.92
How much do you know about topics related to the environment [b]	2.61	.82	.65	.91
How much do you know about ways that scientists design experiments [b]	2.12	.91	.64	.92
How easily could you recognize a science or technology question in a newspaper report on a health issue [b]	2.70	.89	.67	.91
How easily could you explain why earthquakes occur more frequently in some areas than others [b]	2.61	.95	.68	.91
How easily could you describe the role of antibiotics in treatment of disease [b]	2.53	.95	.63	.92
How easily could you identify a science or technology question associated with disposal of garbage [b]	2.57	.91	.67	.91
How easily could you predict how changes to an environment will affect survival of some species [b]	2.60	.95	.68	.91
How easily could you interpret scientific information provided on labels of food items [b]	2.62	.92	.63	.92
How easily could you discuss how evidence can lead to changing understanding about possibility of life on Mars [b]	2.18	.97	.66	.91
How easily could you identify the better of two explanations for the formation of acid rain [b]	2.24	.97	.68	.91

[a] Measured on recoded scale of 1 "much or a bit less," 2 "about the same," 3 "a bit more," 4 "much more."
[b] Measured on scale of 1 "nothing," 2 "a little," 3 "a moderate amount," 4 "a lot."
[c] Overall scale reliability Cronbach alpha = 0.92.

Tables 21 to 26 show reliabilities for most of the dependent measures to determine if these multiple questions could be reliably grouped into single composite indices. There was high reliability for Knowledge and Understanding (Table 21), Interest and Curiosity (Table 22), Engagement Out-Of-School (one item removed; even among adults few individuals indicated they engaged in this activity) (Tables 23a & 23b), Avocation (Table 24), and Science Confidence (Table 26, give that this was framed around the science centre experience, data are only available for those who actually visited a science centre) composite measures. Similar to the youth measures, adult Creativity and Problem Solving measures (Table 25) did not reliably group together. Given that there was only one Vocational item, it represents its own individual concept. With exception of Creativity and Problem Solving, all alphas were high indicating that the items grouped well together and justified creating single indices.

Table 22. Reliability of Adult's science or technology interest and curiosity.

	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," 5 "much more."
[c] Measured on scale of 1 "never," 2 "usually not," 3 "sometimes," 4 "always."
[d] Overall scale reliability standardized Cronbach alpha = 0.88. NOTE: The combined scale was created using standardized z-scores because the variables were measured on different scales.

Table 23a. Reliability of Adult's science or technology engagement *out of school.* [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	4.12	1.59	.58	.69
Use the internet to search for or learn about science or technology related topics during free time	4.06	1.65	.64	.67
Watch or listen to science or technology educational programs on TV, video, podcast, or radio during free time	4.07	1.41	.58	.70
Participate in science or technology related club or group during free time	1.49	1.09	.28	.78
Talk about science or technology with friends or family during free time	3.53	1.53	.54	.71

[a] Measured on recoded scale of 1 "never," 2 "1-2 times every 5 years," 3 "several times a year," 4 "monthly," 5 "weekly," 6 "daily."
[b] Overall scale reliability Cronbach alpha = 0.76.

Table 23b. Reliability of Adult's science or technology engagement *out of school.* [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," 6 "daily."
[b] Overall scale reliability Cronbach alpha = 0.78.

Table 24. Reliability of Adult's science and technology related avocations. [a]

	Mean	Standard Deviation	Item total correlation	Alpha if item deleted
Avocations [b]				
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 = 0.83.
[c] Cannot calculate alpha if deleted for these because if deleted, there would only be a single item left, so no scale.

Table 25. Reliability of Adult's creativity and problem solving.[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	.84	.03	.44
When a problem comes up, do you tend to come up with solutions that are different than most people	2.90	.63	.20	.05
When a problem comes up, do you try to see how others have solved similar problems in the past	3.03	.73	.19	.04

[a] Cell entries are means on scale of 1 "never," 2 "usually not," 3 "sometimes," 4 "always."
[b] Overall scale reliability Cronbach alpha = 0.24.

As indicated above, the items measuring Creativity and Problem Solving (Table 25) do 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, a reliable 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. As with the Youth data, because of concerns about both validity and reliability, these items were excluded from further analyses.

Table 26. Reliability of science centre influence on Adult's perceived confidence in science and technology.[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	0.58	0.95
I discovered things about science or technology I never knew before.	4.64	1.22	0.63	0.95
My understanding of science or technology was strengthened or extended.	4.43	1.17	0.75	0.95
My appreciation of science or technology increased.	4.36	1.27	0.78	0.95
I got new ideas or techniques that have been useful to me in my work or hobbies.	3.61	1.43	0.77	0.95
My interest in a specific area of science or technology increased.	3.92	1.34	0.83	0.95
My curiosity about science or technology increased.	4.06	1.35	0.86	0.95
I found myself thinking about some aspect of science or technology.	4.12	1.33	0.80	0.95
My behavior regarding science or technology changed because of my visit.	3.61	1.41	0.82	0.95
My visit inspired me to learn more about science or technology.	3.92	1.35	0.85	0.95
I discovered or learned new ways to do things.	3.90	1.33	0.83	0.95
My curiosity was ignited.	4.20	1.31	0.80	0.95
My understanding of myself increased.	3.54	1.39	0.78	0.95
I became more confident to question things.	3.60	1.41	0.78	0.95
I found myself thinking about pursuing courses or a career in science or technology.	2.96	1.55	0.68	0.95
My visit inspired me to get involved in a project in the community related to science or technology.	2.90	1.48	0.64	0.95
I realized that someone in my group had knowledge, interest, or skills that I did not know about.	3.52	1.55	0.61	0.95

[a] Measured on scale of 1 "strongly disagree," 2 "moderately disagree," 3 "slightly disagree," 4 "slightly agree," 5 "moderately agree," 6 "strongly agree."
[b] Overall scale reliability Cronbach alpha = 0.96.

Tables 27 to 30 represent the heart of the analysis for adults, indicating what correlation, if any, visits to a science centre had with the five remaining key outcomes. Note that the dependent outcome measures are all combined scales except for the Vocation measure, which was a single item.

Table 27. Relationship between Adult's number of previous 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	2.56	2.58	2.65	106.94	< .001	.23
Interest and curiosity [c]	0.05	0.16	0.25	0.33	35.56	< .001	.14
Out of school engagement [b]	3.77	4.04	4.23	4.41	72.01	< .001	.19
Vocations [e]	3.37	3.30	3.45	3.36	1.17	.319	.03
Avocation [e]	3.90	3.77	3.99	4.02	4.40	.004	.05
Science confidence [d]	--	3.77	3.83	4.10	13.30	< .001	.10

[a] Most variables in index measured on scale of 1 "nothing," 2 "a little," 3 "a moderate amount," 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," 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."

Table 27 shows that for most measures, increasing the number of science centre visits increases the strength of the correlation, with greatest correlations consistently seen for those individuals who visited most frequently. However, there was no clear evidence that visiting a science center related to choice of vocation, and significant correlations with avocations were only seen after multiple visits. Overall, effect sizes were typical, except for vocations and avocations, which were minimal. Generally, the strongest correlations appeared to be between no visits and 1-2 visits and then again at high numbers of visits such as 11+ times.

Table 28. Relationship between year of Adult's most recent 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	2.52	2.61	2.62	2.74	89.93	< .001	.25
Interest and curiosity [c]	0.05	0.20	0.22	0.27	0.49	29.78	< .001	.14
Out of school engagement [b]	3.77	4.09	4.11	4.34	4.55	60.41	< .001	.20
Vocations [e]	3.37	3.21	3.24	3.58	4.01	13.82	< .001	.10
Avocation [e]	3.90	3.73	3.86	4.12	4.44	16.76	< .001	.11
Science confidence [d]	--	3.71	3.84	3.92	4.32	27.17	< .001	.18

[a] Most variables in index measured on scale of 1 "nothing," 2 "a little," 3 "a moderate amount," 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," 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."

There is a clear overall pattern in Table 28 where all measures of correlation increased as visits to science centres became increasingly recent, with the strongest correlations consistently seen for those individuals who had visited most recently. The effect sizes are typical. In general, even experiences quite a while ago (e.g., before 2010) seem to be correlated with the dependent measures, but the strongest correlations were seen amongst adults who had visited within the previous year.

Table 29. Relationship between Adult's 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	2.54	2.58	2.70	2.74	83.01	< .001	.24
Interest and curiosity [c]	0.05	0.20	0.21	0.34	0.38	27.75	< .001	.14
Out of school engagement [b]	3.77	4.06	4.34	4.41	4.44	55.05	< .001	.19
Vocations [e]	3.37	3.17	3.48	3.86	3.90	14.95	< .001	.10
Avocation [e]	3.90	3.70	4.01	4.38	4.46	20.97	< .001	.12
Science confidence [d]	--	3.71	3.86	4.11	4.19	19.22	< .001	.15

[a] Most variables in index measured on scale of 1 "nothing," 2 "a little," 3 "a moderate amount," 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," 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."

Table 30. Relationship between hours Adult's 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	2.57	2.59	2.61	106.45	< .001	.23
Interest and curiosity [c]	0.05	0.22	0.23	0.30	32.25	< .001	.13
Out of school engagement [b]	3.77	4.19	4.20	4.26	64.34	< .001	.18
Vocations [e]	3.37	3.35	3.37	3.54	1.33	.264	.03
Avocation [e]	3.90	3.88	3.92	4.06	1.91	.126	.03
Science confidence [d]	--	3.76	3.78	4.17	27.93	< .001	.15

[a] Most variables in index measured on scale of 1 "nothing," 2 "a little," 3 "a moderate amount," 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," 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."

The pattern in Table 29 is interesting. Although all correlations increased as the number of science centre visits within the past year increased, there was a clear "flattening" out of effect after 2-4 visits. In other words, for adults there appears to be a threshold effect with greatest incremental change in correlation with outcomes seen after 2-4 visits. In general, the effect sizes are typical.

As above, the general patterns in Table 30 are clear, with generally stronger correlations occurring as the number of hours spent on the last visit to the science centre increased. The strongest correlations were seen for those individuals who spent the most time; with the exception of vocations and avocations, which were not significant. The effect sizes for significant items are minimal to typical.

Table 31. Exploratory factor analysis of Adult's visitation experiences on a "typical visit".

	Factor loadings [a]		
Variables	Factor 1: Prolonged Participation	Factor 2: Active Engagement	Factor 3: Mediated Experiences
Attended a camp	.84		
Participated in a long-term special program	.83		
Volunteered at the institution	.82		
Participated in a school field trip	.41[b]		
I thought a lot about science or technology		.75	
I talked with someone about what I was seeing or doing		.74	
I explained or showed someone how or why something worked		.72	
Actively engaged in hands-on activities at exhibits		.64	
Walked around / saw exhibits		.58	
Asked a question to staff about something I saw or did		.52	
Saw a movie or film			.75
Attended a presentation or lecture by a scientist			.72
Attended a demonstration on the exhibit floor			.71
Participated in a non-exhibit public program			.61
Participated in a staff-led class			.58
Eigenvalue	2.91	2.90	2.74
Percent (%) of total variance explained	19.41	19.34	18.29
Cumulative percent (%) of variance	19.41	38.74	57.04

[a] Principal components factor analysis with Varimax rotation. Only factors with eigenvalues greater than 1 and items with factor loadings greater than .40 were retained in the final factor structure. Items coded on 4-point scales of 1 = "not at all" to 4 = "a lot."

[b] Item did not load on any factor, so it was retained as its own factor.

The data were also analyzed to determine whether the nature of the visit experience (i.e., what kinds of visit experiences an adult had) made any difference across these various outcomes. Table 31 shows the results of a principal components exploratory factor analysis (with Varimax rotation) of types of activities engaged in during a "typical visit." Results indicated that all of the various activities factored into three major groupings: (a) Prolonged Participation, (b) Active Engagement, and (c) Mediated Experiences. School field trips did not load on any of the factors and thus was retained as its own factor. Collectively, these factors explained 57% of the variance around what adults did while at the science centre. Table 32 summarizes the reliability of these factors and all three factors had acceptable reliability (i.e., above .65).

Table 32. Reliability analysis of factors describing Adult's visitation experiences on a "typical visit".

Factors and variables [a]	Mean	Percent "Moderate" or "A Lot"	Item total correlation	Alpha if deleted	Cronbach alpha
Factor 1: Prolonged Participation					.85[c]
Attended a camp	1.24	6	.66	.59	
Participated in a long-term special program	1.27	8	.64	.59	
Volunteered at the institution	1.18	5	.59	.64	
Factor 2: Active Engagement					.80
I thought a lot about science or technology	2.79	66	.58	.76	
I talked with someone about what I was seeing or doing	2.34	45	.67	.74	
I explained or showed someone how / why something worked	2.20	40	.55	.77	
Actively engaged in hands-on activities at exhibits	2.51	51	.58	.76	
Walked around / saw exhibits	3.33	87	.40	.79	
Asked a question to staff about something I saw or did	2.03	32	.52	.77	
Factor 3: Mediated Experiences					.80
Saw a movie or film	2.39	47	.54	.77	
Attended a presentation or lecture by a scientist	1.96	30	.63	.74	
Attended a demonstration on the exhibit floor	2.48	52	.60	.75	
Participated in a non-exhibit public program	1.77	23	.56	.76	

[a] Items coded on 4-point scales of 1 = "not at all" to 4 = "a lot."

[b] "Participated in a school field trip" did not load on any factor, so it was retained as its own factor. Mean for this variable = 2.73, percent "moderate" or "a lot" = 62%.

Table 33 compares the relationship between each of the dependent measures as a function of how adults reported spending their time on a typical visit. As with youth, adult engagement in different kinds of activities overall resulted in significant correlations across most outcome dimensions. However, unlike youth, there were differences. In general, if the last science centre experience an adult had was a school field trip experience, correlations with outcomes were marginal or non-existent, except for science confidence which was highly significant across all categories of visit experience, even school field trips. Also noteworthy was that prolonged participation did not seem to impact interest and curiosity.

Table 33. Relationships between Adult's visitation experiences on a "typical visit" and dependent scales. [a]

	Independent scales [a]			
Dependent scales	Prolonged Participation	Active Engagement	Mediated Experiences	School Field Trip
Knowledge and understanding [a]	.15***	.39***	.20***	.06**
Interest and curiosity [c]	.03	.32***	.13***	-.03
Out of school engagement [b]	.15***	.29***	.20***	-.01
Vocations [e]	.14***	.25***	.14***	-.01
Avocation [e]	.12***	.29***	.18***	.01
Science confidence [d]	.226***	.446***	.393***	.167***

Cell entries are Pearson correlations. * $p < .05$, ** $p < .01$, *** $p < .001$. No asterisk = not significant ($p > .05$).
[a] Most variables in index measured on scale of 1 "nothing," 2 "a little," 3 "a moderate amount," 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," 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."

Table 34. Relationship between the two sampled Adult's populations and the dependent scales.[a]

	Population A (General Population) Not Visited or Unsure	Population B (Best Case Visitor) Visited	*t*-value	*p*-value	r_{pb}
Knowledge and understanding [a]	2.32	2.80	24.98	< .001	.34
Interest and curiosity [c]	0.05	0.54	20.50	< .001	.27
Out of school engagement [b]	3.77	4.52	20.77	< .001	.26
Vocations [e]	3.37	4.12	11.10	< .001	.17
Avocation [e]	3.90	4.50	12.23	< .001	.17

[a] Most variables in index measured on scale of 1 "nothing," 2 "a little," 3 "a moderate amount," 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," 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."

Although most Population B data is not included in this report, Table 34 summarizes the differences between Population A individuals who had not visited the science centre and Population B individuals deemed "best case" visitors as a function of dependent measures. As expected, Population B individuals had significantly higher scores on all outcome dimensions. The effect sizes were typical to substantial.

CONCLUSIONS

Overall, the results strongly and consistently showed that for both youth and adults, science centre experiences positively correlated with science and technology-related outcomes. In particular, visiting a science centre significantly correlated with increased:

- science and technology knowledge and understanding,
- science and technology interest and curiosity,
- engagement with and interest in science as a school subject (youth)
- engagement with science and technology-related activities out-of-school, and
- personal identity and confidence in science and technology.

Although more equivocal, there was also evidence that visiting science centres positively correlated with science and technology-related vocations and avocations (e.g., hobbies, habits of mind).

Although results were strong for both youth ages 14-15 and adults ages 18 and above, the effect sizes were almost universally stronger for adults. There could be a number of reasons why there was a stronger correlation between adult science centre experiences and science and technology-related outcomes in general and with respect to vocations and avocations in particular. First, youth are still in a formative stage of development. We purposefully selected youth to investigate as opposed to younger children so that it would be more likely that the effects of science centre experiences on outcomes like career and hobby choices would be visible. Still, at 14-15 years of age career and hobby preferences are not yet fully formed. By contrast, adults have well established career and hobby patterns and the presence of strong correlations between science centre experiences and science-related careers and hobbies were more likely to be evident; which it seemed was the case.

Using a science centre likely always involves a degree of self-selection, particularly amongst adults, who nearly always have a choice of whether to visit or not. Thus the stronger correlations observed for adults may be reflective of a self-selection bias. Although youth do not always have the opportunity to exercise the same degree of choice as do adults, self-selection bias could have potentially affected youth results as well. In general the data for both adults and youth suggest two possible causes for this selection bias. The first was that there was a positive correlation between using a science centre and possessing positive science and technology attributes. In other words, the evidence showing greater scientific and technological literacy amongst science centre users could have been directly caused by the use of the science centers or alternatively it could have been caused by the fact that individuals who already possessed a high level of scientific and technological literacy preferentially visited science centers. The type of research we conducted does not allow us to definitely say which of these two possible causalities is correct. However the most likely reality was that the observed correlations were neither solely caused by the first reason nor the second, but rather caused by some interaction between the two.

The second area of possible bias results from the fact that there was a positive correlation between using a science centre and being more affluent and among adults also more educated. Again, from this correlation we cannot determine the direction of causality. Is it that more educated and affluent individuals utilize science centres or is it that using a science centre throughout one's life tends to increase the likelihood that you will become well educated and thus more affluent? Having said that, a possible clue to the arrow of causality at least in the case of youth and demographics can be gleaned from the results shown in Table 14 in which we found that within the sub-sample of youth who had visited a science centre within the last year there was a significant correlation with increased interest in school science and mathematics but not in such subjects as history or art. This is informative because the population indicating they had increased interest in science and mathematics was the same as the population indicating no increased interest in other school subjects; in other words they were demographically identical. We can assume that this population was generally more affluent than the general population and we know that greater affluence correlates with increased interest and engagement in all school subjects (e.g., science, math, history, art, foreign language and writing) (e.g., Jencks & Mayer, 1990; Lenzi, et al., 2012; Mayer, 2001). However the only factor that was varied for this population was how recently they visited a science centre. Thus, we can reasonably assume that the observed significant correlation of this population with interest and engagement in school science and mathematics only is directly attributable to the science centre visit, not demographics. The data from Table 13 point in a similar direction but are more equivocal. Collectively then, this data would suggest that the arrow of causality likely points to science centre experiences heightening interest and engagement with science and technology independent of any demographic bias. Even though the epidemiological nature of this particular research cannot fully answer the question of bias or causality we certainly have an abundance of short-term, pre- and post-school field trip and general public visit research showing that science centre experiences significantly enhance users' knowledge and interest, independent of prior knowledge, interest, engagement or demographics (see reviews by Bell, et al., 2009; Falk & Dierking, 2013). Taken together then the research suggests that although one or more biases almost certainly exist in the data, those biases may not be dramatically affecting the results we see. Given the free-choice nature of science centres and the experiences they support the most likely scenario is that all of these variables – science centre use, interest and engagement, and demographics – actually co-vary; each influencing the other, rather than one or another being exclusively causal of the others.

In general, the more frequent, the longer and the more recent an experience the greater was the correlation with all outcome measures. This was true for both youth and adults. This is not a surprising finding, but is important nonetheless because it reinforces the potential role that cumulative science centre experiences might have. However, particularly for adults but less so for youth, there was evidence that correlations were not totally linear. Among adults, for example, there appeared to be a threshold phenomenon related to number of visits. Correlations strengthened as the number of science centre visits within a year increased, but there was a clear "flattening" out of effect after about four visits. This was even more striking for youth in the area of interest and curiosity. In other words, for adults in general and youth relative to interest and curiosity, there appeared to be a threshold effect with greatest incremental change in correlation seen when individuals visited between two and four times a year, but not more. Similarly, relationships were relatively flat for visits lasting up to four hours, but then increased markedly after five or more hours; this was particularly notable among adults in the areas of out-of-school experiences, vocations, and avocations. These results are important because historically science centres 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 might be limitations to "more" and there could be a "sweet spot" for achieving optimum effects. These conclusions will be important to verify through future research. However the current research does suggest an initial hypothesis of effect which now could be tested under more controlled conditions.

The research team was quite hopeful that by looking more specifically at the nature of what visitors did during a science centre visit (i.e., whether they were engaged in Prolonged Participation, Active Engagement, Mediated Experiences or the more generic School Field Trip), that it would be possible to see differences in the nature and/or strength of correlations with the different types of science and technology outcomes. The correlations between science centre experiences and the various outcomes were by and large consistently strong making it difficult to easily see how these various experiences differed with regards to the target outcomes. In general, the data suggested that visiting a science centre resulted in significant correlations with the various science and technology outcomes, independent of the nature of the experience. However, it could be possible to infer that since shorter, more superficial experiences such as Mediated Experiences appeared to support comparable outcomes to longer, deeper experiences such as Prolonged Participation that the former might be more cost-beneficial for institutions to support since they require less investment of resources. Also emerging from the data was the one notable exception to the basic generalization that everything resulted in a positive correlation; adults who said their typical science centre experience was solely characterized as a school field trip showed relatively modest, if any, correlations with measures of science and technology literacy. Also deviating from the norm was evidence that those adults reporting that their typical science experience was of the Prolonged Participation nature showed no long term correlation with science interest and curiosity. The first of these two results is consistent with previous research (cf., Falk & Dierking, 2013) indicating that school field trips are less effective than family visits for supporting certain types of long-term engagement and learning. The second finding though is harder to make sense of. Clearly, this first to our knowledge large-scale effort to tease apart the relative cost-benefits of these various science centre experiences requires further study. Though tantalizing, the current findings are difficult to confidently interpret, but clearly will be worth paying attention to as we continue to analyze the data and think about future research. In particular, it will be interesting to look at the adult interest and curiosity results in relation to the Population B sample. Population B individuals were by definition, individuals likely to have had more intensive types of experiences.

In conclusion, it is important to note that as with all types of research designs (including RCT designs), epidemiological approaches have specific limitations. For example, this approach has only allowed us to document the probability of significant relationships between science centre experiences and: 1) improved science and technology knowledge and understanding; 2) science and technology interest and curiosity; 3) engagement with out-of-school science and technology-related activities; 4) engagement with and interest in science as a school subject (youth); 5) personal identity and confidence in science and technology; and 6) a positive, but less strongly correlated relationship between science centre experiences and increased participation in science and technology-related vocations and avocations.

These findings are by no means trivial, but of course as suggested above, what cannot be said is that these outcomes *resulted from* using science centres. Epidemiological designs only permit us to say that these outcomes strongly correlate with using science centres. However, given how consistent the results are across widely differing countries, communities, and circumstances, and how consistent the results are with previous research, this study provides a strong and compelling case for the value of science centres as institutions. This conclusion is true regardless of whether using science centres resulted in enhanced science and technology literacy or enhanced science and technology literate individuals find science centres useful and use them, or most likely a combination of the two. The participating science centres, and by extension others within the science centre community, now will be able to more confidently assert that there is evidence that individuals who use science centres have a significantly greater likelihood than those who do not use them or use them only minimally to understand science and technology, be interested in science and technology, have an enhanced science and technology identity and be more likely to engage in pro-scientific behaviors. This study shows that the presence of one or more healthy and active science centres within a community, region, or country represents a vital mechanism for fostering and maintaining a scientifically and technologically informed, engaged, and literate public.

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NOTES

[1] Formerly the Miami Science Museum

[2] Because of the resources available to institutions varied, some institutions opted to collect data through in-person surveys where staff or volunteers visited locations such as malls or factories while other institutions contracted outside firms to conduct telephone based surveys. In all cases, every effort was made to collect data from as representative sample of the community as humanly possible.

[3] Some institutions chose to subcontract with survey research companies and their data was collected using traditional randomized telephone survey procedures.

[4] The primary goal of the research was to determine whether it was possible to show that visits to a science centre significantly correlated with measurable differences in the public's science and technology literacy outcomes. At the outset of this study there were no guarantees that a representative sampling of the 17 communities being studied, Population A, would reveal sufficient sample sizes of individuals who visited the science centres, or even if science centre visiting populations would be large enough to handle statistically that they would show impact. Population B was included in the design primarily as a "fall back" sample; a sample that would ensure that some comparisons could be made no matter what the results from Population A revealed.

[5] A copy of the instrument and a summary of institution-specific responses to each question is included as a separate Appendix.