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Does the messenger matter? Studying the impacts of scientists and engineers interacting with public audiences at science festival events

Todd Boyette and J. Ross Ramsey

Abstract

Over the past decade, science festival expos have emerged as popular opportunities for practicing scientists to engage in education outreach with public audiences. In this paper, a partial proportional odds model was used to analyze 5,498 surveys collected from attendees at 14 science expos around the United States. Respondents who report that they interacted with a scientist rated their experiences more positively than those who reported no such interaction on five categories: overall experience, learning, inspiration, fun, and awareness of STEM careers. The results indicate that scientists can positively affect audience perception of their experience at these large-scale public events.

Keywords

Informal learning; Public engagement with science and technology; Public understanding of science and technology

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Introduction

Science festivals continue to grow in popularity as innovative opportunities for scientists and engineers to engage in education outreach [Bultitude, McDonald and Custead, 2011; Boyette and Young, 2014; Wiehe, 2018]. Science festivals exemplify the blend of methodologies and goals that define contemporary science engagement efforts [Holliman and Jensen, 2009]. They vary in scope, size, target audience, and mission, yet generally share one characteristic: a large-scale public exposition (expo) event that draws hundreds and possibly thousands of participants. These expos look like a typical street fair, except that exhibitors are engaging the public with STEM education experiences instead of food, music, arts, or crafts. They are a part of an "evolving culture of science engagement" [Durant and Linett, 2014] and are embraced by STEM education institutions as effective ways to promote science engagement among their audiences [Bultitude, McDonald and Custead, 2011; Boyette and Young, 2014]. These public science events are designed to engage public audiences in a meaningful social context [Durant, Buckley et al., 2016]. Exhibitors are primarily practicing scientists, engineers, STEM educators, science communication professionals, and science-based commercial vendors. This study focuses on the interactions between scientists and engineers and the general public that visits these expos.

In an effort to increase public understanding and support of STEM research and practice, science and engineering practitioners are being asked to actively engage in educational outreach and participate in "respectful dialogues between [them] and the general public" [Leshner, 2015]. Liang et al. [2014] suggest that changing socio-cultural patterns and communication environments have increased attention to practitioners' roles in communicating their research "outside the ivory tower." Many STEM researchers and thought leaders believe that "the burden of passing along the understandings and implications of contemporary science falls squarely on the shoulders of those actively engaged in funding, publishing and carrying out research" [Editorial, 2010]. In response, these researchers are increasingly encouraged to participate in outreach and engagement activities, broadly defined as "any scientific communication that [directly] engages an audience outside of academia" [Poliakoff and Webb, 2007]. In recent years, scientists and engineers have increasingly utilized science festivals, and particularly science expos, to participate in STEM outreach and engagement. According to the Science Festival Alliance (SFA), an organization made up of more than 50 science festivals across the United States, nearly 20,000 STEM professionals played "an active role" in SFA member festivals in 2017 [Wiehe, 2018].

Scientists-public interactions

Although opportunities continue to increase for scientists and engineers to become involved in public engagement with science, little research has been conducted on the impacts of such efforts. The sparse research available does suggest positive benefits from public engagement work, especially among the scientists and engineers themselves. An assessment of the National Science Foundation's Graduate STEM Fellows in K-12 Education found that fellows were more engaged in their research, better able to explain STEM concepts to lay audiences, more interested in STEM education and public policy, and had better time management skills than their peers [Boone and Marsteller, 2011]. In addition, experience teaching science has been shown to increase methodological research skills such as developing testable hypotheses and designing valid experiments [Feldon et al., 2011]. In general, academics involved in public engagement work publish their research more frequently than their non-engaged colleagues, and their publication rates increase with increasing public engagement activity [Jensen, Rouquier et al., 2008]. Liang et al. [2014] found that public communication activity increased scholars' scientific impact as measured by their h-index, a metric that quantifies the cumulative impact and relevance of an individual's research output [Hirsch, 2005].

Research is also very limited on the impacts of these kinds of interactions on public audiences, although preliminary work does suggest that the lay public's science knowledge can be influenced by interactions with scientists and engineers [Davis and Russ, 2015]. Perceptions of scientists, in general, can also be influenced by personal interactions. Although public audiences generally hold traditional, outdated, and inaccurate ideas about what scientists and scientific activities look like, [Woods-Townsend et al., 2016; Christidou, 2010], after personal interactions with scientists, children and adults' depictions of them are more accurate [Woods-Townsend et al., 2016].

Surveys and interviews of science festival attendees indicate that the general public benefit from interactions with scientists and engineers. In Jensen and Buckley [2014] study of interests, motivations, and self-reported benefits of public engagement with research at the Cambridge (U.K.) Science Festival, attendees identified social interaction and access to active science researchers as unique opportunities offered by science festivals that are not available with other science engagement activities. In their investigation of impacts of a panel discussion at the Wisconsin Science Festival, Rose et al. [2017] found that the panel increased audience members' understanding of the topic discussed (human gene editing). Science festival evaluation data has also shown positive impacts on public audiences when they interact with "STEM practitioners." In a summative evaluation of the NSF-sponsored Science Festival Alliance project, Goodman Research Group reported that events were rated more positively by survey respondents if they interacted with STEM practitioners compared to those that had not [Manning et al., 2012].

Interestingly enough, the paucity of research in this area means that the strong push for scientists and engineers to become involved in public engagement is based primarily on an assumption that such involvement is effective in increasing the lay public's understanding and appreciation of STEM and STEM research. This current study is an attempt to fill the void in the research and knowledge base for the measured impacts on the public from scientists' outreach and engagement activities.

Methods

EvalFest attendee survey

EvalFest is an NSF-funded project involving multi-site evaluation of science festivals across the United States. As part of this project, the EvalFest team developed a survey to be completed by attendees of science expos at participating science festivals. Demographic data was collected from attendees over 14 years of age. A subset of questions on each attendee survey were considered the "core questions" and included on every survey. Each individual expo site was allowed to customize its attendee survey by selecting other questions from EvalFest's question bank to add to the core questions. All survey questions were validated by collecting response process validity evidence through think-aloud interviews during expos with youth and adults.

Audience perceptions of expo experiences

For the purposes of this study, the investigators analyzed data from the 14 EvalFest science expos that collected attendee demographic data on gender, race, home zip code, and education level at their science expo events. Two categories (*male/female*) were used for analysis of survey responses by gender. For analysis by race, attendees were classified as underrepresented minorities (URM) if they identified as Black, Hispanic, American Indian, or Alaska Native. Here, the term 'underrepresented' alludes to the inequitable representation of these racial groups in the U.S. STEM workforce [National Center for Science and Engineering Statistics, 2017]. It should be noted that respondents did not self-report their income. For analysis of this variable, income levels of respondents are inferred by the median income of their reported home zip code as documented by the U.S. Census Bureau. Median household income is reported using nine categories: *less than $15,000*; *$15,000–$24,999*; *$25,000–$34,999*; *$35,000–$49,999*; *$50,000–$74,999*; *$75,000–$99,999*; *$100,000–$149,999*; *$150,000–$199,999*; and *$200,000 or more*.

In addition to the demographic questions, the expo attendee surveys also ask the respondents to answer three questions evaluating their experience of the event using a five-point Likert scale (Strongly Disagree. . . Strongly Agree) and are asked to rate the event overall using a five-point Likert scale (Poor. . . Excellent). Respondents are also asked whether or not they have interacted with a scientist or engineer within the past year, whether or not they interacted with a scientist or engineer at the event, and whether or not the event increased their awareness of STEM careers. Attendee survey questions are shown in Figure 1.

Eval Fest

Attendee Survey Core Questions

The following questions are related to today's event. Please answer as honestly as you can. If you have any children in your group, please respond to these questions based on your own personal experience, not the child(ren)'s experience.

1. How long have you been at today's event?
❒ > 5 mins ❒ 6-15 mins ❒ 16-30 mins ❒ 31-45 mins ❒ 46-60 mins ❒ 61-90 mins ❒91+ mins

2. How old are you?
❒ Under 5 ❒ 5-9 ❒ 10-14 ❒ 15-17 ❒ 18-24 ❒ 25-34 ❒ 35-44 ❒ 45-54 ❒ 55-64 ❒ 65+

The following items ask you about STEM, which stands for Science, Technology, Engineering, and/or Math.

At today's event:	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
3. I learned something new.	❒	❒	❒	❒	❒
4. I felt inspired by something I did in STEM.	❒	❒	❒	❒	❒

5. Did today's event make you more aware of how STEM is a part of your life? ❒ Yes ❒ No

6. In the past year, I interacted with someone who works with science or engineering. ❒ Yes ❒ No ❒ Not Sure

7. At today's event, I interacted with someone who works with science or engineering. ❒ Yes ❒ No ❒ Not Sure

8. How would you rate today's event overall? ❒ Poor ❒ Fair ❒ Good ❒ Very Good ❒ Excellent

Gender: ____________________

With which of these groups do you identify? Select all that apply.
❒ American Indian or Alaska Native ❒ Hispanic or Latino/a ❒ Prefer not to answer
❒ Asian ❒ Native Hawaiian or Other Pacific Islander ❒ Other; *please describe:*
❒ Black or African American ❒ White or Caucasian

What is your ZIP code? ____________________

Figure 1. Attendee survey core questions.

EvalFest staff members used training videos to help ensure that field researchers at participating science expos used the same procedures to collect data from attendees. These videos included best practices for conducting intercept surveys, such as where a researcher should be located at the expo, how to systematically choose whom to survey, and how to track refusals.

Analysis

The researchers used ordinal logistic regression to examine 5,498 survey responses for attendees of science expos at 14 science festivals around the United States. Specifically, a partial proportional odds (PPO) model was selected after an initial analysis of the data indicated that certain independent variables violated the proportional odds assumption. The proportional odds assumption, or parallel lines assumption, states that the effect of any independent variable upon a dependent variable is uniform across all categories (i.e. survey response ratings) of the dependent variable. A series of Wald tests indicated that this assumption did not hold for all of the independent variables selected for analysis (appendix A). In this case, the PPO model proves to be a more parsimonious alternative to the typical proportional odds model because it allows the effects of an independent variable to vary across each category of the dependent variable. In other words, the proportional odds assumption is relaxed for independent variables that are in violation of the assumption and constrained for variables that are not in violation. The PPO model for determining the probability that an attendee (i) provides a response that is at or above a given threshold (j), assuming there are J categories of the dependent variable, can be specified as:

$$P\left(Y_i \geq j\right) = P_{ij} = \frac{e^{\left(\alpha_j + X_i \beta_j\right)}}{1 + e^{\left(\alpha_j + X_i \beta_j\right)}} \qquad j = 1, 2, \ldots, J-1\,.$$

In this equation, α_j are the cut points for the model, while β_j represent the logit coefficients. The logit coefficients measure the effect of a one-unit change in an independent variable on the log-odds of a specific category of the dependent variable. Other categories are utilized as a basis for comparison. The logit coefficients may vary between outcomes, depending on whether or not a particular variable satisfies the proportional odds assumption.

The PPO analysis uses a series of model dichotomizations to estimate the odds that an attendee of a science expo will provide a response that is at or above a particular rating. Caution must be exercised in the interpretation of logit coefficients for intermediate ratings because the signs of these coefficients do not necessarily indicate the direction of an effect [Washington, Karlaftis and Mannering, 2011]. In order to facilitate interpretation of the results, adjusted predictions at representative values were examined. Adjusted predictions take specified values for independent variables and compute outcome probabilities for individuals with those characteristics. This allowed for a deeper investigation into the effect of scientist interaction by gender identity and URM status.

All statistical analyses were conducted in Stata using the gologit2 program [Williams, 2006]. A multilevel ordinal logistic regression was briefly considered, but an initial analysis indicated that only a small percentage of the variation in survey responses could be attributed to expo location. After running the unconditional (null) model for overall ratings, we found that the ratio of the between-expo variance and its standard error was 1.69. This value was not large enough to indicate that between-expo variance was significantly different from zero. Examining unconditional models with the other four outcomes yielded similar results with intraclass correlation coefficients less than .01. In facilitating the interpretation of results, a single-level model was preferred. Results from the four PPO models — overall ratings, learning, inspiration, and fun — are provided below. Analysis of variance inflation factors indicated that multicollinearity was not problematic.

A fifth survey outcome — awareness of STEM careers — is also included in this paper. Due to the binary and categorical nature of this outcome, a simple logistic regression analysis was preferred to the partial proportional odds model. A stepwise procedure determined that only one independent variable, scientist interaction, sufficiently contributed to survey responses for this outcome. Results from the simple logistic regression analysis are included below.

Results

Table 1 summarizes the descriptive statistics of the survey data. Nearly half (49%) of attendees identified as underrepresented minorities, while 61% identified as female. Survey responses were overwhelmingly positive for all five outcomes. A majority (53%) of attendees assigned the highest overall rating to the expo they attended. Most attendees either agreed or strongly agreed with statements related to learning (84%), inspiration (80%), and fun (92%). In addition, 83% of attendees attested to increased awareness of STEM career opportunities.

Logit coefficients, standard errors, and average adjusted predictions for the Likert scale outcomes — overall ratings, learning, inspiration, and fun — are reported in Tables 3–10. The tables also indicate which p-values proved to be significant and which independent variables violated the proportional odds assumption. If the proportional odds assumption was met for an independent variable, the logit coefficient is recorded only in the first column of the table. Wald test results from each model can be found in appendix A. Within each column, survey data are dichotomized to compare responses at or above specified levels. There are four such comparisons (Table 2). Simple logistic regression results for the fifth survey outcome, STEM career awareness, are reported in Table 11. Any missing data were excluded from the analysis.

Analysis of overall ratings

In examining each outcome, positive logit coefficients are associated with higher odds that an attendee will rate a science expo at or above the specified threshold. For the first outcome, overall expo ratings, the gender variable has a logit coefficient of .319 for all thresholds (Table 3). This indicates that gender did not violate the proportional odds assumption and that female attendees were more likely to give higher overall ratings. A logit coefficient of .319 converts to an odds ratio of $e^{0.319} = 1.38$, indicating that females were 1.38 times as likely as males to assign an overall rating above a given threshold.

Table 1. Descriptive statistics (N = 5,498).

	Poor	Fair	Good	Very Good	Excellent
Overall	<1%	1%	11%	34%	53%
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Learning	6%	2%	8%	43%	41%
Inspiration	3%	2%	15%	47%	33%
Fun	2%	<1%	5%	44%	48%
			No	Yes	
Increased awareness of STEM careers			17%	83%	
Race	49% of participants identified as an underrepresented minority (URM)				
Gender	61% of participants identified as female, 39% male				
Scientist interaction	90.4% of participants interacted with a scientist				
Median income					
	Less than $15,000	0.09%			
	$15,000–$24,999	0.45%			
	$25,000–$34,999	9.72%			
	$35,000–$49,999	19.27%			
	$50,000–$74,999	33.68%			
	$75,000–$99,999	25.40%			
	$100,000–$149,999	8.16%			
	$150,000–$199,999	3.11%			
	More than $200,000	0.05%			

Table 2. Probability comparisons.

	$P(Y > 1)$	$P(Y > 2)$	$P(Y > 3)$	$P(Y > 4)$
Odds	$\frac{P(Y>1)}{P(Y\leq 1)}$	$\frac{P(Y>2)}{P(Y\leq 2)}$	$\frac{P(Y>3)}{P(Y\leq 3)}$	$\frac{P(Y>4)}{P(Y\leq 4)}$
Dichotomization	Category 1 vs categories 2 through 4	Categories 1 and 2 vs categories 3 through 5	Categories 1 through 3 vs categories 4 and 5	Categories 1 through 4 vs category 5

The scientist interaction variable failed to satisfy the proportional odds assumption and is therefore assigned a different logit coefficient for each threshold. Three of these coefficients were significant at the $\alpha = .001$ level and were overwhelmingly positive. A logit coefficient of .777 is associated with an odds ratio of 2.15. In other words, attendees who interacted with a scientist were 2.15 times as likely to assign an expo the highest overall rating (5 = Excellent) as attendees who did not interact with a scientist.

In order to better parse out the effects of scientist interaction, adjusted predictions at representative values were generated. These values are obtained by selecting certain individual characteristics of attendees and computing the probabilities that attendees with those characteristics will assign specific overall ratings. This provides an intuitive and meaningful method for examining the effect of scientist interaction by race and gender. Adjusted predictions for overall ratings can be found in Table 4.

Table 3. Partial proportional odds model for overall ratings.

	$P(Y > 1)$	$P(Y > 2)$	$P(Y > 3)$	$P(Y > 4)$
Gender				
Coefficient	0.319***			
Standard error	0.053			
URM				
Coefficient	-0.442	0.087	-0.101	0.101
Standard error	0.548	0.229	0.082	0.055
Median Income				
Coefficient	-0.040			
Standard error	0.022			
Scientist Interaction				
Coefficient	-0.388	1.265***	1.109***	0.777***
Standard error	1.045	0.260	0.108	0.095
Pseudo R^2 = 0.0151	Log likelihood ratio statistic = 167.81, p < 0.001			
	Degrees of freedom = 10			
	Log likelihood = -5486.36			

*p < 0.05; **p < 0.01; ***p < 0.001. The reference group is comprised of white males who did not interact with a scientist.

Table 4. Adjusted probabilities at representative values for overall ratings.

	Poor	Fair	Good	Very Good	Excellent
Female					
No scientist interaction	0.001–	0.033	0.212	0.360	0.394
Interaction	0.002	0.008	0.087	0.320	0.583
Male					
No scientist interaction	0.002–	0.045	0.263	0.369	0.321
Interaction	0.003	0.011	0.115	0.367	0.504
Underrepresented Minority					
No scientist interaction	0.002–	0.036	0.244	0.341	0.377
Interaction	0.003	0.008	0.104	0.320	0.565
Non-Underrepresented Minority					
No scientist interaction	0.001–	0.040	0.221	0.384	0.354
Interaction	0.002	0.010	0.093	0.355	0.540

– Values were not significant at the $\alpha = 0.01$ level.

For female attendees, interacting with a scientist significantly increased the probability of assigning an expo the highest overall rating (.583), compared to female attendees who stated that they did not interact with a scientist (.394). The model predicts that female attendees who did not interact with a scientist are more likely to assign a rating of "good" or lower (.246 compared to .097 for female attendees who did interact with a scientist). A similar effect was observed for male attendees. Male attendees who interacted with a scientist were much more likely to assign a rating of "excellent" (.504) and much less likely to assign a rating of "good" or below (.129) than their counterparts who did not interact with a scientist (.321 and .310, respectively).

This trend persists even when parsing out the effect of scientist interaction by URM status. Attendees who identified as underrepresented minorities became much more likely to give an "excellent" rating if they interacted with a scientist (from .377 to .565). Those who did not identify as underrepresented minorities saw adjusted probabilities for "excellent" ratings increase from .353 to .540 when they interacted with a scientist. For both groups, the likelihood of assigning a rating "good" or below decreased in the presence of a scientist interaction.

Analysis of learning

The second outcome for the model, learning, is an ordinal variable wherein attendees were asked to rate the extent to which they agreed with the statement: "I have learned something new at this event." Table 5 contains the partial proportional odds results for this variable. None of the independent variables met the proportional odds assumption. Therefore, logit coefficients varied across each threshold.

Table 5. Partial proportional odds model for learning.

	$P(Y>1)$	$P(Y>2)$	$P(Y>3)$	$P(Y>4)$
Gender				
Coefficient	-0.183	-0.117	0.086	0.183**
Standard error	0.118	0.106	0.077	0.057
URM				
Coefficient	-0.290*	-0.238*	-0.098	0.121*
Standard error	0.114	0.103	0.076	0.056
Median Income				
Coefficient	0.105*	0.009	-0.029	-0.058*
Standard error	0.048	0.041	0.031	0.023
Scientist Interaction				
Coefficient	0.177	0.475**	0.989***	1.039***
Standard error	0.182	0.150	0.104	0.110
Pseudo R^2 = 0.0165	Log likelihood ratio statistic = 210.57, p < 0.001			
	Degrees of freedom = 16			
	Log likelihood = -6278.86			

*p < 0.05; **p < 0.01; ***p < 0.001. The reference group is comprised of white males who did not interact with a scientist.

According to the results for the learning outcome, a logit coefficient of 0.183 implies that female respondents were 1.20 times as likely as males to strongly agree with the learning statement. Attendees who identified as underrepresented minorities were more likely to give the most extreme responses — strongly disagree and strongly agree — rather than intermediate responses. Increases in median income tended to solicit more intermediate responses rather than extreme responses. Scientist interaction once again proved to have the most dramatic effect on outcomes. A logit coefficient of 1.039 signifies that attendees who interacted with a scientist were 2.83 times as likely as other attendees to strongly agree with the learning statement.

Adjusted probabilities for learning are contained in Table 6. These values once again parse out the effect of scientist interaction by gender and URM status. For female attendees, interacting with a scientist increased the probability of strongly agreeing with the learning statement from .226 to .452. The adjusted predictions for all other responses decreased. For male attendees, interacting with a scientist increased the probability of strongly agreeing with the learning statement from .196 to .407. This effect held true regardless of whether or not attendees identified as underrepresented minorities (URM). For URM attendees, interacting with a scientist increased the adjusted prediction for "strongly agree" from .224 to .449. For non-URM attendees, the adjusted prediction increased from .204 to .420.

Table 6. Adjusted probabilities at representative values for learning.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Female					
No scientist interaction	0.071	0.042	0.179	0.481	0.226
Interaction	0.060	0.014	0.069	0.415	0.452
Male					
No scientist interaction	0.060	0.042	0.208	0.494	0.196
Interaction	0.051	0.015	0.077	0.449	0.407
Underrepresented Minority					
No scientist interaction	0.076	0.045	0.189	0.456	0.224
Interaction	0.065	0.014	0.064	0.407	0.449
Non-Underrepresented Minority					
No scientist interaction	0.058	0.040	0.191	0.506	0.204
Interaction	0.049	0.014	0.068	0.448	0.420

All values were significant at the $\alpha = 0.01$ level.

Analysis of inspiration

The third outcome for the model, inspiration, is an ordinal variable wherein attendees were asked to rate the extent to which they agreed with the statement: "I felt inspired by something I did in STEM". Partial proportional odds analysis for the inspiration outcome is contained in Table 7. For this survey item, attendees were asked to rate the extent to which they agreed with the statement: "I felt inspired by something I did in STEM." Only the scientist interaction variable violated the proportional odds assumption for this outcome. A logit coefficient of .156 indicates that female attendees were slightly more likely to give higher ratings for the inspiration statement. Across the board, attendees who interacted with a scientist were far more likely to give higher ratings than attendees who did not interact with a scientist. A logit coefficient of .906 indicates that attendees who interacted with a scientist were 2.47 times as likely as others to strongly agree with the inspiration statement. Logit coefficients for URM and median income did not prove to be significant for this outcome.

Adjusted predictions for the inspiration outcome are contained in Table 8. Interacting with a scientist dramatically increased the probability of strongly agreeing with the inspiration statement regardless of gender identity or URM

Table 7. Partial proportional odds model for inspiration.

	$P(Y > 1)$	$P(Y > 2)$	$P(Y > 3)$	$P(Y > 4)$
Gender				
Coefficient	0.156**			
Standard error	0.052			
URM				
Coefficient	0.091			
Standard error	0.051			
Median Income				
Coefficient	0.021			
Standard error	0.021			
Scientist Interaction				
Coefficient	0.497*	0.616***	1.125***	0.906***
Standard error	0.226	0.173	0.097	0.118
Pseudo R^2 = 0.0124	Log likelihood ratio statistic = 161.88, p < 0.001			
	Degrees of freedom = 7			
	Log likelihood = -6423.41			

*p < 0.05; **p < 0.01; ***p < 0.001. The reference group is comprised of white males who did not interact with a scientist.

status. The adjusted predictions for "strongly agree" nearly doubled for every group: from 0.186 to 0.360 for females, from 0.164 to 0.326 for males, from 0.184 to 0.358 for underrepresented minorities, and from 0.171 to 0.337 for non-underrepresented attendees.

Table 8. Adjusted probabilities at representative values for inspiration.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Female					
No scientist interaction	0.043–	0.034	0.307	0.430	0.186
Interaction	0.027	0.017	0.125	0.471	0.360
Male					
No scientist interaction	0.050–	0.039	0.332	0.415	0.164
Interaction	0.031	0.019	0.141	0.483	0.326
Underrepresented Minority					
No scientist interaction	0.043	0.034	0.309	0.429	0.184
Interaction	0.027	0.017	0.127	0.427	0.358
Non-Underrepresented Minority					
No scientist interaction	0.047	0.037	0.324	0.420	0.171
Interaction	0.029	0.018	0.136	0.479	0.337

– Values were not significant at the $\alpha = 0.01$ level.

Analysis of fun

The fourth outcome variable asked attendees the extent to which they agreed with the statement: "I had fun at this event." The partial proportional odds results for the fun outcome are reported in Table 9. In line with results for other outcomes, female attendees were more likely to strongly agree with the fun statement than male attendees. Scientist interaction demonstrated significant and positive effects across most of the thresholds. A logit coefficient of .921 indicates that attendees who interacted with a scientist were 2.51 times as likely as other attendees to strongly agree with the fun statement. Neither URM nor median income proved to be a significant predictor of this outcome.

Table 9. Partial proportional odds model for fun.

	$P(Y>1)$	$P(Y>2)$	$P(Y>3)$	$P(Y>4)$
Gender				
Coefficient	-0.302	-0.291	0.030	0.315***
Standard error	0.242	0.214	0.122	0.067
URM				
Coefficient	0.086			
Standard error	0.634			
Median Income				
Coefficient	0.007			
Standard error	0.026			
Scientist Interaction				
Coefficient	0.449	0.754**	1.170***	0.921***
Standard error	0.319	0.255	0.143	0.114
Pseudo R^2 = 0.0179	Log likelihood ratio statistic = 134.87, p < 0.001			
	Degrees of freedom = 10			
	Log likelihood = -3704.29			

*p < 0.05; **p < 0.01; ***p < 0.001. The reference group is comprised of white males who did not interact with a scientist.

Adjusted predictions for the fun outcome are provided in Table 10. Once again, interacting with a scientist dramatically increased the predicted probability of falling into the “strongly agree” category. The scientist interaction increased the adjusted probability of a “strongly agree” response from .314 to .535 for females and from .251 to .456 for males. This adjusted probability increased from .297 to .514 for underrepresented minorities and from .280 to .492 for non-underrepresented attendees.

Analysis of STEM career awareness

The final survey outcome attempted to identify whether or not attendees’ awareness of STEM career opportunities increased after visiting these science expos. This item was formulated as a binary “yes” or “no” statement on the survey form. Due to the binary and categorical nature of the outcome, a simple logistic regression analysis was preferred to the partial proportional odds model. The gender, URM, and median income variables were excluded from this analysis after it was determined that they did not significantly contribute to the model.

A logit coefficient of 0.779 (Table 11) converts to an odds ratio of 2.18. Thus, attendees who interacted with a scientist were 2.18 times as likely to attest to increased awareness of STEM careers as those who did not interact with a scientist.

Table 10. Adjusted probabilities at representative values for fun.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Female					
No scientist interaction	0.032	0.021	0.131	0.501	0.314
Interaction	0.021	0.005	0.040	0.400	0.535
Male					
No scientist interaction	0.024	0.016	0.149	0.560	0.251
Interaction	0.015	0.004	0.048	0.476	0.456
Underrepresented Minority					
No scientist interaction	0.028	0.019	0.134	0.523	0.297
Interaction	0.018	0.004	0.041	0.423	0.514
Non-Underrepresented Minority					
No scientist interaction	0.030	0.020	0.143	0.527	0.280
Interaction	0.019	0.004	0.045	0.439	0.492

All values were significant at the $\alpha = 0.01$ level.

The Wald z value of 5.82 ($p < 0.001$) indicates that scientist interaction was a significant predictor for the awareness outcome.

Table 11. Simple logistic regression results for STEM career awareness.

	Coefficient	Standard Error	95% Confidence Interval
Scientist Interaction	0.779*** Wald z = 5.82	0.134	[0.516, 1.041]
Pseudo $R^2 = 0.012$		Log likelihood ratio statistic = 31.10, $p < 0.001$ Degrees of freedom = 4 Log likelihood = -1336.02	

***$p < 0.001$.

Discussion

The partial proportional odds results indicate that interacting with a scientist has a significant and positive effect on all of the survey items. On each of the four Likert scale items - overall rating, fun, inspiration, and learning - the probability of assigning the most favorable ratings increased dramatically for respondents who had interacted with a scientist at the expo they attended. Adjusted probabilities at representative values reinforced these findings for all of the survey items. On the binary outcome, awareness of STEM careers, respondents who interacted with a scientist were more likely to say that they became more knowledgeable about STEM career opportunities.

When the effect of scientist interaction was parsed out by gender and minority status, no striking differences were found between groups. Though female attendees were more likely to assign positive ratings in general, being able to interact with a scientist significantly increased the probability of assigning favorable ratings for both males and females. Similarly, although attendees who identified as underrepresented minorities were somewhat more likely to give favorable ratings in general, adjusted probabilities demonstrated that the effect of scientist interaction was overwhelmingly positive regardless of URM status.

These results support previous findings that the general public values and appreciates interactions with scientists and engineers. The results are also consistent with the evaluation data collected by Goodman Research Group for the Science Festival Alliance cited previously, where survey respondents rated events more positively if they interacted with STEM practitioners [Manning et al., 2012]. This study, in particular, begins to create a base of knowledge for the impacts scientists and engineers have on the public audiences with which they engage.

Although a good start at providing research where there has been little conducted, there are several limitations to this study. Survey data was collected by local teams at each of the 14 expos. These teams were trained to use identical protocols for attendee selection, but the differences between survey teams can add variability between individual sites. Additionally, these surveys were completed at events where it was extremely likely that respondents interacted with scientists and engineers. In fact, more than 90% of survey respondents indicated that they had interacted with a scientist and engineer, meaning that this study compared groups (interaction vs. no interaction) of vastly different sizes. However, the large sample size (n = 5,498) of the study and the robustness of the partial proportional odds model dramatically reduce the effects of unequal group sizes [Hsieh, 1989].

Since the survey did not ask specific questions about respondents' income, income levels were inferred based upon their home zip code. Incomes can vary greatly within specific zip codes, therefore using this method also limits the generalizability of the study.

Conclusion

The results from the EvalFest survey data highlight the importance of bringing practicing scientists and engineers to public science events. When members of the public are able to interact with scientists and engineers, their self-perceptions of overall expo ratings, how much they are learning, how much they feel inspired, and how much fun they are having become significantly more favorable. Members of the public are also more likely to attest to increased awareness of STEM careers after interacting with a scientist. These results underline the need to train STEM professionals in effective public outreach and science communication. Further research on public-scientist interactions is needed to inform effective communication training. While this study collected demographic data only on attendees of science expos, future research may analyze the effect of scientists' own racial and gender identities on public-scientist interactions.

Appendix A. Wald Test results

	Gender	URM	Median Income	Scientist Interaction
Overall	0.083	0.041*	0.510	0.004*
Learning	0.019*	0.004*	0.001*	<0.001*
Inspiration	0.067	0.165	0.395	0.005*
Fun	0.031*	0.470	0.9192	0.041*

*Constraints for parallel lines were not imposed.

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Authors

Todd Boyette is the Director of Morehead Planetarium and Science Center and Adjunct Professor of Education at the University of North Carolina at Chapel Hill. He currently serves as Principal Investigator of EvalFest, a project sponsored by the National Science Foundation (U.S.) and designed to increase evaluation capacity within the U.S. science festival community. E-mail: tboy@unc.edu.

J. Ross Ramsey is a doctoral student in Learning Sciences and Psychological Studies at the University of North Carolina at Chapel Hill School of Education and a former high school math teacher. He currently works as a graduate research assistant for the North Carolina Science Festival. E-mail: ramse@live.unc.edu.

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