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Science Self-Efficacy and Lifelong Learning:
Emerging Adults in Science Museums

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Science Self-Efficacy and Lifelong Learning: Emerging Adults in Science Museums

Abstract

Recent research suggests that emerging adulthood—the stage between adolescence and maturity marked by a lengthy process of identity development—constitutes a window of opportunity for museums to influence adults' lifelong science learning trajectories. The current study sought to explore the impact of a single museum visit on emerging adults' science self-efficacy, beliefs about their own abilities to learn or do science. A repeated measures design assessed the science self-efficacy of 244 emerging adults before, immediately after and three months after a science museum visit. Results from surveys and interviews indicate that self-efficacy increased after the visit, but only females maintained their elevated self-efficacy three months after the visit. Increases were associated with the visit and with self-reports citing "mastery" at exhibits, vicariously watching others at exhibits, and positive emotional experiences within the museum. The paper discusses the study's limitations as well as implications for research and museum practice.

A key goal of any educational endeavor is to promote a passion for learning. Leaders of both formal and informal learning environments urge us to view science learning as a lifelong undertaking, driven by curiosity and sustained interest (National Research Council, 2009; President's Council of Advisors on Science and Technology, 2010). Nonetheless, science museums typically focus most of their educational activities on children and families, largely ignoring adult-only groups, despite adults' relatively high visitation rates. According to recent visitor exit data from a consortium of large and small science museums in the United States, an average of one quarter of visiting groups consist of adults without children (Auster & Lussenhop, 2017). At the Exploratorium, adult-only groups comprise over 40% of the groups in attendance.

The high proportion of adult-only visitors point to one of the great strengths of science museums: They engage learners of all ages, including those who have completed their formal education. For some adults, that education successfully developed their interests, knowledge, and skills in science; for others, it did not. Science museums offer opportunities to deepen connections to science for some and establish entirely new ones for others.

A small but growing number of studies have investigated adult learning apart from children. In an early example of adult studies in museums, Sandifer (1997) compared adult-only groups to groups of adults visiting with children and found differences in their learning behaviors in a science museum. The study found that adult-only groups spent significantly less time than family groups in the museum in general and at exhibits in particular. In contrast to the implication that adult-only groups may not be focused on learning within the museum, research on specific learning outcomes for adults shows promise. For example, Falk and Adelman (2003) studied adult aquarium visitors, 90% of whom were attending without children. They found that interest and concern for environmental conservation increased significantly over the course of a single visit, particularly for those who showed minimal or moderate prior environmental knowledge before entering the aquarium. Similarly, Packer and Ballantyne (2005) found that adults visiting a cultural exhibition in a natural history museum engaged in learning behaviors and reported that they had gained new understandings immediately afterwards. The study went further by interviewing participants four weeks after the visit. More than 75% of the adults reported having discussed the exhibition sometime after their visit, indicating that the museum left lasting impressions on many of them.

In these studies, adulthood covered a wide range of ages, experiences, and phases of life for study participants. However, recent research on adult development suggests that *emerging adulthood*—the stage between adolescence and full maturity—may represent a distinct life stage marked by a lengthy process of identity development. Existing primarily in the modern developed world, the phase of emerging adulthood has recently garnered attention from psychologists and sociologists eager to map its characteristics.[1]

This article describes a study of emerging adults' learning experiences in science museums, exploring how museums may affect their science self-efficacy—beliefs about their own abilities to learn or do science.[2] The following pages lay out a case for the existence of emerging adulthood, then proceed to describe a theoretical framework for self-efficacy that suggests strong potential for positive influence from museum experiences. Our team's conviction was that the unsettled nature of identity in emerging adulthood would make emerging adults more impressionable, increasing the likelihood of finding museum impact on their self-efficacy, should any impact exist. The study, using interviews and surveys, sought to assess the immediate and longer-lasting effects of a single museum visit on emerging adults' science self-efficacy. The results justify a focus on self-efficacy and support the notion that emerging adulthood be viewed as an important life stage for adult learning experiences.

Emerging Adulthood

Emerging adulthood is typically defined as the period of life between the ages of 18 and 29 years, before marriage and children (Arnett, 2000; Tanner, Arnett, & Leis, 2009). The traits of being unmarried and childless are critical, more important than the particular age range, because a key attribute of this life stage is a freedom from responsibility for others. As people move from adolescence toward adulthood, they undergo a process called *recentering*, in which they leave behind the rule structures and family relationships of childhood to create new bonds through marriage or parenting (Tanner, et al., 2009). They progress from childhood interactions that foster dependence to adult peer relations and responsibilities that require interdependence. Emerging adulthood lies between these milestones, providing emerging adults with the liberty to engage in identity work (Rounds, 2006), often seeking out experiences of self-discovery (Tanner, et al., 2009).

A relatively recent phenomenon, emerging adulthood as a distinct life phase grew out of vast social changes in developed countries (Arnett, 2000, 2012). Perhaps the most relevant societal shift in the United States over the past 45 years has been the rapid rise in educational opportunities, especially for women. According to the U.S. Census, the number of adults aged 25 or older with a college education tripled from about 11% in 1970 to 33% in 2015 (Ryan & Bauman, 2016). For women, the increase has been more dramatic than for men during that period, with the gender gap in college degree attainment shrinking from about 5% to zero. (Ryan & Bauman, 2016).

As women spend more time within the formal education system, they tend to delay traditional marriage and parenting. Specifically, the average age of first marriage has increased by about 6 years since 1970 (Elliott & Simmons, 2011), and the mean age for women having their first child has risen by nearly 5 years (Center for Disease Control and Prevention, 2016; Mathews & Hamilton, 2002). The number of women bearing their first child after the age of 30 grew from 5% to 25% in that period (Ventura, 2012). These changes in marriage and child-rearing, which hold across all racial categories, have significantly extended the period of freedom associated with recentering and identity development, essentially creating the developmental phase of emerging adulthood.

With deferral of marital relationships and parenting practices, the onset of adulthood has become more subjective (Mayseless & Scharf, 2003; Tanner, et al., 2009). No longer is adulthood regarded as commencing with major life events, such as completing formal education, entering into marriage or embarking upon parenthood. More recently, the feeling of adulthood arises in a gradual way, through intangible shifts in attitudes. People begin to view themselves as adults when they can "accept responsibility for [themselves], make independent decisions, and become financially independent" (Tanner, et al., 2009, p. 37).

During this lengthy transformation, emerging adults test out different social roles, as reflected in a noticeable instability in their lives. For example, people change employment more during this period than any other, taking on an average of seven different jobs before the age of 30 (Arnett, 2012). (In contrast, by the age of 35, over 60% of adults have held a position for 5 years or more (Yates, 2005).) Emerging adults also change their living situations more frequently than older adults, relocating to more residences and different regions of the country, living with a greater variety of acquaintances and friends, and cohabitating with more romantic partners

(Tanner, et al., 2009). Variability in employment and domestic life provides significant opportunities for emerging adults' to experiment with diverse roles and experiences.

Often called the age of possibility, emerging adulthood constitutes a period when people feel they can try anything, even making "dramatic changes in their lives" (Tanner, et al., 2009, p. 37). By directly engaging emerging adults, science museums may help to launch or strengthen lifelong science learning patterns, empowering those who felt less capable in science in school and broadening the connection for those who studied particular science topics. Museums may even influence how emerging adults will later educate their children about science.

Indeed, science museums have begun reaching out to this audience as never before with adult-only programming. Such programs are typically offered in the evening, involve music and alcohol, and provide a social atmosphere for engaging in science learning. Examples include Tinkering and Drinkering at the North Carolina Museum of Life and Science, After Hours at the Denver Museum of Nature and Science, Geek Out! at the Lawrence Hall of Science, NightLife at the California Academy of Sciences, and After Dark at the Exploratorium, just to name a few. However, the field knows little about emerging adults and their learning experiences within science museums, whether during adult-only events or normal visiting hours. Evaluation studies of adult-only programs offer a good foundation, but concentrate mainly on attendance, demographics and attitudes toward the program, rather than on participants' in-depth learning experiences (e.g., Schidlow, Wright, Alexander, & Garcia-Luis, 2012; Tinworth, 2011). The current study focused on changes in science self-efficacy as a potential learning outcome of the museum visit.

Self-Efficacy Theoretical Framework

Science museums seek to empower learners to use the process and content of science to understand and improve the world (e.g., Boston Museum of Science, 2016; Exploratorium, 2016; Science Museum of Minnesota, 2016). For example, Frank Oppenheimer, founder of the Exploratorium, a museum that helped establish the field of science centers (Ogawa, Loomis, & Crain, 2008), once stated, “The whole point of the Exploratorium is to make it possible for people to *believe they can understand* the world around them” (Semper, 1990, p. 55, italics added). This belief about one’s capacity to learn and understand, referred to as self-efficacy in the cognitive sciences literature, is influenced by the reciprocal interaction of environmental, behavioral, and personal determinants (Bandura, 1986; Pajares & Usher, 2008). Social cognitive researchers have shown that self-efficacy can have a strong effect on performance in school and associated learning behaviors such as persistence, expended effort and even emotional responses like excitement or fear (Bandura, 1997; Yoon, 2009; Zimmerman, Bandura, & Martinez-Pons, 1992).

In a review of the research on self-efficacy, Ellen Usher and Frank Pajaraes found evidence from dozens of studies that greater self-efficacy leads to myriad positive outcomes for school students:

> Self-efficacy has been shown to predict students’ academic achievement across academic areas and levels (see Pajares & Urdan, 2006). It has also been shown to predict students’ college major and career choices (Brown & Lent, 2006), and it is associated with key motivation constructs such as causal attributions, self-concept, optimism, achievement goal orientation, academic help-seeking, anxiety, and value. Students who are confident in their academic

> capabilities monitor their work time more effectively, are more efficient problem solvers, and show more persistence than do equally able peers with low self-efficacy. They also work harder, evaluate their progress more frequently, and engage in more self-regulatory strategies that promote success in school. (Usher & Pajares, 2008, pp. 751-752)

While the review included research in various content domains, several studies focused specifically on science self-efficacy, revealing its positive relationship to learning science. And many of the studies included in the review by Usher and Pajares centered on college students, representing part of the emerging adult population. Across the board, relationships between self-efficacy and learning outcomes in college undergraduates were similar to those of younger students.

Sources of self-efficacy. When Albert Bandura (1977a) proposed his theory of self-efficacy forty years ago, he posited different types of experience that would influence a person's self-efficacy, either positively or negatively, and named them *sources*. Since that time, many research studies have found support for his four sources of self-efficacy (Bandura, 1997; Usher & Pajares, 2008):

- Performance Interpretation—perceived success or failure in a task,
- Vicarious experiences—observation of others and exposure to role models,
- Social Persuasions—evaluative messages from others, and
- Physiological/Emotional states—affective or emotional responses.

Performance Interpretation, also called mastery, involves learners noticing the degree of their success in a task, and using that observation to estimate their ability to accomplish similar tasks. As Bandura predicted, this type of experience has been found to be the most influential source of self-efficacy (Usher & Pajares, 2008), even among college students (Lent, Brown, Gover, & Nijjer, 1996). Vicarious Experiences involve learners comparing themselves to others; when such a comparison yields a favorable result, self-efficacy improves. In Social Persuasions, others communicate their own beliefs about learners' abilities. For example, teachers often praise students in the hopes of raising their self-confidence, while peers sometimes mock one another to opposite effect. Finally, Physiological/Emotional states, such as anxiety or excitement when anticipating or engaging in a task, may influence learners' self-efficacy for related tasks. As nearly all studies of sources of self-efficacy has been performed in schools, researchers know more about the effects on self efficacy of negative feelings like fear than they do about positive feelings like joy (Usher & Pajares, 2008). For instance, one study of middle and high school science students found that *at-risk* students—those who performed poorly in science and had the lowest levels of science self-efficacy—tended to form their efficacy beliefs primarily from physiological and emotional states, such as anxiety, stress and fatigue (Chen & Usher, 2013). Finally, weak evidence for gender differences exists among studies of college students, with women employing physiological/emotional experiences as sources of self-efficacy to a greater degree than men (Usher & Pajares, 2008). Moreover, women have been found to have lower STEM self-efficacy and higher science anxiety than men in some domains (Hill, Corbett, & St. Rose, 2010; Nix, Perez-Felkner, & Thomas, 2015).

While most self-efficacy research has been conducted in K-16 settings, a small number of studies of older adults has found similar patterns regarding self-efficacy. In a pair of studies by Amy Zeldin, Frank Pajares and colleagues (Zeldin, Britner, & Pajares, 2008; Zeldin & Pajares, 2000), investigators interviewed women (ages 26-53) and men (ages 24-64) who had careers in STEM about the sources of their science self-efficacy. They found that in general, the same four sources influenced self-efficacy. As with college students, some gender differences emerged: Performance Interpretations were more important sources for men, while social interactions such as Vicarious Experiences and Social Persuasions were more critical for women.

Science museums and self-efficacy. The research on college students and older adults showing connections between self-efficacy, persistence and performance in science suggests that developing positive science self-efficacy may constitute a critical step on the road to lifelong science learning. This is where museums enter the equation. Science museum environments may offer abundant opportunities for positive sources of self-efficacy:

- Science museums allow for positive Performance Interpretations through experimentation at exhibits without adverse academic or professional consequences. Successfully using and understanding many exhibits over the course of a visit could generate positive self-efficacy for learning science.
- By observing fellow visitors, learners exposed to Vicarious Experiences may re-evaluate their own judgments about what they can do (Sawtelle, Brewe, Goertzen, & Kramer, 2012). For example, emerging adults may feel more confident to try an exhibit after viewing a friend succeed at using it.
- Thinking and playing in a relaxed, non-competitive environment like a museum may facilitate supportive conversations in which learners praise or encourage each other’s scientific pursuits (Social Persuasions), possibly raising their self-efficacy.
- Engaging with interactive science exhibits often brings about positive Physiological/Emotional states such as joy, pride and excitement (National Research Council, 2009), which may enhance self-efficacy.

Although self-efficacy and its sources have been examined in formal learning contexts, little is known about how they operate within informal contexts. In one of the only studies of the relationship between science museum visitation and science self-efficacy, Larry Suter (2014) analyzed quantitative, longitudinal survey data from over one thousand school students, following them from seventh through twelfth grade.[3] A univariate analysis found that science museum visitation throughout middle and high school did not directly influence science self-efficacy in the twelfth grade. However, a multiple regression analysis that included more variables found there was a more subtle relationship: “Students who perform well in seventh grade, take more science courses in high school, and attend science museums have somewhat higher self-efficacy and higher science scores by the 12th grade.” (Suter, 2014, p. 830). This study did not investigate sources of self-efficacy, and its various findings raise further questions about the relationship between science museum visitation and science self-efficacy.

In the study described here, the project team sought to explore the extent to which emerging adults’ science self-efficacy would be enhanced by engaging with science museum exhibits and programs in a single visit. The team hypothesized that emerging adults’ science self-efficacy would benefit from all four sources described above.

Methods

The study employed a repeated measures design to gauge the impact of a single museum visit on adults’ science self-efficacy, assessing participants’ experiences before, immediately after and three months after their visit. The investigation was devised to determine short- and longer-term effects of the visit (see Figure 1).

INSERT Figure 1 ABOUT HERE

Participants

Potential participants were recruited upon entry to the Exploratorium, a hands-on science museum located in San Francisco, a large metropolitan area with a culturally diverse population. The museum contains over 600 individual exhibits for interactive exploration of physical, biological and social science phenomena. People typically visit in order to spend time with friends and family and have a fun, educational experience (Auster & Lussenhop, 2017; Wright, Alexander, Garcia-Luis, & Gardella, 2011).

Researchers recruited 244 participants aged 18-29 who had never been married, had no children, were not accompanied by any children, and lived in the United States (to facilitate contact three months after the visit). The sample was stratified by gender. To capture a wide array of experiences, the study ran on days when families with children were present in the museum as well as adult-only evenings.[4] All participants in the study were recruited as individuals, regardless of whether they were visiting the museum alone or in groups. Only person per group could participate.

Procedure

Emerging adults completed surveys before, immediately after, and three months after the visit. The pre and postvisit surveys were completed within the museum, and the delayed-post survey was completed online. About half the emerging adults (116) also were asked to participate in semi-structured interviews. This subgroup was directed to use their phone cameras to take two photographs while in the museum, one of something that raised their self-confidence to do or learn science *even by a little bit,* and the other of something that lowered their self-confidence even by a little bit. When finished with their visit, interviewees were brought into a quiet room off the museum floor and asked about their photos before filling out their surveys.

The 116 participants who were interviewed and surveyed were recruited during the first eight months of the study. After concerns arose that the interviews might affect the survey responses, the team recruited another 128 participants for a survey-only condition that had no photos or interviews. The analyses revealed no significant differences in the outcome survey responses between the two groups, so the datasets were combined, yielding a total of 244 study participants.[5] Figure 2 shows the assessments administered to the two groups.

INSERT Figure 2 ABOUT HERE

Variables and Data Sources

Data were collected using surveys, interviews and participant photographs. Surveys quantitatively measured science self-efficacy, demographics, adult identity, and quality of museum experience. Table 1 shows the internal consistency measures for each survey subscale. The interviews—using mainly open-ended questions about moments of increased or decreased self-efficacy during the visit and relevant experiences in the three months after the visit—provided qualitative data about self-efficacy and its sources. Participants' photographs grounded the postvisit interview discussion in specific experiences within the museum. Below, each set of variables is described in more detail.

INSERT TABLE 1 ABOUT HERE

Demographics and adult identity. The postvisit survey assessed an array of demographic and psychographic information, including:

- Personal characteristics (age, gender,[6] ethnicity, education level, employment status),
- Visitation characteristics (prior visitation, museum membership, group size),
- Motivation for visiting, adapted from Falk (2006, 2009), and
- Adult Identity, adapted from Coté and Roberts (2006).

Adult identity—the degree to which emerging adults feel *settled* in their identity as adults—was captured using a shortened version of the validated Identity Issues Inventory (Coté & Roberts, 2006). For example, participants rated their agreement to items such as, "I make sure that my day-to-day behavior reflects my underlying beliefs and values" and "Most of the time, I dress and act in ways that reflect the kind of person that I really am." The team was interested to determine whether degree of settled adult identity would correlate with any changes in self-efficacy.

Museum experiences. The study assessed the quality of the museum experience in two ways. Total time spent in the museum was noted for every participant, acting as a rough measure of engagement. In free-choice learning environments, time spent has been used as a measure of engagement in learning (Humphrey & Gutwill, 2005; Serrell, 1998). Additionally, the postvisit survey assessed participants' enjoyment levels of various aspects of the visit, such as using exhibits and listening to presentations, which was quantified in the Overall Museum Experience score. Items included "The Exploratorium is an exciting place to spend time" and "I think what I learned at the Exploratorium is important." The delayed-post interview asked participants to recall their museum experiences.

Science self-efficacy. All three surveys (pre, post and delayed-post) utilized identical questions to assess science self-efficacy. The surveys employed seven Likert-type items worded in accordance with Bandura's (2006) guidelines and adapted for the museum context. Participants rated their confidence in their ability to engage in seven different science activities (e.g., "Learn about a new science idea," "Come up with fruitful questions to ask about a science-related issue," and "Do a little experiment to figure out how something behaves or works"). The questions were checked for face validity by experts in self-efficacy advising on the project. Responses from the seven items were averaged to create a self-efficacy score at each time period.

The postvisit interview focused on museum offerings that triggered changes in self-efficacy. Participants were asked to talk about something that raised their self-confidence in science and something that lowered it: "We asked you to take photos of something that raised or lowered your self-confidence in science, even by a little bit. Can you show me one of those photos and tell me about that experience?" and then "Do you also have a photo of the converse…" A researcher coded the dataset for sources of change to self-efficacy: Performance Interpretations, Vicarious experiences, Social persuasions and Physiological/Emotional responses. To check for interrater reliability, a second researcher coded 15% of the data. Interrater reliability measures (Cohen's kappa statistic) for these codes ranged from .74 to .95 (see Table 2), considered substantial to excellent agreement (Fleiss, Levin, & Paik, 2004; Landis & Koch, 1977).

INSERT TABLE 2 ABOUT HERE

The delayed-post interview asked about experiences in the museum or in the three months after the visit that may have affected participants' self-confidence in doing or learning science. Two researchers co-coded all the data for the presence of any "confidence-boosting" experiences. Interrater agreement was 98%.

Results

As is typical for this kind of study, attrition reduced the number of participants—a drop of 38%—between the postvisit assessments (N=244) and the delayed-post assessments (N=152). To maximize sample size in the analyses, the investigation was split into short-term impact, which compares the pre and post assessments, and long-term impact, comparing the pre and delayed-post assessments. The subset of participants who are included in the long-term impact analysis are representative of the full participant group in the short-term analysis; there were no significant differences between them on any of the pre-post outcome measures.

Short Term Impact

The study examined the immediate impact of a single museum visit. The analyses below include planned and post hoc comparisons of survey data as well as descriptive analyses of interview data.

Demographics and adult identity. Table 3 shows the demographics and identity scores of participants. Although age and adult identity correlated with each other, neither correlated significantly with our pre-post outcome variable measures, so they were not used as covariates in the analyses.

INSERT TABLE 3 ABOUT HERE

Museum experiences. Participants spent about 2.5 hours on average in the museum. As for their self-reported level of Overall Museum Experience, the average was a 6 out of 7 for both cohorts, indicating that participants typically had a positive experience. Results of our measures of participants' experience in the museum may be found in Table 4.

INSERT TABLE 4 ABOUT HERE

Science self-efficacy. To measure short term impact on science self-efficacy, the team provided identical survey items immediately before and after the visit. A planned comparison employing a paired t-test revealed a statistically significant increase in emerging adults' science self-efficacy. The effect sizes were relatively small, but this is unsurprising given the brevity of the visit (2.5 hours on average). Table 5 shows the means and standard deviations of the previsit and postvisit survey items. (As a partial replication of these results, colleagues in the Midwest surveyed 90 emerging adults before and immediately after their visit to a different, large, interactive science museum. The same pre/post increase in science self-efficacy was detected: $M_{Pre} = 5.5$, $SD = 1.0$; $M_{Post} = 5.8$, $SD = 0.9$; $t_{89} = -4.1$, $p < .001$.[7])

INSERT TABLE 5 ABOUT HERE

A post-hoc multiple regression analysis of the emerging adult cohort endeavored to determine whether the increase in self-efficacy was related to emerging adults' demographics and museum experience. Two variables were related to change in self-efficacy: Education Level (no college degree, college degree and graduate degree) negatively predicted self-efficacy change, while Overall Museum Experience positively predicted self-efficacy change. (This means that emerging adults without a college degree increased their self-efficacy from pre to post more than those with degrees; and participants who had a better overall experience in the museum increased their self-efficacy more than those who did not.) These two variables explained 6.8% of the variance in change in self-efficacy ($F_{2,219} = 8.03$, $p < .001$). Controlling for education level, overall museum experience explained 5% of the variance in emerging adults' self-efficacy (effect size is small, but notable: semi-partial correlation = .22). Specifically, for every increase of 1 point in the Overall Experience Score, there was an additional 22% increase in Self-efficacy. This suggests that the change in self-efficacy was related to emerging adults' experiences in the museum.

To understand that relationship in more detail, let us turn to the postvisit interviews. The post interview sought to surface the kinds of museum experiences that influenced participants' science self-efficacy. Participants were asked to describe experiences that raised or lowered their self-confidence to do or learn science, even if by a little bit. Afterwards, researchers transcribed the interviews and coded responses for the four sources of science self-efficacy: Performance Interpretations, Vicarious Experiences, Social Persuasions and Physiological/Emotional States.

INSERT Figure 3 ABOUT HERE

As shown in Figure 3, the most common source of change in science self-efficacy was Performance Interpretation. This could be a positive interpretation of performance (e.g., "I understood the concept") or a negative one (e.g., "I couldn't get it to work"). A significantly larger fraction of participants mentioned positive Performance Interpretations leading to increased self-efficacy than mentioned negative Performance Interpretations as sources of decreased self-efficacy (McNemar $\chi^2 = 8.6$, $p < .01$). This finding reflects the overall increase in self-efficacy found in the surveys, and suggests that successful use of exhibits was the main contributor to enhanced self-efficacy during the museum visit. For instance, one participant described her feeling of increased self-efficacy due to an experience of mastery and understanding of musical harmony at the Harmonic Series Wheel (see Figure 4), an exhibit that produces a suite of tones which can be used to explore the influence of harmonics on tone quality:

> And it was another thing where it kind of reinforced what I had been learning in class. You can make, like, fifths or fourths or a major triad. And I was like, oh, *I know what those are, and it relates to science. So just making that connection between the music and science was, I guess, like confidence-boosting, seeing that relationship*. (Italics added to show coding for Performance Interpretation.)

INSERT Figure 4 ABOUT HERE

The high fraction of participants mentioning some form of Performance Interpretation mirrors results from studies of self-efficacy in formal education: Students often justify their increased or decreased self-efficacy based on how well they performed on tasks or tests (Chen & Usher, 2013).

Interestingly, Figure 3 also shows that a majority of participants cited *positive* Physiological/Emotional states as sources of self-efficacy (McNemar $\chi^2 = 22.8$, $p < .001$). Many participants described exhibits and experiences as "fun," "cool," and "exciting," which would elicit the Physiological/Emotional code, but some people went further, describing in some detail how the emotional power of an exhibit inspired them to feel more confident in their own science abilities. For example, one man in our study enthused about the Museum of Wear and Tear exhibit (see Figure 5), a shrine of sorts to the pounding that museum exhibits endure over time. In his description of his own emotional response to the exhibit, he relates to the passions of the exhibit developers:

> I love the exhibit over on this side of the pieces of exhibits that have broken down over time…It makes it feel very real, *very sort of personal* to realize that these aren't just static examples that are always going to be true. They're maintained by people that had to conceptualize them and then build them and maintain them. And even so, they are things that sort of degrade in *funny* ways, even in front of the people that are most passionate about them. And then that those people are able to sort of be delighted in the strange ways that they've fallen

apart is, *I like it. It's amusing*…It makes it feel like it's not an ivory tower of a museum…You know, I make mistakes all the time. And I have silly, unexpected things happen to me all the time. And so do these physical apparatuses. And it's like, I don't need to be perfect to make something interesting work. And none of the demonstrations are going to be perfect. *And to see that they're not is heartening*. It makes me want to play around more, understand that I can, you know, make stuff that breaks, make stuff that works for a second and flies apart. *And that's cool*. (Italics added.)

INSERT Figure 5 ABOUT HERE

This result for Physiological/Emotional states differs from findings in dozens of studies of self-efficacy in high schools and colleges, where negative emotional states like fear and anxiety were prevalent (Chen & Usher, 2013; Lent, Lopez, & Bieschke, 1991; Usher & Pajares, 2008). The interview data underscore the emotionally positive nature of museum experiences, not only for children (National Research Council, 2009), but for emerging adults as well.

A relatively small percentage of participants mentioned Vicarious Experiences when talking about positive impact to their self-efficacy. Again, results indicated that positive mentions outnumbered negative ones ($p < .01$). In such situations, people made inferences about their self-efficacy by comparing themselves to others, such as this young woman at the Bike Cycle exhibit (see Figure 6), who compared her performance to that of her friends:

It's a…model of a bike that you have to push different buttons to turn [the pedals], but they mimic different muscles in your legs. And you have to get it in

> the right pattern. And I was able to get it in the right pattern, after some experimentation. So that raised my, my faith in my own ability, I guess, that I can experiment and figure out how to do something…*My friends couldn't do it and I was able to*.

INSERT Figure 6 ABOUT HERE

Virtually no one mentioned Social Persuasions as sources for their self-efficacy. Perhaps this source is more common in schools where teachers give encouragement to students, raising self-efficacy, and students make fun of one another, lowering it. Another possible explanation of its absence in our study stems from our measurement technique; perhaps adults who are describing their self-efficacy rarely self-report on moments when others praise or disparage them.

Finally, there were no significant gender differences in the number of participants mentioning the four sources of self-efficacy.

Longer Term Impact

To investigate the longer term impact of a single visit on emerging adults, the team compared participants' responses on the previsit survey to those on the delayed-post survey given three months after the visit. A total of 152 emerging adults were included in the Longer Term Impact analysis. About half of the emerging adults were also interviewed three months after the visit.[8]

Science self-efficacy. There was no overall change in self-efficacy from immediately before to three months after the visit. However, females did show a long term increase in their self-efficacy. As in the Short Term analysis, a post hoc multiple regression analysis of the emerging adult cohort was conducted to determine if any variables were associated with longer-term change in self-efficacy. Two variables, Education Level and Gender, were related to longer-term change in self-efficacy. Education Level continued to negatively predict change in self-efficacy, and female gender was associated with positive change.[9] In fact, post hoc comparisons revealed that *females'* self-efficacy significantly increased ($M_{\text{Pre}} = 5.2$, $SD = 1.0$; $M_{\text{Delayed}} = 5.4$, $SD = 1.0$; $t_{77} = -2.1$, $p < .05$), while that of males did not ($M_{\text{Pre}} = 5.7$, $SD = 0.9$; $M_{\text{Delayed}} = 5.6$, $SD = 1.0$; $t_{73} = 1.0$, $p = .32$). In other words, emerging adults of both genders experienced increases in self-efficacy from pre to postvisit. Although that elevated level of self-efficacy was only temporary for men, it persisted for women. As with the short-term impact on self-efficacy, the size of the longer term effect for women was small (d = .24). Figure 7 shows the means at pre and delayed-post. Emerging adult men and women came to the museum with different levels of self-efficacy in science; three months after the visit, those differences had shrunk.

INSERT Figure 7 ABOUT HERE

The delayed-post interviews may shed some light on the gender effect found in the surveys. Interviewers asked respondents if they had had any experiences in the past few months that affected their *self-confidence in science* in any way. A relationship emerged between gender and confidence-boosting experiences: Significantly more female emerging adults tended to have experiences that inspired self-confidence in the months after the visit than males ($\chi^2 = 6.2$, $p < .05$). See Figure 8.

INSERT Figure 8 ABOUT HERE

For example, in the post interview immediately after the visit, a school teacher talked about her experience playing with magnifying glasses in the museum. Three months later, she mentioned that she subsequently introduced magnifying glasses to her students and felt greater confidence teaching science with them:

> I have, in my classroom, put magnifying glasses, and now all my kids are obsessed with looking at them, looking at each other, looking at different things. And they go around the room exploring everything with the magnifying glasses….It's definitely made me feel like I understand more, like learning the magnifying glasses, telling the kids….So it just kind of made me feel more confident in knowing more about what I knew in science and giving—and trying different things.

Some women spoke of confidence-boosting experiences in their science courses:

> Well, the more I learn in my classes in electrical engineering, the more confident I am about how I approach solving circuits problems and how I approach electrical engineering.

Others told us that their museum visit sparked new conversations with friends and family afterwards. For example, one woman said that the Wisdom Arc exhibit, in which people can write messages to their *younger selves*, encouraged her to ask her older friends and relatives to share the wisdom they had gained through experience:

> I think what triggered me was [to] just ask, ask more of those type of questions [from] the older people that are in my [life] and ask wisdom from them.

In another example, a young woman said that she felt more capable of talking about science:

> I feel like I know a little about a lot more….I don't feel that I'm by any means an expert, but just going there makes me feel like I have a little bit more, I feel a little bit more entitled to kind of be like, "Oh, I know what you're talking about—I saw that at the museum."

This study cannot confirm causal relationships between gender and positive experiences after the museum visit. Was gender the key factor or did a third factor underlie the relationship? If gender was indeed a critical element, it is not yet clear why more young women would have had experiences that increase their confidence in the three months after a museum visit than young men.

Discussion

Based on the results reported here, a single science museum visit, lasting about two to three hours, can have a small but significant short-term impact on emerging adults and a small but significant long-term impact on female emerging adults. Immediately after the visit, emerging adults (at two science museums) showed increased science self-efficacy, which was significantly associated with the overall museum experience. The effect was less pronounced for participants who were better educated, suggesting a possible ceiling effect for initial self-efficacy.

According to prior research, self-efficacy is affected by four general types of experiences: task success and failure (Performance Interpretations), exposure to social models (Vicarious

Experiences), evaluative messages from others (Social Persuasions), and one's own physiological or affective state (Physiological/Emotional State) (Bandura, 1997; Usher & Pajares, 2008). As individuals interpret information from these sources in various ways, their science self-efficacy is raised or lowered (Chen & Usher, 2013). Interviews with a sub-sample of participants indicated that self-efficacy was amplified primarily through mastery experiences in which participants succeeded in using or understanding phenomenological exhibits. In addition, self-efficacy was enhanced through vicariously observing others and through positive emotional responses, such as joy, pride and excitement. There was no evidence of social persuasions influencing self-efficacy. This may have been due to the prevalence of peer interactions rather than teacher-student relationships in our study; the former may elicit supportive comments about performance only rarely. The performance interpretations, vicarious observations and positive emotions that contributed to science self-efficacy may also have been related to the high average overall experience score of 6.0 (out of 7). Moreover, positive emotions as a source of self-efficacy in museums stand in contrast to school studies where negative emotions like fear and anxiety reign as contributors to (lowered) self-efficacy (Usher & Pajares, 2008). Together, the results emphasize the importance of focusing on emerging adults in museums, expanding beyond the widely-held notion that science museums provide enjoyable learning experiences for children and families.

Beyond the immediate impact, the enhanced self-efficacy of female emerging adults remained elevated three months after the visit. This suggests that museums may make lasting contributions to lifelong science learning trajectories of emerging adults. The delayed-post interviews revealed an interesting association in the months after the visit: A greater fraction of young women had confidence-boosting experiences than young men after the visit. Why? We are left with at least three competing explanations, each of which could be tested in future research.

Competing Explanations of Longer Term Results

Activated new behaviors for young women. Researchers in the museum field have hypothesized that museum visits may *activate* people, making them crave additional, related experiences (Dorph, Cannady, & Schunn, 2016; Falk & Dierking, 1992, 2000; Falk et al., 2016; Vincent-Ruz & Schunn, 2017). Perhaps female participants' increased sense of self-efficacy from the visit led more of them to seek out additional science experiences. One way to test for this explanation would be to compare the number of science related activities before and after a museum visit. Activated emerging adults would have more science encounters afterwards.

Primed awareness for young women. Another possible explanation is that the young women's greater science self-efficacy during the visit made them more aware of their positive competency beliefs. This greater awareness could help them notice when they feel greater science self-efficacy in subsequent experiences. In short, the visit may have primed women to be aware of ensuing, confidence-boosting encounters with science. Priming fits well with Bandura's (1977b) theory that learners' current self-efficacy will influence how successive experiences affect future self-efficacy: "The extent to which people will alter their perceived efficacy through performance experiences depends upon…their *preconceptions* of their capabilities" (p. 81, italics added). Evidence for priming might take the form of women keeping constant the number of science-related activities in their lives before and after a museum visit, but describing the experiences afterwards as being more relevant to science.

Leveled the playing field for all. Emerging adult women entered the museum with lower science self-efficacy than men, and Education Level negatively predicted change in self-efficacy. It is possible that the Longer Term results were due more to these disparities than to gender differences. Perhaps people of both genders with lower initial science self-efficacy were more affected by the visit than those with higher self-efficacy, or perhaps there was a ceiling effect for the high science self-efficacy participants. Some researchers argue for a *gender similarities hypothesis*—the notion that most gender differences are much smaller than commonly believed—and point out that emphasizing gender differences comes at the cost of strengthening stereotypes and limiting the roles that both men and women take in society (Hyde, 2005, 2014). Unfortunately, there were too few young men with low initial science self-efficacy in the sample to rule out the possibility that the true effect was masquerading as a gender effect. Future studies could recruit participants by stratifying initial self-efficacy within gender to disentangle this potential confound. If both men and women with low initial self-efficacy increase their self-efficacy three months after the visit, one could conclude that museums support learners who have greater need, regardless of gender.

Although these competing explanations cannot be substantiated in the current study, they provide guidance for future research. One next step involves replicating the full results, particularly the Longer Term results, with stratified sampling and additional assessments that would allow researchers to distinguish among the three competing explanations. The critical components include assessing science-related experiences before and after the visit, and recruiting young men with initially low science self-efficacy. Taking another tack for future studies, the links between mastery and self-efficacy could be further explored by replicating the study at science museums that offer less interactivity, such as natural history museums. If positive performance interpretation primarily emerges from successfully using and understanding an exhibit, then interactivity may be an important mediator variable.

Limitations

This study had limitations that threatened both internal and external validity. Internal validity was constrained by the self-report nature of the interview and survey data. The team attempted to enhance internal validity by using a repeated measures design, testing the internal consistency of the survey items, checking items' face validity with expert advisers, and triangulating between interview and survey data. Internal validity may also have been compromised through several sampling issues. The interviewed and non-interviewed emerging adults were sampled at different times of the year. Although the interviewed participants were younger and included more full-time students, no differences were detected in the pre-post outcome measures for the two subgroups, suggesting that neither season nor interview affected the outcomes. Second, 38% of the emerging adults could not be reached for the delayed-post measures. Fortunately, no differences were measured between participants in the Short term and Longer term analyses, suggesting that attrition did not interfere with the representativeness of our sample.

In terms of external validity, perhaps the greatest threat arose from the omission of a control condition: The team did not compare participants who experienced a museum visit to those who did not. Identifying an appropriate control condition was too challenging for this initial investigation of self-efficacy in museums. For example, people who do not voluntarily visit a science museum might have different science self-efficacy from museum-goers. This could lead them to seek very different kinds of (science-related) experiences in a three month period, regardless of whether they had visited a science museum at the start of that period. Random assignment of some participants to an immediate science museum visit and others to a museum visit after the assessments were complete seems an effective design, but would be costly to implement. (Finding, recruiting and retaining participants would be difficult and expensive.) Our repeated measures, quasi-experimental study of real science museum participants had ecological validity, but produced weaker evidence of causal relationships. Secondly, although the Short Term analysis was partially replicated at a second museum, Longer Term impacts were studied at only a single institution. External validity would be improved through the inclusion of multiple institutions in future studies.

Implications for Practice

Bearing in mind these limitations, the results indicate that informal experiences of relatively short duration may be capable of contributing to lifelong learning habits by incrementally raising self-efficacy. This, in turn, suggests that practitioners continue designing experiences that offer occasions for mastery, vicarious experiences and positive emotional responses.

In terms of mastery, exhibits certainly provide such opportunities, but museums may inspire even more self-efficacy by creating meaningful experiences that require additional effort. True mastery comes as a result of struggling through something important until a breakthrough is reached (Chen & Usher, 2013). Tinkering and Making spaces in museums and afterschool programs often emphasize meaningful struggle in their activities (Honey & Kanter, 2013; Petrich, Wilkinson, & Bevan, 2013; Sheridan et al., 2014). Similarly, citizen science projects ask participants to expend substantial effort, sometimes over years, growing their skills as observers (Bonney et al., 2009). Perhaps activities such as these and exhibits that engage visitors in more prolonged effort would produce even larger increases in self-efficacy than found in this study.

Vicarious experiences also seemed to contribute to self-efficacy. Seeing others, especially peers, go through an exhibit or program experience may help learners gauge difficulty levels.

Importantly, watching others struggle before succeeding may be a more effective way to raise self-efficacy than watching someone succeed quickly (Schunk & Hanson, 1989). In practice, this may suggest the need for “open-ended” exhibits that allow for false-starts and forking paths, and exhibit designs with multiple stations that offer clear sightlines to others’ work (Dancstep & Sindorf, 2016; Gutwill, 2008; Humphrey & Gutwill, 2005; Szechter & Carey, 2009). Interactive programs, especially those with longer timelines like afterschool and camp programs, may ask learners to work in “jigsaw” groups that mix and remix participants over the course of a project, allowing learners to observe each other in different roles and situations (Aronson, 2010).

Finally, the study found that positive emotional experiences—joy, excitement, satisfaction, and accomplishment—promoted self-efficacy. Creating whimsical, funny, supportive, and exciting science learning experiences may be important for sparking emotional responses that enhance self-efficacy (cf. Dancstep & Sindorf, 2016). I would speculate that prioritizing engagement over content transmission will produce exhibits and programs most likely to succeed in this arena (Serrell, 2015).

In conclusion, this initial investigation of the impact of a single science museum visit on emerging adults found that success in using exhibits in an emotionally positive, social atmosphere contributed to a small but real gain in science self-efficacy. This gain persisted over time for females, suggesting that science museums may indeed contribute to the lifelong learning trajectories of adults.

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Within Museum			Outside Museum
Pre	**Visit**	**Post**	**3 Months Delayed-post**
O_1	X	O_2	O_3

O_i = Assessments
X = Museum Visit

Figure 1. Repeated measures study design. Pre-post changes reflect short-term effects, while pre-delayed-post changes indicate long-term effects.

Sub-group	n	Pre	Visit	Post	3 months delayed-post
		Time →			
A	116	Survey	Take photos	Interview Survey	Interview Survey
B	128	Survey		Survey	Survey

Figure 2. Assessments given over time for two sub-groups of emerging adults. All participants completed surveys at three time periods (pre/post/delayed-post). About half of the emerging adults (Group A) also took photos while in the museum and discussed them and other issues in interviews at post-visit and three months after the experience.

Figure 3. Sources of short-term increases and decreases in science self-efficacy.

Figure 4. Harmonic Series Wheel exhibit where visitors can explore musical harmonics.

Figure 5. Museum of Wear and Tear exhibit where visitors can see how exhibits incur damage from near-constant use.

Figure 6. Bike Cycle exhibit which challenges visitors to coordinate timing and sequence of robotic legs to spin a bicycle wheel.

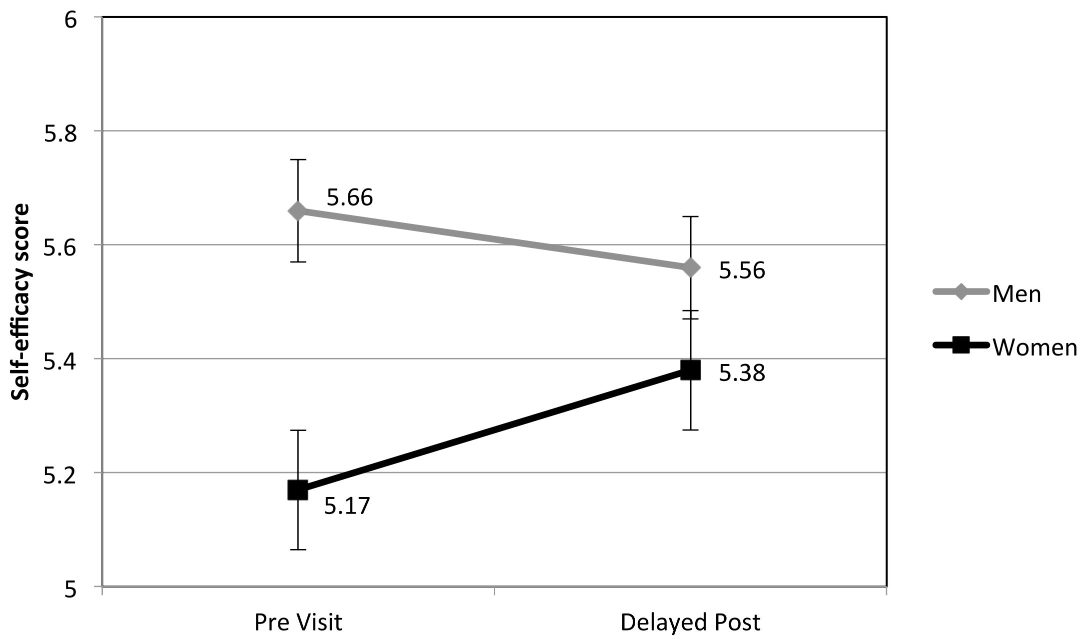

Figure 7. Longer term change in self-efficacy scores for emerging adult women and men. Men's self-efficacy is statistically flat while women's significantly increases, shrinking the difference between the two groups. Error bars represent standard errors.

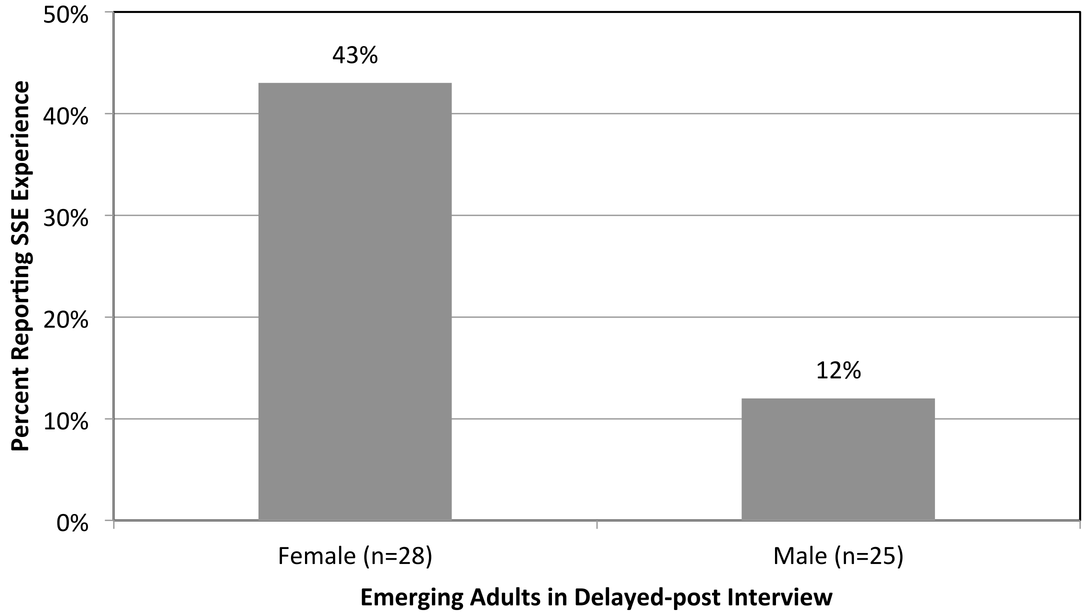

Figure 8. Percentage of emerging adults, by gender, who reported having an experience after the visit that raised their science self-efficacy.

Table 1

Internal Consistency Measures for Survey Items

Scale	Items	Cronbach Alpha
Self-efficacy		
Pre-visit	7	.90
Post-visit	7	.90
Delayed-post-visit	7	.93
Identity as Adult	24	.84
Overall Museum Experience	14	.83

Table 2

Interrater Reliability for Postvisit Interview Coding

Code	Cohen's kappa coefficient	Interpretation of Cohen's kappa
Impact on Self-efficacy		
Increase	.85	Excellent
Decrease	.85	Excellent
Other	.85	Excellent
Source of Self-efficacy Change		
Performance Interpretation	.74	Substantial
Affective / Emotional	.95	Excellent
Vicarious Experience	.85	Excellent
Social Persuasion	.95	Excellent

Table 3

Characteristics of Participants in Short Term Impact Analysis

Demographic variable	Emerging Adults (n=244)
Gender	
Male	48%
Female	52%
Ethnicity	
Caucasian / White	51%
Asian	25%
Hispanic / Latino	9%
African-American/Black	4%
Native Hawaiian / Pacific Islander	2%
Other	9%
Group size	
Two people	62%
Three or more people	34%
Other / Missing	4%
Education level	
No college	32%
College degree	51%
Graduate degree	17%
Employment status	
Full-time student	35%
Employed	63%
Other / Missing	2%
Recruitment context	
Daytime (all ages)	49%
Evening (adults only)	51%
Museum Member	2%
First time visitor	60%
Completed interview	47%
Reason for visit	
Enjoyment / fun	65%
Science learning	18%
Socializing	17%
Mean age (SD)	24.6 (2.9) years
Adult identity score (SD)	4.4 (.56)

Table 4

Museum Experience Measures

Variable	Emerging Adults *M* (*SD*)	Full Adults *M (SD)*
Time spent in minutes	149 (54)	154 (62)
Overall museum experience	6.0 (.8)	6.1 (.8)

Table 5

Change in Emerging Adults' Short-term Science Self-Efficacy

Cohort	n	Pre-visit *M* (*SD*)	Post-visit *M* (*SD*)	t	*df*	Cohen's d
Emerging Adults	244	5.37 (1.01)	5.61 (.89)	-5.0***	243	.32

***p < .001

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[1] The Society for the Study of Emerging Adulthood holds an international conference biennially, and is affiliated with the journal Emerging Adulthood.
[2] The study described here, which focuses on self-efficacy, was part of a broader investigation of general impact of a museum visit on emerging adults. Additional variables studied were omitted from this article for the sake of clarity and brevity.
[3] Data were obtained from the Longitudinal Survey of American Youth (LSAY).
[4] Participants were offered two free entry tickets in exchange for their involvement in the study. Three months after the visit, participants were allowed to choose between two more free admission tickets or an Amazon gift card worth $15 to complete the delayed-post assessments.
[5] Only two demographic differences between the two conditions emerged in the survey responses: Interviewed participants were significantly younger (M_{Int} = 23.8 years, SD = 3.1; M_{Svy} = 25.2 years, SD 2.7; $t_{232} = -3.8$, $p < .001$) and were more likely to be full-time students (67%) that those who were not interviewed (41%; $\chi^2 = 5.5$, $p < .05$).
[6] Respondents could select male, female or other for their gender.
[7] Participants at the Midwest museum were not contacted three months after their visit, so no longer-term impact on science self-efficacy was measured for them.
[8] Participants in the Long Term Impact analysis were representative of those in the Short Term Impact analysis: There were no demographic differences between them. There were also no differences in demographics or outcome measures between participants who were interviewed and those who were not. Finally, no correlation was found between time spent in the museum and longer term change in self-efficacy.
[9] These two variables explained 11% of the variance in change in self-efficacy ($F_{2,136} = 7.9$, $p < .001$). Controlling for education level, gender explained 3% of the variance in emerging adults' self-efficacy (effect size is small, but notable: semi-partial correlation = .17).