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Impact of a Science Art Exhibit on Public Interest and Student Comprehension of Disease Ecology Research

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Art is a common approach for communicating and educating about science, yet it remains unclear the extent to which science art can benefit varied audiences in varied contexts. To examine this gap, we developed an art exhibit based on the findings of two publications in disease ecology. In study 1, we asked visitors with varying formal science, technology, engineering, and math (STEM) education backgrounds to complete a survey about their interest in science research before and after viewing the exhibit. In study 2, we recruited upper-level ecology undergraduate students to receive one of three treatments: engage with the art exhibit, read the abstracts of the papers, or do neither. Students completed a comprehension quiz immediately after their learning treatment and again 2 weeks later to evaluate retention. Following the exhibit, visitors who did not report a career or major in STEM showed a greater increase in research interest than visitors who did report a career or major in STEM. For the ecology undergraduate students, comprehension quiz scores were higher for students in the abstract group than the art exhibit group, while both groups scored higher than the control group. Retention of information did not significantly differ between the three groups. Overall, these findings suggest that science art exhibits are an effective method for increasing the accessibility of science to broader audiences and that audience identifiers (e.g., level of formal education in STEM) play an important role in audience experience of science communication and science education initiatives.

KEYWORDS science communication, science education, science art, art exhibit, student comprehension, science attitudes, science accessibility, STEM, STEAM

INTRODUCTION

Aiding audiences to develop science literacy (e.g., having content, procedural, and epistemic knowledge of science [1]) is a key goal of both science communication and education. Science literacy can refer to knowledge about science generally (2) or in specific domains of science (e.g., agricultural biotechnology [3], climate science [4, 5]). While global data indicate that populations typically hold positive attitudes toward science (6), a unique challenge of developing literacy in specific domains of science is that not all audiences have interest in the topic (7). This prerequisite of developing interest is critical to acquiring science literacy and seeking science careers (8, 9). For example, in 2010 Miller found that interest in scientific, technological, and environmental issues was a main predictor of informal science resource use in adults (10). This suggested that interest is a key factor influencing decisions to seek informal science education and an important precursor to content knowledge. Indeed, the Program for International Student Assessment (PISA) included attitudes and interest as forming "part of the construct of scientific literacy" (1). Thus, it is essential to examine not only how formal and informal education initiatives impact audience development of content, procedural, and epistemic knowledge (e.g., literacy), but also how and if they impact previously uninterested audiences in development of interest in the topics at hand.

Art is a popular approach for engaging both the general public and distinct groups in science (11–13), specifically for improving audience literacy in specific science domains (7). Projects combining art, science communication, and science education utilize a diversity of forms, from exhibits to performances to classes (12). However, even when initiatives have the same goals of increasing audience knowledge and awareness of a topic, some studies find that art-science collaborations are effective (14), others report that they are not (15), and still others report unanticipated results and consequences (16). The equivocal impact of art in science communication and education underscores the need to better understand the mechanisms and contexts for when science art initiatives are effective in promoting audience interest and knowledge in specific science domains.

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Audience identifiers (e.g., age, gender, education) are well-established factors that can influence the effectiveness of science communication (17). Specifically, educational background in science, technology, engineering, and math (STEM) can play an important role in baseline interest in and knowledge of science (18), and it can differentially influence the ability to find, perceive, and understand (e.g., accessibility [19]) science resources. For instance, traditional media of scientist-to-scientist communication (e.g., academic publications, posters, talks) facilitate communication to experts in the field but not to nonexpert audience members; thus, they typically have high accessibility to scientists but low accessibility to nonscientists (13). Conversely, approaches that increase public access to scientific findings through media other than traditional scientific publications (i.e., art) are hypothesized to improve accessibility to nonscientists (13) and aid in developing interest in specific science topics (7). However, communicating through art may or may not have the same beneficial impacts for individuals with a strong educational background in STEM, for whom "traditional" scientific media is also accessible. Therefore, it is critical to evaluate the generalizability of art as a science communication tool across audience members with diverse STEM backgrounds in order to understand the mechanisms influencing the effect of art on developing specific science domain interest and literacy. To date, this relationship between art and educational background in STEM has not been directly examined.

To address these gaps, we conducted two studies. In study 1, we asked, "Does interaction with a science-based art exhibit impact public interest in research in a specific science domain relative to their background education in STEM?" Next, in study 2 we asked, "Does interaction with a science-based art exhibit impact science student comprehension and retention (e.g., content literacy) of specific domain knowledge relative to reading a publication abstract?" To answer these questions, we developed an interactive art exhibit based on the findings of two scientific publications and invited members of the public (study 1) and current ecology students (study 2) to interact with the exhibit. We hypothesized that interaction with the exhibit would improve research interest overall, with individuals with less background education in STEM improving more than individuals with more background education in STEM (study 1). Next, we hypothesized that interaction with the art exhibit would be as good or better at improving student comprehension and retention of science knowledge than reading a publication abstract (study 2).

METHODS

Art exhibit development

To examine the impact of art on public interest and student comprehension of science, we chose to develop an art exhibit, as science art exhibits have been shown to engage wider audiences in science and clarify misunderstandings about certain science topics (20, 21), as well as supporting the development of critical thinking skills in the classroom (22).

We first developed an interactive exhibit with 20 pieces of original art designed to communicate the major findings of two scientific papers in the fields of disease ecology and global change biology (23, 24). The art pieces were designed to engage visitors through various multimedia installations, including sculpture, painting, video, digital media, and live specimens (see Appendix S1 in the supplemental material). The exhibit was advertised via social media posts through official Binghamton University accounts as well as in-person announcements to classes. The exhibit was presented at Binghamton University's Bartle Library on 2 May 2016 and was open to the campus community as well as the broader public. This study was approved by the Binghamton University IRB (protocol 3780-16; approved 15 March 2016).

Study 1: research interest

To investigate the impact of the art exhibit on participant interest and engagement with research in this science topic, we asked adult visitors ($n = 90$) to complete anonymous surveys about their research interest before and after interacting with the exhibit (Appendix S2). We also collected demographic information regarding visitor profession, level of education, major in college (if applicable), gender, and ethnicity.

Study 2: student comprehension and retention

To examine the impact of the art exhibit on student comprehension and retention of science, we recruited Binghamton University college students enrolled in an upper-level ecology class ($n = 65$). We chose to recruit from this population to control for student background education in ecology. Students were randomly assigned to one of three learning treatments: engage with the art exhibit, read the abstracts of the papers, or do neither (control). All text presented alongside the installations was identical to the abstracts of the papers. Participants remained blind to the purpose of the study until its conclusion.

To evaluate comprehension, students began their assigned treatments concurrently on 2 May 2016. To account for variation in learning speed, students were instructed to use as much time as needed to adequately process the information in all treatments. Following conclusion of the learning treatment, students completed an anonymous, multiple-choice comprehension quiz to evaluate their understanding of the two papers presented in the art and abstract treatments (Appendix S3). To evaluate retention, students were asked to complete the same multiple-choice comprehension quiz on 9 May 2016, one week after completion of their learning treatment. We also collected demographic information regarding student level of education, major, gender, ethnicity, overall grade point average (GPA), expected letter grade in the ecology course, and research experience.

Statistical analyses

We first conducted regression analyses to examine relationships between research interest (study 1) or comprehension

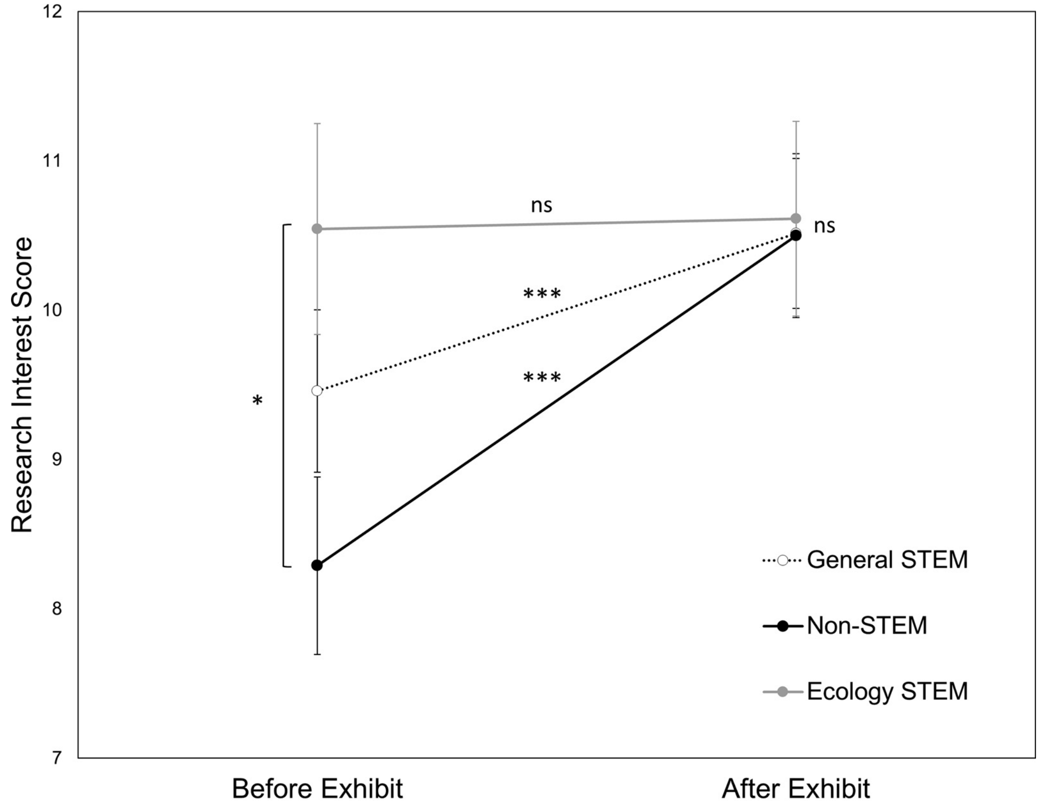

FIG 1. Research interest scores. Research interest scores were calculated as the total sum of three positively worded 5-point Likert scale items regarding participant interest in scientific research, with the most positive score assigned a maximum of 15. ns, $P > 0.05$; *, $P \le 0.05$; **, $P \le 0.01$; ***, $P \le 0.001$.

(study 2) and demographic variables. We found no correlation between any demographic variables (e.g., gender, ethnicity, level of education, student GPA) and any outcome variables (e.g., research interest or quiz scores, pre- or poststudy). Demographic variables were thus excluded from further analysis.

To understand how engagement with the art exhibit impacted public interest in science research depending on educational background (study 1), we conducted a repeated measures analysis of variance (rANOVA) to examine participant responses before and after interacting with the art exhibit using formal STEM educational background as a between-subjects factor. Participants were coded as general STEM, non-STEM, or ecology STEM based on their reported major in college. Students currently enrolled in an upper-level ecology class (ecology STEM) were included in the analysis but grouped separately from those in the general STEM group to control for background education in this topic gained from being enrolled in an ecology course concurrently with the experiment. Cases with missing or incomplete information regarding research interest surveys ($n = 3$) were excluded from analysis.

To understand how our learning treatments impacted student comprehension and retention (study 2), we conducted an rANOVA to compare student comprehension quiz scores immediately after learning treatment (comprehension) and 1 week post-learning treatment (retention) using treatment type as a between-subjects factor.

For all significant main effects or interactions of rANOVAs, we conducted Bonferroni-corrected pairwise comparisons. All analyses were conducted in SPSS 25 (IBM).

RESULTS

Study 1: research interest

We found no significant effect of STEM educational background on research interest ($F = 0.971$; $P = 0.383$). In contrast, we found a significant effect of time (Wilks λ = 0.71; $F = 35.75$; $P < 0.001$) and a significant interacting effect of time and STEM educational background on research interest (Wilks λ = 0.81; $F = 10.21$; $P < 0.001$) (Fig. 1).

Pairwise comparisons indicated that research interest in non-STEM participants significantly increased by 26.66% after viewing the art exhibit ($P < 0.001$) relative to interest before viewing the exhibit. Similarly, interest for general STEM participants significantly increased by 11.15% after viewing the art exhibit ($P < 0.001$) relative to interest before viewing the exhibit. In contrast, we found that interest for ecology STEM participants did not change after viewing the art exhibit relative to interest before viewing the exhibit.

Prior to visiting the art exhibit, baseline research interest scores for non-STEM participants were 23.94% lower than

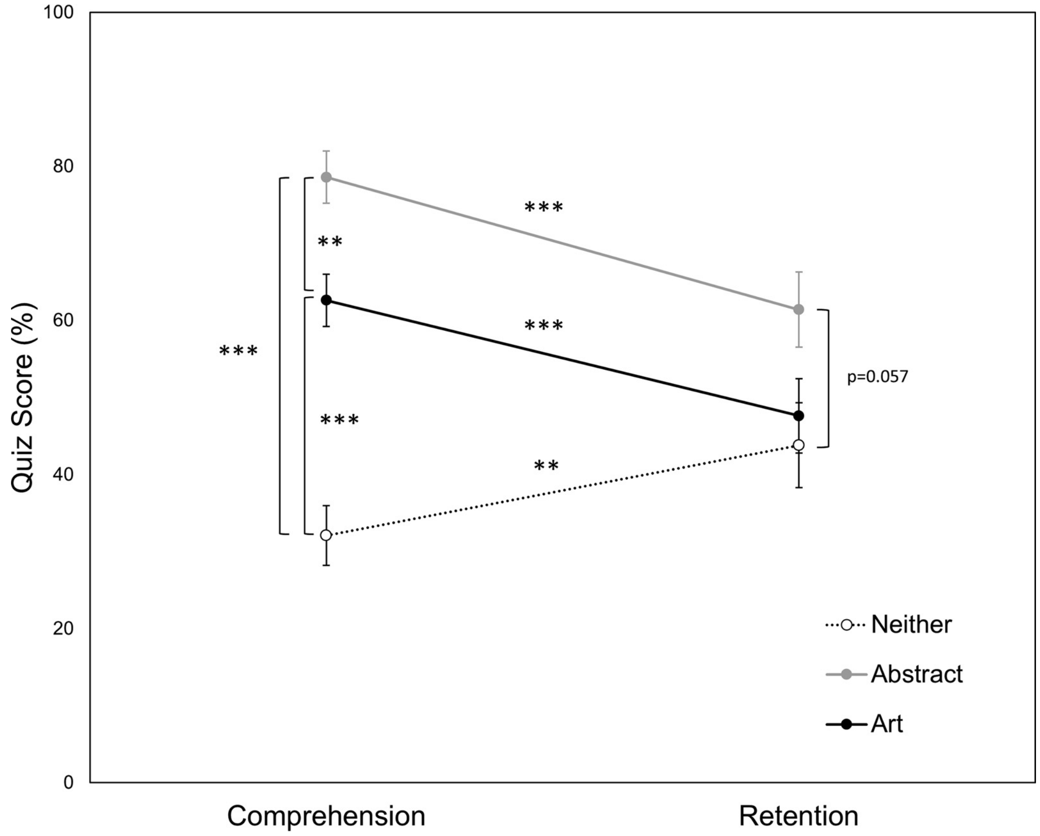

FIG 2. Student quiz scores. Student quiz scores were calculated as percent correct for both the first quiz (measuring comprehension) and the follow-up quiz (measuring retention). ns, $P > 0.05$; *, $P \leq 0.05$; **, $P \leq 0.01$; ***, $P \leq 0.001$.

those for ecology student participants ($P = 0.05$). Baseline research interest did not differ significantly between general STEM and non-STEM participants or between general STEM and ecology student STEM participants. Additionally, research interest after viewing the exhibit did not differ between any of the STEM educational background groups.

Study 2: student comprehension and retention

We found a significant effect of learning treatment on quiz scores ($F = 17.2.1$; $P < 0.001$). Additionally, we found a significant overall effect of time (Wilks $\lambda = 0.9$; $F = 7.19$; $P = 0.01$) and a significant interacting effect of time and learning treatment on quiz scores (Wilks $\lambda = 0.7$; $F = 12.1$; $P < 0.001$) (Fig. 2).

Pairwise comparisons indicated that quiz scores for students in the art learning treatment declined by 23.96% between the initial quiz testing comprehension and the follow-up quiz testing retention ($P = 0.001$). Similarly, scores for students in the abstract learning treatment declined by 21.88% between the initial quiz and the follow-up quiz ($P < 0.001$). In contrast, we found that quiz scores for students in the control group improved by 36.45% between the initial quiz and the follow-up quiz ($P = 0.018$).

For the initial quiz measuring comprehension, scores for students in the abstract treatment ($P < 0.001$) and students in the art treatment ($P < 0.001$) were both significantly higher than scores for students in the control treatment, differing by 84.01% and 64.41%, respectively. Additionally, comprehension scores for students in the abstract treatment were 22.66% higher than scores for students in the art treatment ($P = 0.005$).

For the follow-up quiz measuring retention, students in the abstract treatment group scored nearly significantly higher than students in the control treatment ($P = 0.057$) but did not differ significantly from students in the art treatment group ($P = 0.14$). Retention scores for students in the art treatment group also did not differ significantly from students in the control group.

DISCUSSION

Study 1: research interest

We examined public research interest to better understand this critical phase of developing science literacy in specific science domains. We found that the art exhibit effectively "closed the gap" between science research interest in STEM and non-STEM visitors (25). Interestingly, the similarities in posttest interest across groups indicated a potential "ceiling" on research interest scores. It has been suggested that gaining knowledge on a topic through observing (e.g., learning secondhand information) does not convey the same benefits as gaining knowledge through actively creating it (e.g., creating primary information through taking part in the research process) (26). Perhaps the mode of learning about scientific research secondhand (as opposed to participating in the research process) limits the maximum potential for shifts in research interest and could thus be in part responsible for the apparent ceiling. Overall, these findings indicate that interacting with a science art exhibit can positively influence audience development of interest in the research subject; however, we join others in suggesting that communication and education which lack audience participation in knowledge creation may be limited in the ability to maximize shifts in audience attitudes.

We also found that STEM educational background impacted change in interest. This finding supported the hypotheses that science art exhibits can act by increasing the accessibility of science content to broader audiences (13) and that audience level of formal education in STEM modulates the impact of this accessibility. Other work has shown that art can act to increase accessibility depending on audience identity (e.g., to overcome various language [27, 28] and literacy [28, 29] barriers) (reviewed in reference 13). These findings stress the importance of carefully considering target audience, including levels of formal education in STEM. This audience consideration is critical for setting communication and education goals with a given audience and deciding whether art is the most appropriate medium through which to achieve those goals.

Research interest at baseline was directly related to the amount of formal STEM education that the participants reported. Numerous other studies have also identified a relationship between science knowledge and attitudes toward science; however, the mechanism that underlies this relationship remains a topic of investigation (30). Specifically, the directionality of the relationship remains unclear: does more knowledge about science lead to more positive attitudes, or does a more positive attitude toward science lead to knowledge-seeking and thus more knowledge? The former hypothesis has been extensively examined in various studies (31, 32), yet contradictory findings make it a controversial topic (30, 31). The latter hypothesis is supported by findings that engagement with and attitudes toward science have been shown to be strong predictors of STEM career aspiration in middle and high school students (e.g., positive attitudes lead to increased knowledge-seeking) (33, 34). Thus, the differences in baseline research interest in our study population could be caused by a self-selecting group who is interested in STEM research (attitudes) and therefore seeks out related educational opportunities and careers (knowledge). Conversely, this difference could be caused by higher levels of education in science (knowledge) leading individuals to appreciate science more (attitudes). However, like other work which has identified this knowledge-attitudes relationship, differentiating between the two mechanisms is beyond the scope of this study. Future work should include identifying when these research interests begin to form to further understand the mechanism underlying the relationship.

Study 2: student comprehension and retention

We examined student development of domain-specific science literacy in the form of comprehension and retention of science knowledge. Consistent with our predictions, students in both the art and abstract learning treatments had higher comprehension scores than the control group, indicating that students were able to acquire knowledge through both learning treatments. Similarly, other studies have found that integrating art into science education can be effective for enhancing science knowledge in undergraduate students (20, 35, 36). However, some studies have found that art can hinder education, either by oversimplifying complex issues (37) or by communicating in an overly subtle or abstract way (38, 39). Despite these challenges, results from this study combined with past work reinforce the viability of using art exhibits for promoting interest as an important precursor to the development of domain-specific content literacy (7), especially when considering the appropriate content and context.

Contrary to our hypothesis, we found that while both art and abstract groups gained knowledge, the abstract group scored significantly higher for initial comprehension. One explanation for this finding is that the arts engage by focusing on the affective (i.e., attitude, emotion) domain of learning, rather than on the cognitive (i.e., comprehension, understanding) domain (40, 41). In the adult education literature, Lawrence discusses the ways that art can influence affective learning (e.g., via transformative [42, 43] and experiential [44, 45] learning pathways). Science education often emphasizes cognitive goals over affective goals (46); indeed, our own survey on student comprehension was intended to measure cognitive rather than affective learning. While our findings suggest that traditional reading of primary science literature is more effective than interacting with an art exhibit to achieve student learning goals, our measure of comprehension did not address the potential gains in affective learning that students may have made in either treatment group. Indeed, one study in a microbiology laboratory course found that both "traditional" and "art" groups had similar knowledge gains, yet students in the "art" group had a higher sense of science self-efficacy, supporting the idea that student benefit through art may be less cognitive and more affective (36). Future studies should assess multiple domains of learning to further understand the full impacts of art-based learning on the development of science literacy.

Another potential contributor to why the abstract group scored significantly higher for initial comprehension compared to the art group could be that our study population of undergraduate science students brought prior knowledge of both how to read a scientific paper and of how to report its contents for assessment. Extensive investigation has shown that prior knowledge is an important factor in acquiring new knowledge (47, 48). As upper-level science undergraduate students, it is likely that our study population brought prior knowledge in how to read and interpret abstracts from scientific literature; indeed, second- and third-year undergraduate students report the abstract as one of the most important and easy-to-read sections within a scientific paper (49). Conversely, it is unlikely that they bring the same prior knowledge of how to extract information from an art exhibit for the purpose of educational assessment. This discrepancy may have allowed for a more "expert" understanding of how to extract and reproduce knowledge on the part of the abstract group as opposed to a more "novice" understanding by the art group. When faced with new information, experts are able to use their domain knowledge to extract and synthesize more concepts, while novices lack this trait (50, 51). As such, this process-expert versus process-novice imbalance should be examined in future studies to determine the extent of its influence in the development of science literacy.

Students in both the art and abstract groups declined in quiz scores between the first (comprehension) and second (retention) assessments, and the initial comprehension advantage gained by the abstract group was nullified when assessing retention. One study demonstrated that student interaction with an art exhibit in the context of biology promoted deeper engagement with course material when specifically integrated into course lessons and assessments, supporting the use of an art exhibit for encouraging content retention when used as a long-term classroom integration strategy (22). However, in our study, content knowledge gained from each treatment was not directly integrated into the students' overall course knowledge and was instead an isolated learning experience. It is common, if not expected, for scores on follow-up assessments to be lower than those for the initial assessments, especially when students are not asked to recall the information in the period between assessments (52). Indeed, we found that an isolated learning experience without course integration or recall conveyed an initial learning benefit but did not have a lasting effect. This points to the importance of continued effort toward integration of art and other nontraditional learning experiences into the course curriculum in order to convey their full benefits, as opposed to an isolated add-on activity or experience.

An unexpected finding was that students in the control group significantly improved in their quiz scores between the comprehension and retention assessments. One possible explanation for this finding could be that the students who did not receive either treatment may have sought out more information on the topic after taking the quiz. Hidi and Renninger's model of interest development indicates triggered situational interest (e.g., encountering a new topic via a quiz) as the first step to developing emerging and, later, well-developed individual interest (53). Thus, it is possible that being faced with unfamiliar questions sparked an interest that inspired students to independently investigate the topic, resulting in higher scores on the follow-up quiz. Alternatively, the finding could be statistical in nature and due to regression to the mean, where an initially large or small measurement is followed by a measurement that is closer to the mean (54). While our design did not allow for differentiation between these explanations, future studies should consider assessing the likelihood of student independent investigation on a topic when faced with unfamiliar quiz questions.

Limitations

We were not able to determine if art alone was the element primarily responsible for participant outcomes. While the art exhibit was designed chiefly to communicate science through the use of art, other potentially important factors that could be at least in part responsible for our results were not experimentally manipulated. This limitation has been noted in other work regarding science communication and education through art (55), as study designs are not often equipped to separately examine the different fundamental components that are involved with art communication (e.g., visuals [56], metaphor [57], or local nature of the work [58]). Thus, our design does not control for the unique role of "art" specifically being the driver of outcomes. Future work should examine the efficacy of additional elements of outreach initiatives by experimentally controlling for these factors.

Conclusions

We found that a science art exhibit was effective in achieving goals of developing public interest and attitudes toward specific domains of science research. However, content acquisition goals of developing comprehension and domain knowledge with science students may be more effectively addressed using traditional means, such as reading primary literature. Additionally, we found that audience identifiers (e.g., level of formal education in STEM) play an important role in the magnitude of change. We conclude that science art exhibits are a promising and effective method for increasing the accessibility of science to broader audiences, yet they may not be the ideal medium when targeting audiences with more formal STEM education. Overall, by targeting audience interest, science art exhibits show promise for aiding audiences in the development of science literacy in specific domains of knowledge.

SUPPLEMENTAL MATERIAL

Supplemental material is available online only.

SUPPLEMENTAL FILE 1, PDF file, 0.5 MB.

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