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Comparing the Impact of an Informal Education Program on Participant Attitudes Towards Science Across Remote and In-Person Settings

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ABSTRACT: The Girls at the Museum Exploring Science (GAMES) program, run out of the University of Colorado Museum of Natural History for the last 20 years, is a community engagement program that aims to foster a positive attitude towards science in elementary school-aged girls. Since the start of the COVID-19 pandemic, the in-person GAMES program has added remote sessions. We use 5 years of survey data collected from program participants to gauge the impact that the GAMES program has on participant attitudes towards science and scientists. We partition these data into four groups based on instructional setting: in-person at school, in-person at University of Colorado Museum of Natural History, remote from home, and remote from school. We find that the GAMES program increases the proportion of participants who can see themselves becoming scientists across all instructional types. Notably, the programs that take place outside of school settings (either in-person or remote) have greater positive impacts on participants than programs that take place inside of schools. Additionally, participants across all groups use more technical language in their post-program survey responses than in their pre-program responses, indicating increased comfort with scientific concepts. Remote GAMES programs have more modest impacts on participant attitudes towards science and scientists, though a positive impact is still observable. This positive impact on participant attitudes towards science across all instructional groups leads us to conclude that both in-person and remote instruction of the GAMES curriculum benefits children from underrepresented groups in science. Remote instruction in particular has the ability to reach many more participants, specifically participants located in rural areas and/or areas with less direct access to science resources and represents a promising avenue for future informal science education opportunities.

INTRODUCTION

The Girls at the Museum Exploring Science (GAMES) program, run out of the University of Colorado Museum of Natural History (CUMNH), is an informal education program (Doberneck et al., 2010) for girls in fourth and fifth grade that runs annually through the academic year. GAMES is a public, community-based engagement program (Boyer, 1990; Saltmarsh and Hartley, 2011; Benneworth et al., 2008) that uses an informal setting to educate participants about broad scientific concepts. The program curriculum is presented by academic professionals at different career levels—from full-time faculty to museum coordinators, to graduate and undergraduate participants.

In 2021, fewer than 50% of American scientists were women, and only 33% were people of color (Fry et al., 2021). The underrepresentation of these demographic groups, while attributable to a variety of different sociological circumstances, is indicative of lingering inequity across all fields of science. This inequity reflects the long impact that structural racism and misogyny has had on the exclusion of underrepresented groups from participating in science (Burton et al., 2022). Approaches to dismantling exclusionary systems must be multifaceted and provide support for budding scientists at each life stage, and removing barriers from science will undoubtedly take concerted effort from institutions across all age groups (Duran et al., 2021). Here we focus on the impact that exposure to science in elementary school-aged girls may have on their interest in science as a career and subject area. Early-life exposure to science has been shown to increase participant interest in pursuing science as a career (Jones and Stapleton, 2017). The goal of the GAMES program is to expose girls from underrepresented groups in science to female scientists, as well as a wide array of scientific processes and topics, ranging from evolutionary biology to archeology to biogeochemistry. The GAMES program is intended to encourage participants to see themselves as capable of becoming scientists.

At the start of the COVID-19 pandemic, GAMES transitioned from an in-person, museum-based model to a virtual learning one. From Fall 2020 through Fall 2021, GAMES was deployed as a remote program in two different styles: remote programs based at participants' homes, and remote programs based at participants' schools. The remote version of the GAMES program allows participants to engage in hands-on learning activities from their homes or school classrooms, while connecting to educators using the Zoom platform (San Jose, CA: Zoom Video Communications, Inc). The onset of the COVID-19 pandemic has led to an increase in remote educational instruction at schools and universities (Lindner et al., 2020). Due to the increase in the use of remote instruction, there is a need to understand the efficacy of this educational model.

Since Fall 2021, GAMES has partially returned to an in-person learning environment, but it is based out of participants' schools rather than the museum. Thus, there are four different categories of GAMES sessions: in-person at CUMNH, in-person at school, remote at school, and remote at home. Through all these changes to the program, GAMES educators have been collecting survey data from participant cohorts, in the form of pre-program and post-program surveys. We therefore can qualitatively assess the impact that the GAMES program has on participants' attitudes towards science, in both remote and in-person learning environments. Here we present a detailed description of the GAMES program as well as a dataset of survey results from the past five years that gauge participant interest in science.

BACKGROUND

Informal Science Education as a Pathway to Making Science More Equitable. Informal science education is often defined as an active learning environment outside of a traditional school setting (Richardson and Wolfe, 2001; Kimm and Dopico, 2016). Informal education programs are frequently employed by institutions of higher learning as a form of community outreach or engagement (Boyer, 1990; Richardson and Wolfe, 2001, Benneworth et al., 2008; Allen, 2008; Hart and Northmore, 2011), intended to support local communities. Since its initial formal description as a form of university outreach in the 1990s (Boyer, 1990), community engagement in the context of universities has expanded to encompass a variety of forms, from engaging community members in scientific research to creating educational opportunities for community members (Doberneck et al., 2010; Saltmarsh and Hartley, 2011; Doberneck et al., 2017).

Demographic inequities in science are a result of numerous structural barriers that require, at least in part, active approaches from academic institutions (Pearson et al., 2022). One potential avenue to decrease underrepresentation in science is the deployment of enrichment programs that cater to members of underrepresented groups and allow participants to foster a sense of belonging in science (Lane, 2016). Differences in levels of interest in science across demographic groups often begin as early as elementary school (Sullins et al., 1995; Portsmore and Swenson, 2012), so enrichment programs that engage underrepresented demographic groups at this critical life stage may be especially influential. Furthermore, female scientists report more frequently than male scientists that their interest in science began through positive exposure during education, either in school or after-school programs (Maltese and Tai, 2010).

After-school informal educational programs are especially effective at increasing levels of engagement, as they tend to be inquiry based rather than knowledge based (Gibson and Chase, 2002). Inquiry-based learning includes hands-on activities, which give students a sense of agency as they learn (Hansen et al., 1995). These types of programs also allow students to interact with scientists and educators in an informal, low-pressure environment, which leads to increased levels of engagement (Laursen and Brickley, 2011). Informal education programs targeted to children from underrepresented groups in science can potentially lead to positive outcomes later in life, as these programs have been shown to improve participant attitudes towards science (Wulf et al., 2010; Habig et al., 2020).

Part of the success of informal education programs comes from the sense of belonging and agency that participants report after participating in such programs (Habig et al., 2020). Informal education programs can achieve this by taking place in locations where scientific research occurs. Museums are already a place of informal learning for communities (Finkelstein and Wever-Frerichs, 2007; Mujtaba et al., 2018; Stocklmayer et al., 2010), and they are places where scientific research takes place, so they are an ideal location for informal science education programs (Melber and Abraham, 1999; Tišliar, 2017).

GAMES specifically targets girls of elementary school age as participants because the interest gap in science, where boys show more interest in science than girls, appears to emerge by middle school (Maltese and Tai, 2010). This difference can be attributed, at least in part, to boys attending more after-school informal science education programs than girls (Fancsali, 2002; Lareau, 2003). The lack of exposure to science from out-of-school programs is especially exacerbated for low-income students, who tend to lose access to educational opportunities outside of school (Alexander et al., 2001). Indeed, one ongoing problem in informal science education programs is the barriers to entry for participants who are socioeconomically disadvantaged (Hinojosa et al., 2021; Bruyere et al., 2009; Dawson, 2014). The GAMES program was specifically designed to be equitable by making participation and any associated costs free for all participants. As such, the participants of the GAMES program are girls belonging to communities historically underrepresented in science, including socioeconomically disadvantaged participants and/or participants of color.

Evaluating the Impact of the GAMES Program. To assess the impact that an informal science education program has on participants, we need to evaluate how it facilitates learning and engagement in science. The varied aspects of learning science in an informal setting can be categorized into six distinct "strands" (from Bell et al., 2009; Rodari, 2009):

Strand 1: Experience excitement, interest, and motivation to learn about phenomena in the natural and physical world.

Strand 2: Come to generate, understand, remember, and use concepts, explanations, arguments, models, and facts related to science.

Strand 3: Manipulate, test, explore, predict, question, observe, and make sense of the natural and physical world.

Strand 4: Reflect on science as a way of knowing; on processes, concepts, and institutions of science; and on their own process of learning about phenomena.

Strand 5: Participate in scientific activities and learning practices with others, using scientific language and tools.

Strand 6: Think about themselves as science learners and develop an identity as someone who knows about, uses, and sometimes contributes to science.

We use strands 1, 5, and 6 to guide our evaluation of the impact of GAMES, as the focus of the program is to encourage girls to experience science as hands-on activities and to cultivate a sense of belonging in scientific environments. One way to measure these strands is to evaluate participant attitude or affect. Affect refers to the emotional state of a person, and in contexts of education it has major implications for learning outcomes (Pell and Jarvis, 2001; Alsop and Watts, 2003; Shah and Mahmood, 2011; Lin and Schunn, 2016). Students who feel uninterested in science typically absorb less information than those who are engaged in scientific material (Alsop, 2005). Furthermore, positive attitudes towards science improve cognitive learning in children (Snow and Farr, 1987), allowing them to build knowledge more easily. We therefore interpret changes to affect over the course of the program as an indicator of the impact that GAMES has on its participants.

Surveys are particularly useful in assessing attitude or affect, since they provide survey-takers with the opportunity to share their thoughts and feelings (Allen et al., 2008; Sasson, 2014). In this study, we use surveys with two types of questions that are useful for evaluating attitude towards science: multiple choice questions with trichotomous answers (Lovelace and Brickman, 2013) and questions about word-associations. While word associations are useful in measuring affect, these types of questions can also provide information about changes in word knowledge, and thus underlying attitudes (Nakiboglu, 2008).

Remote Versus In-Person Learning: Are They Both Effective? Since the start of the pandemic, there has been emerging interest in the efficacy of remote learning, especially in comparison with in-person instruction (Lindner et al., 2020; Aldhahi et al., 2022). Remote education has applicability outside of the context of the COVID-19 pandemic because of its potential to increase accessibility to educational materials (Fedynich, 2013; Banas and Emory, 1998). While increased accessibility is a benefit of remote education, there have been several major identified problems in remote education, including insufficient support for socioeconomically disadvantaged participants, problems in levels of engagement from participants, concerns about impacts of remote education on student mental health, and the potential barrier of internet access (Tomasik et al., 2021; Yılmaz et al., 2021; Golberstein et al., 2020; Acosta et al., 2021).

The COVID-19 pandemic resulted in unprecedented steps pursued by public officials to slow the spread of the highly contagious SARS-CoV-2. Emergency closure of schools meant there was a rapid transition to remote educational instruction for students and teachers. The impact that emergency remote teaching had on student mental health and wellbeing during the height of the pandemic is largely dependent on the socioeconomic status of students' families and mental health of students. While remote learning appeared to be neutral for non-disabled students from financially stable families (Acosta et al., 2021), children who are from families with fewer economic resources and children with disabilities experienced poor outcomes (Masonbrink and Hurley, 2020). The pandemic also had far-reaching economic impacts on families with young children, leading to an exacerbation of existing economic inequities, and likely further contributing to the poor outcomes of socioeconomically disadvantaged students.

While emergency remote teaching during the height of the pandemic did not provide adequate emotional and educational support to many students, we posit that remote teaching can be made more equitable by providing students with hands-on material that allow them to fully engage with educational content remotely. The full extent of the difference in efficacy between remote and in-person education programs outside the context of a global pandemic has yet to be fully realized. The GAMES program began remote instructional sessions for participants beginning in 2020. We therefore have an opportunity to evaluate the different impacts that remote and in-person learning have on participant affect.

What Is the GAMES Program? During the academic year (September-May), GAMES runs as a seven-week after-school program for girls in fourth and fifth grade, with one 1.5-hour meeting per week. Participants in the program are recruited from schools around the state of Colorado. Schools with high proportions of participants qualifying for free or reduced lunch are targeted specifically for the GAMES program. Teachers at these schools typically select participants whom they believe would benefit from the GAMES program, thus creating a cohort of around 15 girls for each seven-week program. The GAMES program is funded by a series of grants from the National Science Foundation (in the form of broader impacts) as well as long-term funding from the University of Colorado Boulder's Office of Outreach and Engagement and several local foundations so it can be free for all participants.

The GAMES program is cost-free, meaning that it covers most associated transportation and food costs for participants, and it provides a scientific toolkit (e.g., forceps, goggles, magnifier lens, etc) to participants for use outside of the program. The cost-free nature of GAMES is an integral part of making the program accessible, as informal science education is most successful when it can engage communities that would otherwise be unable to access comparable programs (Hinojosa et al., 2021). Nevertheless, there are still some barriers to participation in the program. For example, while transportation to the program is provided, families of participants are still responsible for picking their children up at their schools or bus stops after the program ends. Other community engagement projects should consider these types of impacts to families when constructing a low-cost program for participants in order to maximize engagement with marginalized communities.

Pre-pandemic, the GAMES program occurred at the University of Colorado's Museum of Natural History. In these programs, participants explore the sciences associated with the museum: paleontology, zoology, anthropology, archeology, and botany. During each GAMES session, participants visit research spaces and labs across campus and, where possible, go behind the scenes into the museum's collections, where millions of objects and specimens are studied and preserved. They receive a scientific tool to take home (e.g. forceps, goggles, measuring tape, cleaning brush) that is related to the subject area for that session; this is always a real tool used by scientists in their field of study. During each session, participants participate in authentic hands-on activities using the tool they receive and have the opportunity to talk to scientists in relevant subject areas about their career pathways, childhood aspirations, and fields.

The activities available to participants are wide-ranging, from measuring and interpreting potsherds from the museum's archeology education collection to identifying fossils from paleontology education collection. Activities are designed to have participants engage with aspects from different fields of science, and to increase participant interest in and comfort with these fields by making them accessible. To encourage participants' families to support their daughters' pursuit of scientific interest after the program ends, the families of participants are invited to attend the last GAMES session, which is advertised as a 'Family Science Night.' In pre-pandemic GAMES sessions, the final GAMES session took place at dinner time, which may have impacted attendance for the final session, as participants needed to be transported by their families to the session. In post-pandemic GAMES sessions, the final session takes place at the same time as other sessions, minimizing additional barriers to attendance. This final session of each cohort is intended for participants to give their families a tour of the museum and demonstrate their newfound knowledge to their families. During this session, families and participants are provided with free dinner, and content is delivered in both Spanish and English. The goal of this final session is to encourage the families of participants to support their interest in science, and to provide resources that aid in this encouragement.

For the first year of the COVID-19 pandemic, in-person programs were suspended. In-person programs partially resumed in the Fall of 2021, but shifted location so they take place in participants' schools rather than CUMNH. For these in-person school-based programs, instructors bring the same materials that would be present in the museum and invite the same scientists who work in the museum to each GAMES session, so that the only primary difference in the program is the location. For these GAMES cohorts, Family Science Night also occurs during the last session of the program, but participants and their families go to the participating school, rather than CUMNH, for this final session.

The start of the pandemic also led to a new form of program instruction: remote learning. In addition to having adapted in-person school-based sessions for participants, there are now completely remote cohorts of the GAMES program, whose participants live outside of the area constrained by transportation times between school and the CUMNH. Participants in the remote programs attend sessions using Zoom. For all of the Fall 2020 and most of the Spring 2021 cohorts, participants joined the GAMES program remotely from their homes. Beginning in the spring of 2021, one remote session shifted so it took place in the participants' school rather than from participants' homes. Starting with Fall 2021, all remote cohorts have taken place at participants' schools, where participants are together in their classroom and are guided by GAMES instructors over Zoom.

During all Zoom sessions, participants engage virtually with scientists. Materials for all remote program activities are shipped to participants' schools in advance, for distribution by teachers. In remote at-home cohorts, participants' families would pick up materials from school and bring them home for GAMES sessions. For remote in-school cohorts, teachers would distribute materials to participants once they arrive to the classroom for GAMES sessions. Included in these remote materials are toolkits with items for the activity in each session. While the delivery of the content is different for remote cohorts than in-person ones, remote sessions engage participants using the same content as the in-person sessions, with the addition of pre-recorded videos made by scientists specifically for the GAMES program. For example, one content topic covered in sessions is marine biology. For this topic, participants' schools are sent an overnight shipment of sea anemones and brine shrimp. The participants hatch the shrimp, then in tandem with a scientist instructor they feed shrimp to the anemones, make observations about what they see, and explore other aspects of these animals. Allowing remote participants to handle the same materials used in in-person cohorts gives participants the opportunity to be highly engaged in content pieces of the GAMES program.

Remote cohorts also have the benefit of including schools outside of the Boulder Valley School District, since transportation is not required for each session. Schools in Pueblo and Lake City, Colorado were selected as good candidates for remote school-based instruction, due to the low socioeconomic status and diverse populations of students and the large transportation distance required to reach a physical meeting place. All remote cohorts, regardless of location, have Family Science Night as their final session.

Specific details of cohorts from Fall 2019-Spring 2022, including specific logistical details of how materials were provided and distributed, as well as how Family Science Night was organized, can be found in Appendix A.

METHODS

Measuring Participant Attitudes: Surveys and Anecdotes. To evaluate the efficacy of the GAMES program, we use surveys with questions intended to gauge the attitude (Allen et al., 2008; Sasson, 2014) of participants towards science and scientists. The surveys used in this study were designed to improve the program and to apply for funding, so our use of these survey data is a post-hoc analysis of data collected between the fall of 2017 and the spring of 2021. Since these data were collected for non-research purposes, IRB approval for this study is not necessary. Surveys were administered to participants immediately before and after the GAMES program. Both sets of surveys contain the same 3 questions, intended to gauge participant attitudes towards science (Table 1). Though the GAMES program is primarily instructed in English, surveys are written in both Spanish and English so that participants can respond in the language they prefer. Participants fill out surveys anonymously, and no randomization procedure is followed, as data are collected anonymously. The data used in this study come from the following GAMES cohorts as a combination of in-person, on-campus; in-person, off-campus; and remote sessions: Spring 2017, Fall 2017, Spring 2018, Fall 2018, Fall 2019, Fall 2020, Spring 2021, and Fall 2021.

We can compare pre-program and post-program survey data across two different modes of instruction: in-person and remote. Surveys are uploaded into the University of Colorado Boulder's Qualtrics system by cohort, which includes cohort year, term (fall or spring), and type of instruction (remote or in-person).

Administration and Collection of Surveys. We use two similar methods to administer surveys in in-person and remote environments. For in-person programs, the pre-program survey is printed on paper in both Spanish and English and handed out to participants either once they arrive at the program location or on the bus on the way to the program location. Instructors provide minimal information about the program to participants before survey administration, to limit bias before filling out the pre-program survey. Participants are asked to complete the survey, which requests no identifying information from participants. While all participants are handed surveys, they are given verbal instruction that the surveys are completely optional, that there are no "right" or "wrong" responses, and that they can be handed in blank, or not handed in at all. After ten minutes, the surveys are collected and stored for future uploading into the University of Colorado Boulder's Qualtrics system by student assistants. The post-program survey is administered in the same way as the pre-program survey, but it is handed out during the last

Table 1. *Survey questions given to participants in both pre-program and post-program surveys.*

Question 1	Do you think you can be a scientist? ¿Tu crees que puedes ser una científica?
Question 2	What do you think when you hear the word 'science'? Write 3 words. ¿Qué piensas cuando escuchas la palabra 'ciencia'? Escribe tres palabras.
Question 3	What do you think when you hear the word 'museum'? Write 3 words. ¿Qué piensas cuando escuchas la palabra 'museo'? Escribe tres palabras.

session of the program, during the family visitation session.

For remote programs, participants at home were sent a Google form as a link in the Zoom chat at the start of the first program session, and at the end of the last program session, which includes the survey questions in Spanish and English. The Google form anonymously records responses from participants, which are then uploaded into the University of Colorado Boulder's Qualtrics system. Remote sessions taking place in schools had surveys sent to the cohort chaperone who then provided a paper version of the survey to students. The participants are given ten minutes to fill out the survey.

Survey Data Processing and Analysis. Survey results were separated according to question number, program term, and the timing of the survey (i.e., pre- or post-program) (Table 2). To compare surveys between in-person and remote groups, we pooled survey results together and noted whether cohorts participated in the in-person or remote program. We further categorized the data according to whether they are pre-program or post-program data.

To further understand the differences in responses between groups, we also grouped survey responses into two different in-person and remote options: in-person at the University of Colorado Museum of Natural History, in-person at participants' schools (where GAMES instructors present content to students in-person), remote from home, and remote from participants' schools (where GAMES instructors present content to students via Zoom). We consider this additional partitioning of the data because it allows for detection of potential differences within our in-person and remote conditions (Table 2, Appendix A).

Due to our small sample size in each cohort (no more than 20 participants per cohort, Table 2), and the different sample sizes in the pre- and post-survey groups, it is not possible to assess the statistical significance of the differences in survey responses across groups. Therefore, we primarily use qualitative analysis to evaluate the efficacy of the GAMES program in improving participant attitudes. There are two main ways in which we analyze the data: bar charts and word clouds.

To construct bar charts, we calculated the proportion of participants in each cohort who selected each answer. In word association instances where participants write their own responses, answers were categorized according to the type of words written, with four different groups that words could be placed into. These four categories are emotional words (e.g. "fun", "boring","excited"), experiential words (e.g. "discover", "experiment", "explore"), scientific words (e.g. "biology", "nature", "rocks", "history"), and technical words (e.g. "tweezers", "goggles", "microscope", "specimens"). Proportions of responses falling into each category for each survey cohort were calculated for analysis via bar charts.

To construct word clouds, we counted the number of times a word appeared in written participant responses to questions (Questions 2 and 3). We then made word clouds using words with more than one appearance in our dataset, with the size of the word directly corresponding to the number of responses. We also provide a discussion of words used in pre-program surveys but not post-program surveys and vice versa. All analyses were performed in RStudio 2021.09.0 (RStudio 2020).

Since these surveys were written in both Spanish and English, there are some responses provided in Spanish for the open-ended questions. We translated these responses to English (when applicable) so that the meanings of the words used could be directly compared regardless of the initial language in which they were provided.

Table 2. *Sample sizes for each GAMES cohort in the pre-program and post-program surveys. Whether the program was in-person or remote, and whether the program took place from home, from participants' schools, or onsite at CUMNH is indicated on the left. The numbers of pre- and post-surveys vary in each cohort because not every student who takes one survey necessarily takes the other.*

Term	Pre-Program Surveys	Post-Program Surveys
Spring 2017 (in-person, at CUMNH)	15	9
Fall 2017 (in-person, at CUMNH)	17	7
Spring 2018 (in-person, at CUMNH)	19	20
Fall 2018 (in-person, at CUMNH)	19	7
Fall 2019 (in-person, at CUMNH)	15	8
Fall 2020 (remote, at home)	13	16
Spring 2021 (remote, at school)	20	20
Fall 2021 (in-person, at school)	15	11
Fall 2021 (remote, at school)	11	10
Spring 2022 (in-person, at school)	9	6

RESULTS AND DISCUSSION

Responses to "Do you think you can be a scientist?" In both remote and in-person programs, participants responded that they believed they could be scientists in a higher proportion in post-program surveys than in pre-program surveys (a change from 43.6% to 53.8% for in-person cohorts, and 45.4% to 50.0% for remote cohorts) (Figure 1, Appendix B). This result indicates a general increase in the proportion of participants who can self-identify as scientists after completing the GAMES program. Notably, this improvement in attitude towards science is more prominent in in-person groups than in remote groups. Nevertheless, remote groups still see a modest increase in the number of "Yes" responses to Question 1.

In the remote group, there was a slight increase in the proportion of participants who indicated that they did not believe they could be scientists from the pre-program survey to the post-program survey.

To better understand the patterns in our remote and in-person results, we considered whether program location,

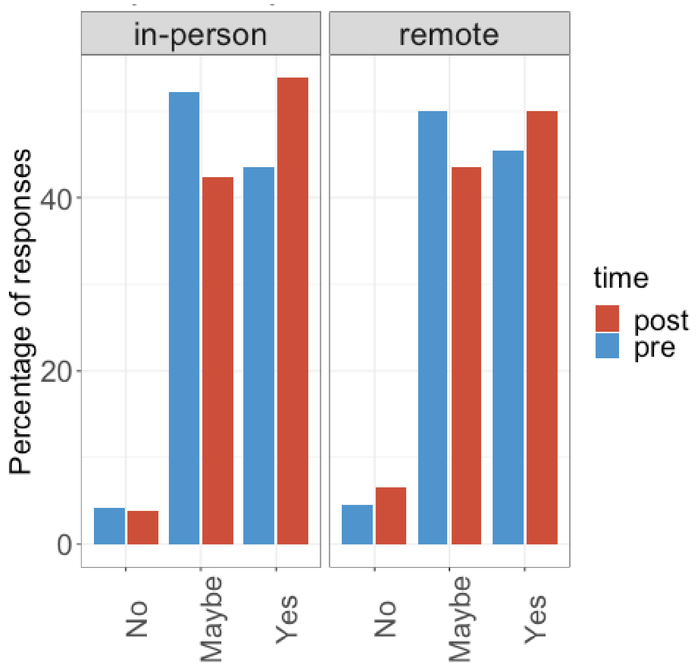

Figure 1. Survey responses to "**Do you think you can be a scientist?**" Blue bars correspond to pre-program survey responses, and red bars correspond to post-program survey responses.

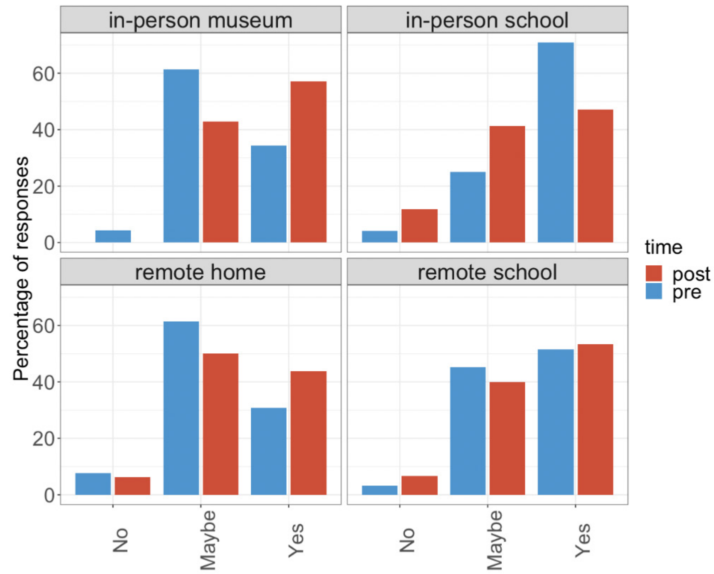

Figure 2. Survey responses to "**Do you think you can be a scientist?**" Pre-program and post-program survey results, partitioned according to location as well as delivery style.

in addition to content delivery style, had an impact on the survey results. In our four-way partitioning of the dataset (in-person at CUMNH, in-person school, remote at-home, remote in-school), we find that location of the program (in-school, at-home, at CUMNH) had a larger effect on the results than the delivery style (remote, in-person) (Figure 2). The increase in "no" responses in our remote cohorts appears to primarily come from the remote in-school cohorts, where the number of "no" responses increased from 1 to 2 between pre- and post-program surveys for the Fall 2021 cohort.

Surprisingly, we also find an increase in "no" responses from pre-program (0 "no" responses) to post-program (1 "no" response) surveys in our in-person school-based cohorts. Furthermore, for our in-person school-based cohorts, there is also a notable decrease in "yes" responses from pre-program (8 "yes" responses) to post-program surveys (6 "yes" responses).

We offer several explanations for this increase in "no" responses and decrease in "yes" responses for our school-based cohorts. First, our partitioning of the dataset into four different cohort types greatly reduces our sample size for each group. This reduction in sample size may lead to an inflation of our differences between groups due to change. Second, since surveys are optional, it is possible that different students submitted responses for the pre- and post-program surveys. Perhaps a participant who dislikes science and did not enjoy the program filled out a post-program survey but not a pre-program one, which would result in our observed increase in "no" responses. Similarly, a participant who enjoys science and enjoyed the program may have filled out the pre-program survey, but not the post-program one, leading to an apparent decrease in "yes" responses after the program. The impact of this difference is not possible to determine with our dataset since surveys are completed anonymously. There is no evidence of bias favoring the completion of pre-program surveys over post-program surveys or vice-versa, as the program settings where participants complete surveys are comparable: they occur at the same location and time of day.

Alternatively, we consider the possibility that school-based programs are not as effective as at-home programs or museum-based programs in increasing participant interest in science. Prior study has found that formal science programs in school can be boring for students for a variety of reasons, including lesson difficulty (Prokop et al., 2007). However, little attention has been paid to the impact that the location of school itself may have on student interest in science. It is possible that students associate the location of school itself with boredom, driving their interest in science downward when informal science education programs are based in school rather than at an external location.

An additional consideration in the interpretation of these results is the existence of potential language barriers for participants. While responses given in Spanish have similar proportional responses as those given in English, it is essential to note that the content of the GAMES program is primarily delivered in English. This represents an inherent barrier for some participants, and multilingual implementation of informal education programs should be considered for optimized program efficacy (Medina Luna et al., 2019). While these results do not indicate that Spanish-speaking participants had worse outcomes than non-Spanish-speaking participants, Spanish-language instruction can play an important role in expanding the positive impact of the GAMES program.

The potential for bias in our in-person at CUMNH dataset must also be considered. Since 'Family Science Night' occurred at a different time from other GAMES sessions for in-person cohorts at CUMNH and required families/parents/guardians to bring participants to the session, it is possible that participants who disliked the program would be less likely to attend the final session. The lack of attendance of these participants in the final session may positively skew our results for this group of cohorts, leading to an overestimation of the program's positive impacts. In post-pandemic programs, however, 'Family Science Night' has changed to take place at the same time as other sessions, so transportation is provided to students (in in-person contexts), overcoming this barrier. Our results for remote at-home cohorts do not have this same bias, and show similarly positive results, so it is possible that this potential bias does not apply in our in-person at-CUMNH cohorts.

Overall, our results suggest that participants in the GAMES program can see themselves becoming scientists more readily after the program ends than before the program begins. While both in-person and remote groups show an increase in the percentage of "yes" responses to this question in post-program surveys, the effect is greatly reduced in cohorts taking place at schools. Excitingly, the remote cohorts, especially those based at participants' homes, saw similarly positive changes in participants' self-reporting of whether could see themselves as scientists compared to students learning in an in-person museum-based setting (Figures 1 and 2), indicating that the remote form of instruction can have a positive impact on participant feelings of ownership over scientific activities, especially if participants begin the program with neutral attitudes.

We have also collected anecdotal evidence over the past five years of the GAMES program, from participants, chaperones, and scientists that provide additional insight into the impact of the GAMES program on participant attitudes towards science. These anecdotes provide additional context to the impact that the GAMES program has on students, which go beyond measurable estimates based on survey responses. We include some excerpts from chaperone, student, and scientist feedback below.

One chaperone reported:

> [T]*he GAMES students loved this program; they get to experience science in real life and directly see how science can be a career for them in the future. The most beneficial thing is that the girls get to see examples of themselves in science careers.*

Another chaperone shared that,

> [...] *one student was particularly interested in our visit to the vertebrate zoology collection. Being able to handle real specimens and artifacts was a unique experience, and I think that helped the kids identify themselves as scientists. The following week she shared a pile of books about birds that she had borrowed from our library at school related to what she had experienced in the lab.*

A school chaperone commented:

> *Kids would come in my room outside of sessions to look at the anemones, to check on them and notice some were quite a bit bigger than others because they were voracious eaters! [It was] neat to have the students come back in and check to see what was going on. I have several of these students in small reading groups and they would talk about what they were doing with the program outside of the GAMES sessions.*

One instructor recalled a meaningful connection she made with a student over the course of a GAMES program:

> *A participant showed particular interest in paleontology, and as an invertebrate paleontologist, I was able to show her the many fossils in our museum's education collection. On the last day of the program, she declared, 'I want to do what you do when I grow up!' as she said goodbye to me. It was a meaningful experience for me as an instructor!*

One student reported "I already love working in my mom's garden and now after being in the lab with [one participating scientist], I know that I can become a botanist when I grow up!"

One of the CU Museum archaeologists does research on domesticated horses. One GAMES student interacting with him rides and loves horses and was in awe as she held a horse skull and teeth specimens. Weeks later when at the family science event celebrating the work of the GAMES kids, she spent nearly the whole evening expertly explaining to her mom and sister the details of the archaeologist's research on horses and the many additional details she had learned about this human-animal interaction.

An undergraduate CU Boulder student assisting with GAMES noticed one particularly quiet student watching a demonstration from a geologist. She said,

> *After the scientist was done drilling the calcium carbonate rock to make a powder, she asked if any other girls would like to try the drill. Most of them tried it, but* [this student] *held back, then hesitantly asked if the geologist could demonstrate the drill again. After which* [she] *confidently stepped up to take hold of the drill, put it on high, and drilled the rock into a powder. I noticed in this one moment*

> [the student] *gained a lot of confidence, maybe from being inspired by this female scientist role model. Once her confidence was established, she felt comfortable and excited to use scientific equipment.*

A PhD student serving as an instructor shared a particular memory from a group working on a Family Day presentation about polar bears:

> *The students came together excited to collaborate,* [and they] *came up with an idea, researched their topic, discussed what visual aids would be relevant to explain their main points, and then gave a great presentation. Even though the students didn't necessarily use those words, to me it felt like I was watching them be scientists. And it was so cool that I was able to participate and aid in that experience; it's moments like those that can shake off the wear and tear of day-to-day work as I get my PhD.*

Another PhD student instructor commented that program participants

> *...asked great questions and enthusiastically engaged in activities… GAMES allows me to pay forward the help I received from similar programs as a young girl, programs which inspired me to pursue STEM. Presenting at GAMES has provided me with an important outreach opportunity that is easy to fit within my schedule, professionally helpful, and enjoyable to participate in.*

A University of Colorado faculty member reflected on their time as a GAMES instructor:

> *It was a thrilling experience working with students from the University Hill Elementary School. Their excitement and curiosity were contagious. I felt tremendous fulfillment when the students connected with materials I presented (marine biology) and shared their experiences with me. The students were so happy to see live marine organisms in the classroom and asked impressive scientific questions. It was a privilege for me to share a piece of my research with them and I hope I planted some seeds of environmental conservation.*

Responses to "What do you think of when you hear the word 'science'?" For in-person programs, emotional words made up the most common category of responses used in pre-program surveys (Figure 3, Appendix C), but this varies with cohort (Figure 4). The categories of words become more varied in the post-program surveys. For post-program surveys, scientific words (like "fossil" and "chemistry") and technical words (like "laboratory" and "goggles") were more common than in pre-program surveys. More experiential words were used in pre-program surveys than in post-program surveys. Experiential words were neither the most-used nor least-used words.

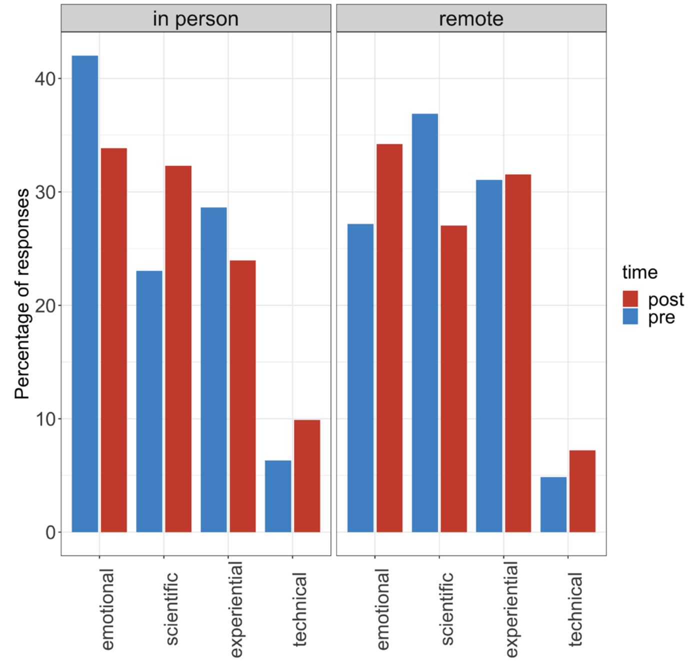

Figure 3. Responses to the question "**What do you think of when you hear the word 'science'?**" The percentage of responses in each category are shown, with blue bars corresponding to pre-program survey responses, and red bars corresponding to post-program survey responses.

Scientific words were the most common category used in remote pre-program surveys. For remote post-program surveys, there was a proportional increase in responses us-

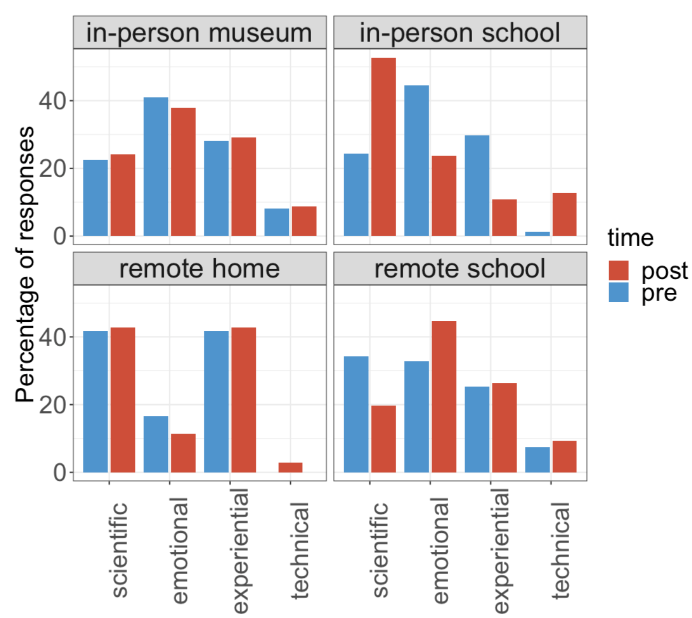

Figure 4. Survey responses to "**What do you think of when you hear the word 'science'?**" Pre-program and post-program survey results, partitioned according to location as well as delivery style.

ing emotional words and technical words increased relative to pre-program surveys. In this group, the proportion of responses using experiential words remained nearly constant in pre-program and post-program surveys.

The use of different word categories varies widely across cohorts. One trend consistent across in-person and remote programs is the increase in percentage of technical words used. This may be a result of participants having gained new knowledge over the course of the GAMES program. While our surveys were intended to be affect measures, the word association model opens the opportunity for changes in knowledge to be evaluated (Nakiboglu 2008). The use of technical words suggests that particular vocabulary terms, including those promoted by use of the GAMES toolkits, impacted the ways in which participants thought about science. The increase in the percentage of participants using technical words suggests that there may be improvements in knowledge in addition to effects as a result of the GAMES program.

When partitioning our results according to location as well as delivery style (in-person museum, in-person school, remote home, remote school), we find that the use of technical words generally increased between pre- and post-program surveys for each group (Figure 4), suggesting that participants did learn new vocabulary, regardless of setting. Interestingly, in-person school-based cohorts had the largest increase in the use of technical words between pre- and post-surveys, reflecting an increase in knowledge. Why this increased learning did not appear to be reflected in participant confidence in seeing themselves as scientists (Figures 1 and 2) is unclear, and could be the focus of future study.

The most commonly used word in both the pre- and post-program surveys across remote and in-person programs is "fun" (Figure 5). This result can have two distinct interpretations. First, it is possible that the children who participate in the GAMES program already have the tendency to view science in a positive light, even before the program begins. Since this is a program that children have to actively enroll in, it would make sense that most of the participants who enroll are at least modestly interested in science. Second, since Question 2 is open-ended, a large portion of words used only appear once or twice in survey responses. Since "fun" is a common word in vernacular English, especially among children, it makes sense that it would come up the most frequently, even if emotional words are not the most-used category of words in our categorical analysis. We find these results particularly significant because the GAMES program does not introduce the activities as "fun" before or during program sessions. The participants associated "science" with "fun" without being primed to conflate the two concepts.

It is worth noting that there was a modest increase in frequency of the word "fun" in the post-program surveys compared to the pre-program surveys (for in-person groups, the frequency of "fun" increased by one percent in the post-program surveys and in remote groups, the frequency increased by ten percent, Appendix C). This result indicates that participants associate science with "fun" in greater proportion after the GAMES program ends than before it begins. The increase in use of the word "fun" further qualifies the impact that the GAMES program has on participant attitude towards science: participants leave the GAMES program with a positive attitude toward science, primarily viewing it as "fun."

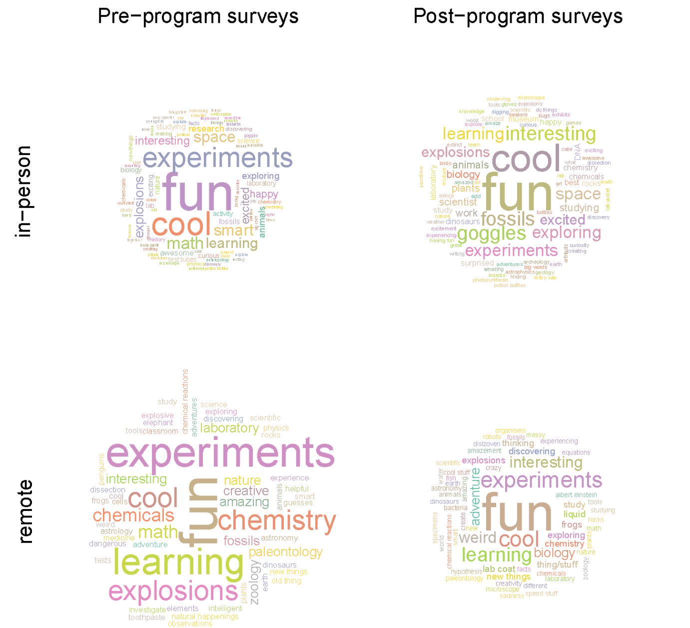

Figure 5. Word clouds of written responses to the question **"What do you think of when you hear the word 'science'?"** Colors correspond to word count. Full list of words can be found in Appendix C.

There were several words that appear in pre-program surveys and not in post-program surveys and vice-versa (Appendix C). Like our other results, we discuss these words in a purely qualitative context. The words "activity" (n=3) and "making" (n=2) were used in pre-program surveys but did not appear in post-program surveys. These words are vague experiential words, and their absence from post-program surveys may indicate that students turned to using more specific terms in their post-program surveys. The words "lab coat/jacket" (n=3) and "DNA" (n=2) appear in post-program surveys but not pre-program surveys, perhaps reflecting increased comfortability in using specific scientific jargon or descriptions. Additionally, negative words like "boring" and "nervous" each appear once in pre-program surveys but do not appear in post-program surveys, potentially reflecting a shift away from negative attitudes in some students. However, the word "sad" appears a single time in the post-program surveys, either reflecting sadness that the program is ending, or a sadness associated with science.

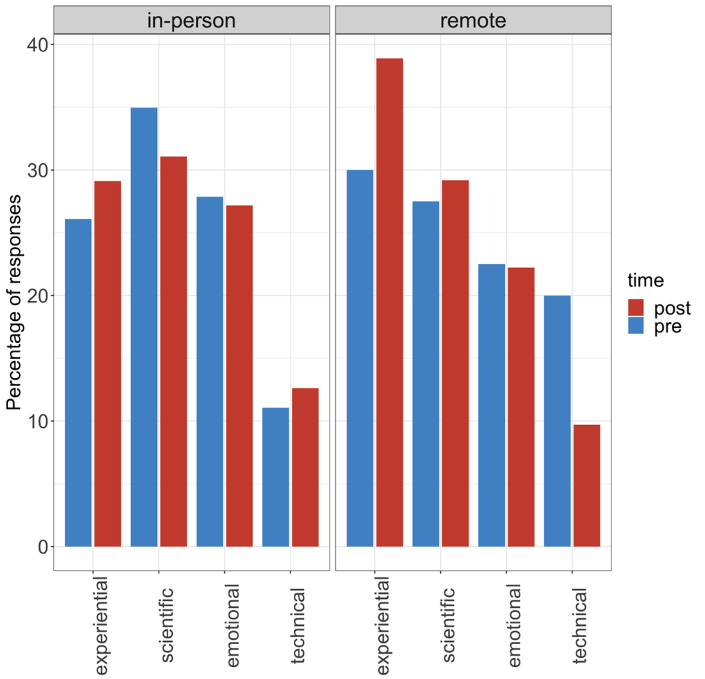

Figure 6. Categorical responses to the question "**What do you think of when you hear the word 'museum'?**" Pre-program survey response categories are in blue, while post-program survey response categories are in red. Quantities of responses are portrayed as percentages

Responses to "What do you think of when you hear the word 'museum'?" In in-person programs, scientific words were the most commonly used categories for both pre- and post-program surveys (Figure 6, Appendix D). In remote programs, the most commonly used word categories were technical for pre-program surveys and experiential words in post-program surveys. While scientific words were used most frequently in pre-program and post-program surveys in in-person cohorts, relatively more scientific words were used in the pre-program compared to the post-program survey. The biggest proportional increase occurred in the experiential word category, which saw the largest jumps in use between pre- and post-program surveys for both in-person and remote groups.

We did not expect to see more scientific words in pre-program surveys than in post-program surveys, which made our result for in-person programs surprising. Additionally, we did not expect to find that students would use more technical words in pre-program surveys than in post-program surveys in remote cohorts. We believe this result may be a consequence of participants coming into the program having fairly neutral attitudes about museums. Neutrality tends to reflect a base-level understanding of a concept (Khine 2015), which in this case is the concept of a "museum". This neutrality led to the use of general, knowledge-based terms such as "history", "art", and "animals", which fall into the science category. Also popular were terms such as "exhibits", "artifacts", and "displays", which fall into the technical category (Figures 6 and 7). The decrease in the use of neutral terms

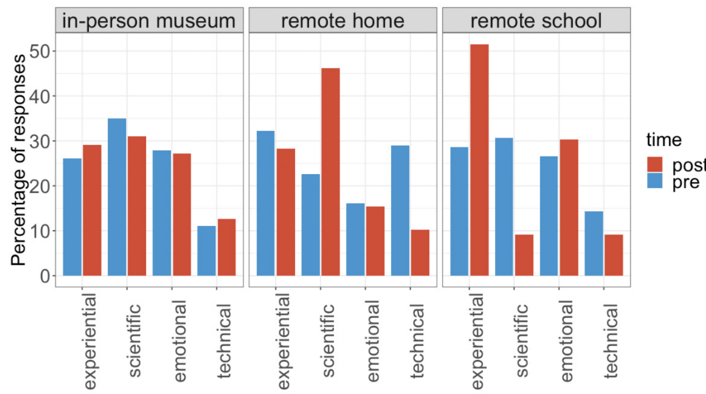

Figure 7. Categorical Responses to the question "What do you think of when you hear the word 'museum'?" Pre- and post-program response categories are partitioned according to delivery style and location.

in post-program surveys, coupled with the increase in experiential words, indicates that participants may have shifted their view of museums over the course of the program. Rather than viewing museums as a neutral place of study, participants may instead view museums as a place where they participate in activities. This suggests that there could be an increase in a sense of "belonging" that participants feel in museums, as experiential words imply agency.

Since the term "museum" refers to a physical place (as opposed to "science", which is a conceptual term), it is possible that more technical terms were used in this word association prompt in the pre-program surveys because objects frequently seen in museums ("artifacts", "specimen", "tools") are considered technical terms in our categorization scheme. Since there were no in-person school-based cohorts that had surveys with this question, our ability to compare responses across cohort location is limited. Nevertheless, the results between in-person and remote cohorts are similar when comparing them across locations and when locations are pooled together (Figures 6 and 7).

Our word clouds introduce more nuance into our interpretation of participant responses to Question 3. While technical and scientific words were the plurality categories in our pre-program surveys, the word "fun" is still the single most common word that appears among written responses, particularly in the in-person pre- and post-program surveys (Figure 8). For remote surveys, "fun" was certainly still a common word, but in pre-program surveys, "cool", a similarly generic term reflecting a positive emotional attitude towards museums, was the most common word. In remote post-program surveys, the single most frequent word used was "fossils," which likely reflects one of the program's emphases: paleontology.

In post-program surveys, while not the most commonly used word, "science" increased in frequency for both remote and in-person groups, which may be a result of the GAMES program encouraging participants to view museums as a lo-

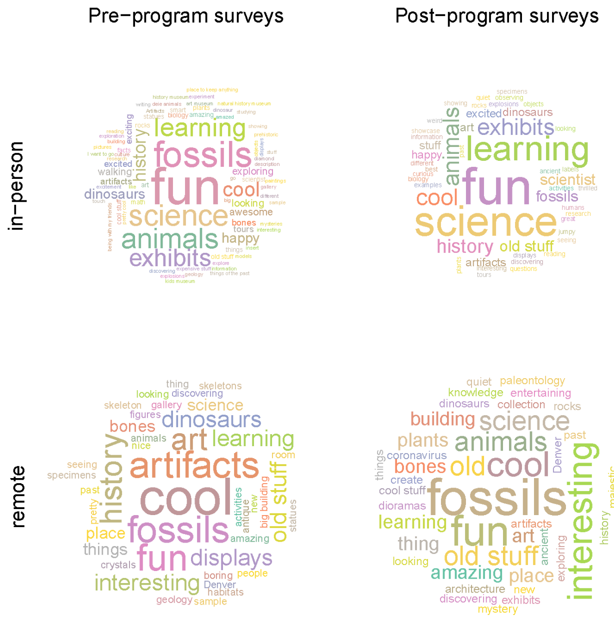

Figure 8. Word clouds of written responses to the question "**What do you think of when you hear the word 'museum'?**" Colors correspond to word count. Full list of words can be found in Appendix D.

cation where "science" is centered. The increase in frequency of the word "science" in post-program responses shows that the GAMES program helped participants view museums as locations of scientific research and inquiry, perhaps further encouraging them to view themselves as scientists.

Remote and In-Person Instruction. Our results indicate that both in-person and remote programs increase the proportion of participants who can see themselves becoming scientists (Figures 1 and 2). While improvement in participant affect and attitude was more modest than in in-person programs, our remote programs were still effective in improving participants' ability to see themselves as scientists. Remote programs from home outperformed those based in school, suggesting that at-home instruction may be more effective than instruction in school. This result holds true for in-person programs as well as remote ones, indicating that programs taking place outside of a school setting may be especially important in improving student attitudes towards science.

The responses to word association prompts were widely variable across all groups, which we interpret to mean that participants have individualized takeaways from the program. In both remote and in-person programs, participants used a wide variety of words to describe science and museums. This makes it difficult to identify a single trend in participant attitude; however, the heterogeneity of responses likely illustrates the heterogeneity in participant experiences. Different participants enjoyed different parts of the program, so that there is no universal response to the GAMES program. We consider this variation to be inherently beneficial to student engagement, since the program is broad enough to engage participants with a broad variety of interests.

Despite the success of the GAMES program, we believe that there are several ways to improve the remote implementation of informal distance education. Most apparently, remote implementation of the GAMES program relied on participants' families having access to the internet from their own home computers. This potential barrier to participation could be removed by hosting remote sessions of the GAMES program at local libraries in addition to the homes of participants.

CONCLUSIONS

There are three main takeaways we want to highlight. First, informal science education programs in both remote and in-person environments, especially outside of school, increase the proportion of girls who can visualize themselves as scientists. This suggests that the GAMES program cultivated a sense of belonging for participants. Second, remote programs appear to have modest but still positive impacts on participants, indicating that remote outreach programs have the potential to increase engagement in communities that cannot participate in in-person programs. Finally, we find that our informal science education program increased the comfort of participants in using technical language to describe science and museums, while still maintaining positive emotional connotations. These results indicate that science outreach programs can positively impact students from underrepresented communities, and potentially increase the proportion of students who pursue science. The long-term impacts of these programs on student outcomes require future study.

To increase the impacts that these types of programs have on girls' interest in pursuing science, we implore other institutions and museums to replicate the GAMES program. In-person programs have the added benefit of allowing participants to explore science on-campus, especially outside of a school context, which allows them to feel as if they belong on a university campus or museum. We believe in-person programs may work best for institutions in suburban or urban environments, where travel to and from an in-person meeting location is not an unreasonable burden on participants or their families. For school districts lacking a local museum that can host a comparable program, potential alternative locations include libraries or recreational centers.

Programs should also consider multilingual implementation of educational outreach programs to increase accessibility. While the GAMES program is provided in English, some survey responses were received in Spanish, indicating a preference for Spanish language. While this study did not include results for Spanish-instructed cohorts, the use of multilingual approaches to education outreach may be effective in enhancing a sense of belonging from program participants.

Remote programs can also play a critical role in expanding the impact of such informal science education programs, since they remove cost barriers associated with transportation to in-person programs. Remote programs have the added benefit of engaging participants who are in more rural environments, where travel to and from an in-person location is infeasible. Thus, remote programs might be a better fit for institutions in rural areas. In areas without community centers that can host a program, at-home programs might be more effective than in-school ones.

While running these programs can be expensive, especially transportation costs, it is possible to cover costs associated with the program through institutional support and external grant funding. More information on starting a program like GAMES at institutions can be found by sending correspondence to cumuseum@colorado.edu.

ASSOCIATED CONTENT

Supplemental material mentioned in this manuscript can be found uploaded to the same webpage as this manuscript.

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The manuscript was written through contributions of all authors. All authors have given approval to the final version of the manuscript.

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ABBREVIATIONS

CUMNH: University of Colorado Museum of Natural History; GAMES: Girls at the Museum Exploring Science

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