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### Developing Outreach Events That Impact Underrepresented Students: Are We Doing It Right?

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**Title:** Developing outreach events that impact underrepresented and underserved students: Are we doing it right?

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**Abstract:** Many outreach programs share the common goals of serving underrepresented groups in STEM and improving public attitudes toward science. To meet these goals, scientists must find ways to both reach the appropriate audience, and to communicate the importance of science in meaningful and accessible ways. This requires careful consideration of the outreach method being used. Two common outreach methods include in-school visits (scientist-in-the-classroom) and science fairs or open houses. Here, we compare the effectiveness of these two outreach methods in meeting the goals of reaching underrepresented students and/or students with less initial interest in science. We have found that in-school visits reached more underrepresented students, and that initial attitudes toward science scores were lower for in-school visit participants than for open house event participants. Importantly, positive attitudes toward science increased significantly after in-school outreach events. Taken together, these data suggest that outreach events that are taken out into the community will reach a less enthusiastic but more diverse audience, and can have a positive impact on attitudes toward science within these populations. These studies highlight the importance of knowing the goals of your outreach program and choosing the method that is best suited to meeting those goals.

**Keywords:** outreach; neuroscience; diversity; attitudes toward science; underrepresented minority; science communication

## Introduction

Effective communication of science is critical for informing and sculpting the attitudes of the general public, and scientists are becoming more aware of the need to communicate with the general public about the importance of science (Davies, 2008; Dudo & Besley, 2016; Greenwood & Riordan, 2001; Leshner, 2003; Martin-Sempere et al., 2008). This is evident in the increasing number of outreach efforts by professional scientists, driven in part by government initiatives looking for “broader impacts” of funded research, which is one key merit review criterion that is required by the National Science Foundation (NSF) in grant proposals (Friedman, 2008; Kamenetzky, 2012; Mathieu et al., 2009). Often, the goals cited by scientists for engaging in outreach are to improve public attitudes toward science and/or to reach underrepresented groups in STEM. In fact, data suggest that public engagement has the potential for significant positive effects on society, including increasing science literacy and education, stimulating critical thinking skills, improving attitudes toward science, and increasing diversity in STEM fields (Beck et al., 2006; Bruce et al., 1997; Friedman, 2008; Krasny, 2005; Laursen et al., 2007; Rumala et al., 2011). In addition, the benefits of these events are not unidirectional; scientists benefit from outreach with the community by considering the societal impacts of their work, improving communication skills, and understanding the issues facing their

community (Clark et al., 2016; Laursen et al., 2007). These interactions can lead to discoveries that improve the health and general well-being of the entire community (Bjorkland & Pringle, 2001; Conway, 2006). Other outreach efforts can open lines of communication with individuals who may be skeptical of science or scientists (American Academy of Arts & Sciences, 2018; Pew Research Center, 2015; Sterman, 2011; Tsipursky, 2018). It is important to remember that not all outreach techniques have the same impact. Thus, it is critical to determine the goals of an outreach event before determining the format of that event. Here, we examine the effectiveness of two different outreach methods, in-school visits and open houses, in meeting two common outreach goals: 1) Improving attitudes toward science in middle schoolers, and 2) Reaching underrepresented groups in STEM. We hypothesized that in-school visits would reach a more diverse student population than open house events while also reaching more individuals who were not already “science enthusiasts.” Our work suggests that taking outreach into the community is a more effective way to reach those less interested in science, as well as underrepresented populations that scientists hope to engage.

## **Methods**

In order to examine the effectiveness of these two forms of outreach, we engaged undergraduate students in outreach events during Brain Awareness Week at Hope College. One of these activities is a series of single visits to local elementary and middle school classrooms, during which undergraduate instructors deliver a lesson focused on sensory perception and integration (Vollbrecht, Frenette & Gall, 2019). The week culminates with a free on-campus open house style event that is open to the community and engages participants in a number of hands-on activities geared towards K-8 students. The use of multiple event formats through the course of the week allowed for the examination of differences in demographics at various events, and comparison of attitudes toward science in different populations.

### *Subjects*

A total of one hundred and sixty-nine 10-14 year-old students in grades 6-8 participated in our in-school outreach activities and took a pre-event survey to assess baseline attitudes toward science (see Supplementary Materials and Assessment section below). A total of 105 students completed the post-test (62.1% retention) to assess science attitude changes following our lesson. Students in grades 6-8 were selected by emailing teachers in the Holland, Michigan region. Middle school students were selected from a total of 7 classes with 2 different teachers in the Holland area.

In order to have a comparison group that was of a similar age range to our in-school outreach participants, we assessed pre-event data from thirty-four 10-13 year olds that came to the open house. Of these 34 open house participants, only 9 (26.5% retention) completed the post-event survey.

All methods involving middle school students were approved as an internal review board exemption from Hope College under the following section of the Federal Common Rule: *45 CFR 46.104(d)(1) Research conducted in established or commonly accepted educational settings,*

*involving normal educational practices* (U. S. Department of Health and Human Services, 2018). This exemption allowed us to collect non-identifiable data in local middle schools.

### *Outreach Events*

All in-school events followed a previously described lesson plan that was created to meet the criteria for the Next Generation Science Standard MS-LS1-8 (Vollbrecht, Frenette, & Gall, 2019; NGSS Lead States, 2013).

All of the activities used during in-school visits were also available at the open house event. The open house event was advertised via flyers distributed to local schools in both Spanish and English for students to take home. The event was also mentioned in a weekly institutional radio show highlighting upcoming local events. Social media (Twitter, Facebook, Instagram) was also used through institutional accounts and with local Twitter/Facebook groups to inform the community about our open house event.

### *Assessment*

In order to assess attitude changes toward science, we used the *Student Attitudes Toward STEM Survey—Middle and High School Students* (Friday Institute for Educational Innovation, 2012). We only selected questions that pertained to attitudes toward science. The specific questions can be found in the Supplementary Materials.

In addition to assessing attitude changes toward science, demographic data were collected, which included age, gender, and race/ethnicity.

Finally, students responded to one open-ended question in order to assess neuroscience knowledge gains relating to the lesson plan (see Vollbrecht, Frenette, & Gall, 2019).

Pre-event and post-event responses for in-school outreach visits were collected via Qualtrics (2019 Qualtrics LLC, Provo, UT). Teachers were asked to have their students take the pre- and post-test on a computer. Pre-tests were completed between 1-3 days before the outreach visit and post-tests were completed at least 7 days but less than 14 days after the outreach visit. Pre- and post-test assessments were matched to randomly assigned IDs, so that identifying information was not collected from the students.

Pre-event responses for open house visits were collected via pencil and paper. At check in, students were asked if they would be willing to complete a pre-test. If the participants agreed, a random ID number was assigned. Email addresses were also collected at check in, and participants were emailed and asked to complete a post-test 7 days after the open house via Qualtrics.

### *Statistical Analyses*

Demographic data were collected and converted separately into percentages for in-school visit participants, and open house participants.

For the 9 questions that assessed attitudes toward science, a score was assigned as follows: 1 to “Strongly Disagree,” 2 to “Disagree,” 3 to “Neither Agree nor Disagree,” 4 to “Agree,” and 5 to “Strongly Agree.” Question 8 was reverse-coded. Each student’s score was summed with a maximum possible score of 45, a higher score indicating a more favorable attitude toward science.

To assess neuroscience knowledge gains relating to our lesson plan, we asked students to describe everything they knew about the following concept using complete sentences: “*When a person touches a hot iron, describe what causes the person to move their hand away from the iron*” (see Supplementary Materials). For this question, two independent evaluators (TT & AJG) blind to condition scored each response on a scale of 0-5. The average of the evaluators’ scores was calculated for each response. A score of 0 was assigned if the student didn’t answer the question or if their answer was irrelevant. A score of 1 was assigned if the student was overly simplistic in their response by saying either “heat” or “pain”. A score of 2 was assigned if they described that “heat” led to “pain,” indicating a cause and effect response. A score of 3 was assigned if the student indicated that the cause and effect was due to the involvement of the nervous system. A score of 4 was assigned if the student also explained that nerves receive and send signals. A score of 5 was assigned if the student demonstrated complete understanding of the concept, including sensation, motor responses, nervous system integration, and reflexes. Each student’s score was assessed in the pre-test and again in the post-test.

Independent-samples t-tests were used to examine differences in initial attitudes scores for in-school visits (pre-event) vs. open house (pre-event), and open house event comparison (pre vs post). Multiple t-tests were used to examine initial attitudes scores by gender and race/ethnicity. A Paired-samples t-tests was used to examine differences in attitude scores for in-school visits, and knowledge gains in the open-ended question (pre-event vs. post-event scores).

## **Results**

### *Demographics Survey*

Demographics data for both the open house outreach event (Fig 1A; n=34) and the in-school outreach event (Fig 1B; n=169) were collected. Over seventy percent of open house participants were caucasian, with 20% of participants being hispanic/latino, 6% being black or african american, and 3% being asian. In contrast, only 45% of in-school participants identified as caucasian, 29% reported as hispanic/latino, 11% as black or african, 5% as asian, and an additional 10% reporting as other races or ethnicities.

### *Attitudes Toward Science Survey*

Science attitude scores were calculated from responses to both pre- and post-event surveys from in-school and open house event participants. Prior to participation in either event individuals who participated in the open house event had significantly higher attitudes toward science scores than individuals participating in the in-school event (Fig. 2A;  $t_{201}=3.863$ ;  $p<0.0005$ ). Similar effects were observed when data were separated by gender in both males (Fig. 2B;  $t_{68}=2.266$ ;  $p<0.05$ ) and females (Fig. 2B;  $t_{65}=2.939$ ;  $p<0.01$ ). When data were separated by race/ethnicity a significant effect was observed in between white students who were to participate in the in-school event and those who were to participate in the open house event (Fig. 2C;  $t_{71}=3.569$ ;  $p<0.005$ ). While similar trends were apparent when examining other ethnicity/races no statistically significant differences were observed.

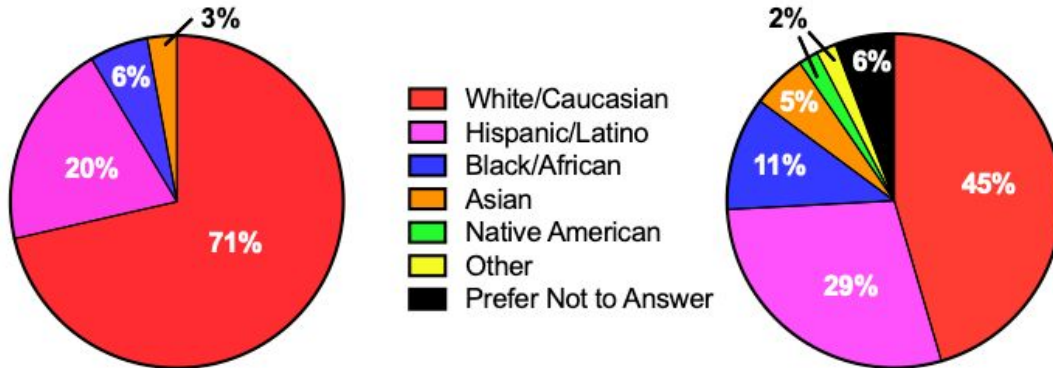
Attitudes toward science scores of individuals participating in the in-school event were significantly improved one week following the event when compared to pre-event scores (Fig. 3A, left panel; paired samples t-test,  $t_{104}=3.059$ ;  $p<0.005$ ). No significant difference was observed between pre- and post-event attitudes toward science scores for the open house event (Fig 3A, right panel;  $t_{41}=0.7888$ ;  $p=0.4347$ ). An independent samples t-test was used due to the low number of post-event responses.

#### *School Visit Effects on Neuroscience Content Knowledge*

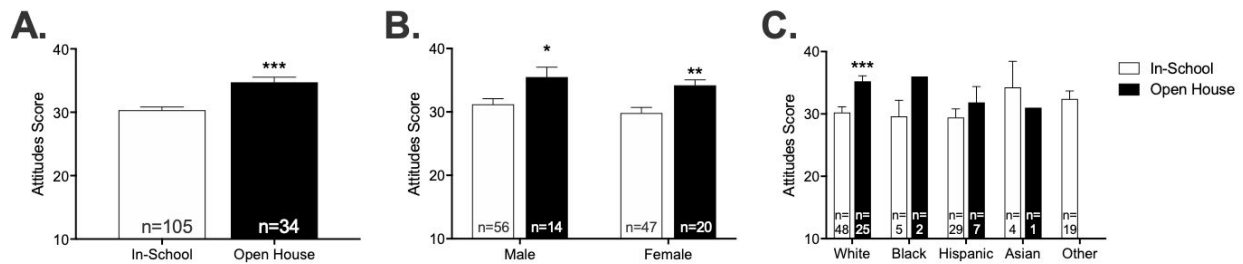
Blinded evaluation of responses to an open-ended prompt regarding a neuroscience topic revealed a significant increase in scores of students who participated in the in-school outreach event (Fig. 3B; paired t-test:  $t_{103}=3.028$ ;  $p=0.0031$ ).

### A. Open House Participants

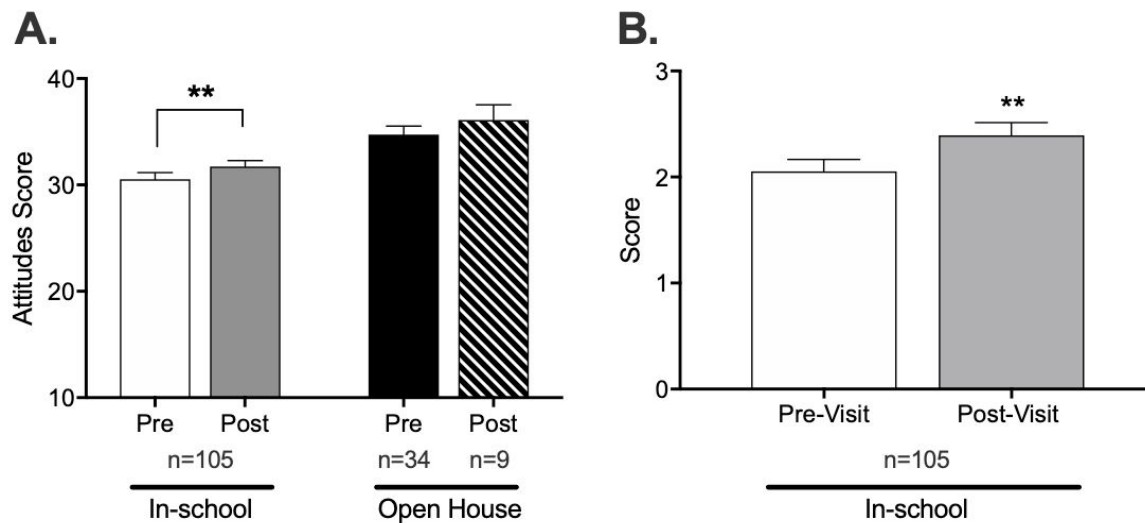
### B. School Visit Participants



**Figure 1. An in-school event reaches a more diverse population of students than an open house event.** Nearly three quarters of open house participants were white, while over half of participants at in-school events were from other racial or ethnic groups.



**Figure 2. An in-school event reaches students with lower initial attitudes toward science scores than an open house event.** A) Comparison of pre-event attitudes toward science surveys demonstrate that open house participants had significantly higher initial science attitude scores than in-school outreach participants. B) This observation remained when individuals were separated by gender with both males and females who attended the open house event having higher initial attitudes toward science scores. C) Similar trends were observed when evaluating race/ethnicity with significantly higher initial attitudes toward science scores in white individuals attending the open house event. \*\*\* =  $p < 0.001$ ; \*\* =  $p < 0.01$ ; \* =  $p < 0.05$



**Figure 3. An in-school event improves neuroscience attitudes and content knowledge.**

A) Our in-school event successfully improved science attitude scores, while no significant improvement was observed in open house participants. B) In addition, an open-ended response assessment verified that our developed lesson plan is effective in increasing neuroscience knowledge a minimum of one week after the in-school outreach event. \*\* =  $p < 0.01$

### Discussion

Science communication and public outreach are important for promoting science literacy in the general public (Andrews et al., 2005; Friedman, 2008; Baron, 2010; Illingworth and Prokop, 2017). With more individuals and groups engaging in outreach activities, it is becoming increasingly important to evaluate outreach effectiveness (Varner, 2014; Illingworth, 2017; Spicer, 2017; Vollbrecht et al., 2019). In order to evaluate whether or not an outreach event is effective, one must have goals, and specifically, one must have goals that can be evaluated (Staton & Tomlinson, 2001; Jensen, 2015; Spicer, 2017). Two common goals of today's outreach efforts include improving public attitudes toward science, and increasing diversity in STEM fields (Clark et al., 2016; Payne, 2017). Here, we demonstrate that different types of outreach events reach different members of the community. Specifically, our data demonstrate that in-school outreach events reach individuals with less positive initial attitudes toward science, while also reaching a more diverse population than an open house style event.

In addition to reaching individuals with lower initial science attitude scores, our in-school outreach event also reached a more diverse student population when compared to the open house style event. Seventy percent of middle school open house participants were caucasian (Figure 1A), while the local school district is nearly 50% hispanic and only 37% caucasian (Michigan's Center for Education and Performance Information, 2016-2017a). However, our in-school outreach event reached a much more diverse population with 45% caucasian, 29% hispanic and greater than 10% African-American students participating (Figure 1B). A number of variables could be responsible for these differences. A Pew Research Center survey has shown



that among high school seniors, hispanic and black students “like” science less, and view careers in science less favorably than white or Asian/Pacific Islander students (Pew Research Center, 2017). Thus, it is possible that a lack of interest or accessible resources may result in fewer underrepresented students seeking out the open house event. In addition, greater than 63% of the local school district students are considered economically disadvantaged (Michigan’s Center for Education and Performance Information, 2016-2017b). This has the potential to create barriers such as transportation to the event, greater conflicts with weekend work schedules, and less time to devote to science opportunities (Barnett, 2008; Ngai, 2014). Despite the difficulty in determining which factors underlie demographic differences, the fact remains that in-school visits successfully reached a more diverse population of students than an open house outreach event.

In-school visits are perfectly positioned to reach not only those students who are science enthusiasts, but also those students who feel science is less interesting or less important. Students who participated in the open house style event during Brain Awareness Week scored significantly higher on an initial science attitudes survey than students who participated in our in-school visits, regardless of gender or race/ethnicity (Fig. 2). This is not altogether surprising when one considers that a Saturday morning open house event requires that the student and/or their parents actively seek out the opportunity to participate. Indeed, data have shown that science festivals are preaching to the scientifically converted (Kennedy et al., 2017), resulting in outreach that is not accessible to a broad, diverse audience (Jensen, 2015; Dance, 2016). In-school visits do not require initiative on the part of the student or parent, and thus reaches individuals with less enthusiasm for science. Our data suggest that in-school outreach events effectively reach those students with less positive attitudes toward science (Fig. 2). These are exactly the type of individuals that scientists should be engaging at a young age, if their aim is to improve public attitudes toward science. In addition to reaching individuals with lower attitude toward science scores, it is also important to determine whether these outreach events actually have a positive impact on student attitudes. While data were collected one week after a single in-school outreach event, significant improvements in student attitudes toward science scores were observed (Fig. 3A). Importantly, significant gains in science attitudes were not apparent in open house participants (Fig. 3A, right panel) While a significant discrepancy persists between post in-school visit participant scores and the initial attitude scores of open house participants, the increases observed following our in-school visit did narrow the gap (Fig. 3A, left panel). Thus, our data suggest that in-school outreach programs more effectively reach those with less positive initial attitudes toward science, and are also effective in improving attitudes toward science of those who participate, when compared to participants at an open house style event. It will be important to examine whether this gap can be further narrowed with repeated in-school outreach events or other interventions.

Finally, our data further demonstrate that our in-school outreach lesson is effective in promoting learning gains in students. Previous work used a multiple-choice assessment to demonstrate content learning gains were maintained in students one week after our in-school visit (Vollbrecht, Frenette & Gall, 2019). Here we utilized an open-ended question assessment to

evaluate content gains. This open-ended question allowed students to more effectively describe what they learned from our lesson plan. Their answers were more complete, more descriptive, and students exhibited a higher level of understanding in responses after the event as compared to before the event. Two blinded reviewers coded each recorded response on a scale of 0-5, with 5 demonstrating complete understanding of the topic. Significant improvement was observed one week following the in-school event (Figure 3B), further demonstrating the effectiveness of our event in delivering neuroscience content.

In future outreach events, it will be important to collect data regarding socioeconomic status and parent education level for participants of both the open house and in-school events. This data could uncover underlying causes that drive differences in participation. Additionally, information regarding where open house participants attend school could help us to better understand the differences between in-school and open house populations as we did not determine whether or not we reached some of the same students at the open house event that we reached during in-school visits. These additional data points may help to explain why students that attended the open-house event had higher initial attitude scores than those participating in the in-school visits.

Our data suggest that in-school outreach events are more effective than an open house style event at reaching underrepresented groups in STEM and individuals with lower initial attitudes toward science, two populations that many outreach events desire to reach. It is important to note that with appropriate planning, some of the barriers that exist for an open house style event can be overcome, such as providing transportation, or having multi-day events to improve access. While this may help in reaching individuals with a lower socioeconomic status, it still does not solve the problem of reaching students with lower science interest levels. Bringing the discussion to them is the best way to reach those individuals.

In the current social media age we tend to surround ourselves with like-minded people and rarely seek out the opinions of those who disagree with us. Social media platforms allow individuals to feel as if everyone agrees with them, creating the proverbial echo chamber (Pew Research Center, 2019; Garimella et al., 2018; Del Vicario et al., 2016). We note that open house style events may be providing the same experience, in physical form, as a poorly curated Twitter feed provides on the Internet. These types of activities attract science enthusiasts, and allow science enthusiasts (both scientists and those in the general public) to meet and agree about the importance of science. This does not mean that these events lack value, as there certainly is value in encouraging and developing awe and excitement in science among science enthusiasts, and encouraging interactions between amateur and expert. What we encourage here is that scientists carefully evaluate the goals of their outreach event, and with those goals in mind, utilize the best outreach format to achieve those goals. For many of us, while open house style events are fun and exciting, they are not achieving the goals we have set forth for ourselves.

Scientists should consider making the effort to perform outreach in places that are convenient for *community members*, rather than performing outreach in places that are convenient for the scientist. One way to do this is to work with local schools to perform outreach in the classroom as described here. Additional possibilities include running booths at local fairs or other public events that allow for spontaneous interactions with the public. Doing so will reach a more diverse population, and may reach those who are more skeptical about science. Creatively designing outreach events that reach these populations is critical to improving attitudes toward science in our society.

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## Supplementary Materials

### ***Demographic Questions***

1. What is your age?
2. What is your gender?
3. Please specify your ethnicity (select all that apply).
  - a. Asian
  - b. Black/African
  - c. White/Caucasian
  - d. Hispanic/Latino
  - e. Native American
  - f. Pacific Islander
  - g. Prefer not to answer
  - h. Other: \_\_\_\_\_

### ***Open-ended Question***

Directions: Please answer the following question completely. Write in complete sentences, and describe everything you know about the concept. Take your time answering this question.

1. When a person touches a hot iron, describe what causes the person to move their hand away from the iron.

### ***Student Attitudes Toward Science Questions [Adapted from Student Attitudes Toward STEM (S-STEM) Survey, 2012]***

Directions: There are lists of statements below. Please choose the answer that best describes how you feel about each statement. As you read the sentence, you will know whether you agree or disagree. Fill in the circle that describes how much you agree or disagree.

***Even though some statements are very similar, please answer each statement. This is not timed; work fast, but carefully.***

There are no “*right*” or “*wrong*” answers! The only correct responses are those that are true *for you*. Whenever possible, let the things that have happened to you help you make a choice.

**PLEASE FILL IN ONLY ONE ANSWER PER QUESTION.**

1. I am sure of myself when I do science.  
Strongly Disagree - Disagree - Neither Agree nor Disagree - Agree - Strongly Agree
2. I would consider a career in science.



Strongly Disagree - Disagree - Neither Agree nor Disagree - Agree - Strongly Agree

3. I expect to use science when I get out of school.

Strongly Disagree - Disagree - Neither Agree nor Disagree - Agree - Strongly Agree

4. Knowing science will help me earn a living.

Strongly Disagree - Disagree - Neither Agree nor Disagree - Agree - Strongly Agree

5. I will need science for my future work.

Strongly Disagree - Disagree - Neither Agree nor Disagree - Agree - Strongly Agree

6. I know I can do well in science.

Strongly Disagree - Disagree - Neither Agree nor Disagree - Agree - Strongly Agree

7. Science will be important to me in my life's work.

Strongly Disagree - Disagree - Neither Agree nor Disagree - Agree - Strongly Agree

8. I can handle most subjects well, but I cannot do a good job with science. (R)

Strongly Disagree - Disagree - Neither Agree nor Disagree - Agree - Strongly Agree

9. I am sure I could do advanced work in science.

Strongly Disagree - Disagree - Neither Agree nor Disagree - Agree - Strongly Agree

Thank you for participating in our survey!