RESEARCH ON LEARNING

STEM Summer Camp for Girls Positively Affects Self-Efficacy

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Abstract

Women and racially and ethnically minoritized populations are underrepresented in science, technology, engineering, and mathematics (STEM). Out-of-school time programs like summer camps can provide positive science experiences that may increase self-efficacy and awareness of STEM opportunities. Such programs often use the same high-impact practices used in K–12 classrooms including relating concepts to real-world examples, engaging students as active participants in inquiry-driven projects, and facilitating learning in a cooperative context. They additionally provide opportunities for engaging in STEM without fear of failure, offer a community of mentors, and allow families to become more involved. We designed a summer camp for middle schoolers who identified as girls, low-income, and as a minoritized race or ethnicity. We describe the design of the camp as well as the results from a simple pre- and post-camp questionnaire that examined each camper's relationship to science, scientific self-efficacy, and interest in having a job in STEM. We found an increase in self-efficacy in camp participants, which is important because high scientific self-efficacy predicts student performance and persistence in STEM, especially for girls. We did not detect an increase in interest in pursuing a STEM job, likely because of already high values for this question on the pre-camp survey. We add to the growing body of work recognizing the potential of out-of-school time STEM programs to increase scientific self-efficacy for girls and racially minoritized students.

Tweet: Summer camp for minoritized middle-school girls increases scientific self-efficacy, a characteristic that may be important for removing barriers to participation in STEM.

Key Words: *middle school; minoritized; out-of-school time; science.*

○ Introduction

The science, technology, engineering, and mathematics (STEM) workforce is essential to maintaining the global competitiveness and economic advantage of the United States, yet women and minoritized races and ethnicities are underrepresented in STEM fields (e.g., Beede et al., 2011; National Research Council, 2011; National Science Foundation, 2011, 2021). A number of factors have been shown to be related to the underrepresentation of women in STEM including social factors (e.g., stereotypes, cultural norms) and motivational beliefs like self-efficacy (belief in ability to do science, as defined by Bandura & Locke, 2003), interest, and values (reviewed by Wang & Degol, 2013; Dasgupta & Stout, 2014).

One strategy to increase the representation of minoritized women in STEM is informal learning (or out-of-school time) programs like STEM camps. Such programs (including the one we describe here) often involve K–12 teachers and use similar practices to those used in K–12 classrooms, including relating concepts to real-world examples, engaging students as active participants in inquiry-driven projects, and facilitating learning in a cooperative context (American Association for the Advancement of Science, 2011). Notably, out-of-school time programs also provide opportunities for students to engage in STEM without fear of failure, offer a community of mentors, and allow families to become more involved in student learning (Dasgupta & Stout, 2014; Froschl & Sprung, 2014). STEM camps have been shown to increase positive attitudes and interest toward STEM (Gibson & Chase, 2002; Hayden et al., 2011), increase interest in STEM careers (Kong et al., 2014), and increase self-efficacy (Phelan et al., 2017). Our work explores the role of an informal STEM camp for low-income, minoritized middle-school girls on participants' (1) relationship with science, (2) scientific self-efficacy, and (3) interest in a STEM job.

Both *relationship with science* and *scientific self-efficacy* affect interest in careers in STEM (Chemers et al., 2011). We use *relationship with science* broadly here to describe how students engage with science and see their role in science. This idea is related to STEM identity, which encompasses how people internalize science experiences, their sense of individual agency, and the societal constructs that may constrain individual possibilities (Carlone & Johnson, 2007; Barton et al., 2008). One pernicious societal construct that may constrain possibilities in STEM is the stereotype that women are not as competent as men (Hill et al., 2010), which children as young as six years old believe (Bian et al., 2017). This false belief reduces girls' performance in and aspirations for STEM (Hill et al., 2010; Bian et al., 2017; Galdi et al., 2014). *Scientific self-efficacy* predicts students' performance, motivation to pursue goals, and persistence in STEM (Bandura & Locke, 2003; Lent et al., 1994; reviewed in Rittmayer & Beier, 2008). The link between self-efficacy

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and choosing a STEM career path is especially important for girls (Larose et al., 2006) and racially and ethnically minoritized communities (Chemers et al., 2011).

We explored students' relationship with science, scientific self-efficacy, and interest in pursuing a STEM job both before and after they participated in a one-week STEM summer camp. Camp participants were middle schoolers who identified as girls, identified as minoritized races or ethnicities, and qualified for free/reduced lunch. We chose to work with middle-school students because middle school is thought to be a time when students identify their own interests and abilities (Reynolds, 1991), and because students who express interest in STEM fields in middle school are more likely to earn a college degree in a STEM-related field (Tai et al., 2006). This age is also an especially critical time for girls as there is a significant drop in girls' (but not boys') confidence in their academic abilities during middle school (American Association of University Women, 1991).

The identity of the authors shapes how work is conducted and presented, so we acknowledge our positionality. All authors are women or nonbinary, are white, are U.S. citizens, and have bachelor's degrees as well as some graduate/professional education. EDB had no authentic science experiences until college and is therefore passionate about providing such experiences to K–12 students. JLH, SMM, and RMT each had formative experiences as one of only a handful of women in high school and/or college science courses. All authors are committed to increasing diversity in STEM and contributing to a future where the STEM workforce and academia reflect the diversity of our communities. This commitment prompted us to create the summer camp we describe in this article and to ask whether it increases participants' scientific self-efficacy and interest in a STEM career. We also recognize that the language describing individual identities is complex and ever-changing. In this article, we follow Rudzki et al. (2022) and use the term "marginalized" to refer to individuals who face bias and discrimination, such as racially and ethnically marginalized individuals, women, individuals with disabilities, those who identify as LGBTQIA+, and others. The term "marginalized" highlights the marginalizing action of societal and institutional barriers, however, we recognize that the term may still contain negative connotations.

○ Methods

The summer camp took place in 2017 in Denver, Colorado, and was free to attend (see funding information in Acknowledgments section). The authors recruited participants via a flier that was shared with the middle-school science coordinator for Denver Public Schools (and forwarded to middle-school science teachers) and distributed in person to recreational centers in the Denver Metro area, as well as through a timely newspaper article published in the local media (Denver Post). Students' families submitted applications in which all attendees and their parents signed assent and permission forms (respectively), and all campers agreed to participate in pre- and post-camp assessments. There were 16 participants (ages 12 and 13).

In designing the camp, we drew heavily on biology education literature to incorporate high-impact practices into the camp design. For instance, all activities were hands-on (Satterthwait, 2010), we used living organisms when possible (Allen, 2004), and we encouraged students to work in groups (Johnson et al., 1991). Additionally, students conducted science as if they were practicing scientists, a teaching approach known as *authentic science* (Buxton, 2006; Chinn & Malhotra, 2002) that has been shown to increase self-efficacy (e.g., Broder et al., 2019). Further, all camp coordinators (STEM professors and graduate students) and visiting scientists identified as female, and many were from minoritized groups. This was by design since role models that more closely match students' backgrounds can increase self-efficacy and lead to increased participation in STEM (Stout et al., 2011). Camp coordinators led experiential workshops focusing on biology/ecology, entomology, astronomy, physics, programming, and electronics. The girls completed six major activities during the camp; they (1) built electric circuits using conducting Play-Doh (squishycircuits.com), (2) built their own Raspberry Pi computers and learned the basics of Scratch coding (scratch.mit.edu), (3) designed and executed an ecological experiment investigating the relationship between plant biodiversity and insect biodiversity, (4) constructed and learned to use their own telescopes (Galileoscopes), (5) designed and sewed buttons with flashing LED lights (e-sewing), and (6) learned about science communication by designing and creating their own posters to show their families what they learned during the camp (Figure 1; see Supplemental Material available with the online version of this article for a camp schedule as well as descriptions of the main activities). We also included a visit to the Denver Museum of Nature and Science with a guided tour of the private museum collections. Daily guest speakers from the community and the University of Denver campus visited the camp to discuss college planning and STEM career pathways. The girls took home all camp materials, including a computer and peripherals, a telescope with tripod and solar filter, and a professional-grade insect collection kit. At the end of the camp, the girls worked in groups to develop demonstrations and posters about their favorite activities (science communication). They shared their work with family and friends who gathered for a camp "capstone" presentation at the end of the week, a component we added because disseminating science may increase scientific self-efficacy (Broder et al., 2019).

We administered identical surveys before and after students participated in the camp. We wrote 22 questions that were both short answer (e.g., yes or no) and open-ended (e.g., asking why they thought something). Here we present responses to 12 questions that were thematically related and designed to reveal students' relationship with science, scientific self-efficacy, and interest in having a job in STEM (Appendix available in the Supplemental Material online; IRB 1043075; questions are also included in the results figures). Each camper completed the surveys by recording their answers on an Aketek Multifunctional Rechargeable 650HR 8 GB Digital Audio Voice recorder.

On day 1 of the camp, we taught students to use the recorders and provided them with printed booklets of survey questions so they could read and respond to questions at their own pace. Students were instructed to find private places where they dictated their answers into the recorders. The students did not identify themselves, making the recordings completely anonymous. On day 5 of camp, after finishing all activities, each student used the same recorder (recorders were numbered) to complete the post-survey so that we could link pre- and post-responses. KJF transcribed all recordings. Most questions prompted answers of "no," "maybe," or "yes," and many respondents also explained their answer. When participants did not directly use one of those three words (yes, no, maybe), KJF and EDB categorized responses into one of those three categories or omitted the response if it was ambiguous. For questions related to self-efficacy (e.g., "Can you complete a science-related activity?"), KJF and EDB categorized responses as low, medium, or high self-efficacy depending on the confidence with which the girls spoke about their abilities (see Table 1 for an exhaustive list of responses and their categorization).

We statistically analyzed responses for all of the campers who answered the questions; however, not all campers answered all questions and so our sample sizes do not always add up to 16. For questions about students' relationship with science in which students could respond with "yes," "no," or "maybe," we used one-sided sign tests with matched pairs to compare the change in pre- vs. post-survey for each participant. For example, if a student responded "maybe" in the pre and "yes" in the post, that would count as an increase or a + in the sign test. Student responses that did not increase or decrease between time points were scored a 0 and not included in the sign test. Similarly, for responses related to self-efficacy that we coded at three levels (low, medium, or high self-efficacy), we used one-sided sign tests to compare changes in individual responses from pre- to post-surveys. All sign tests were performed by hand following Siegal (1956). For a question where students ranked their ability on a scale of 1–5, we used repeated measures analysis of variances with individual ID as a random effect and pre or post as a fixed effect (in JMP Pro 15.0; we could not use paired t tests because not all respondents answered each question in both the pre- and post-camp surveys). For the question about interest in a STEM job, we report the open-ended responses qualitatively with select quotations.

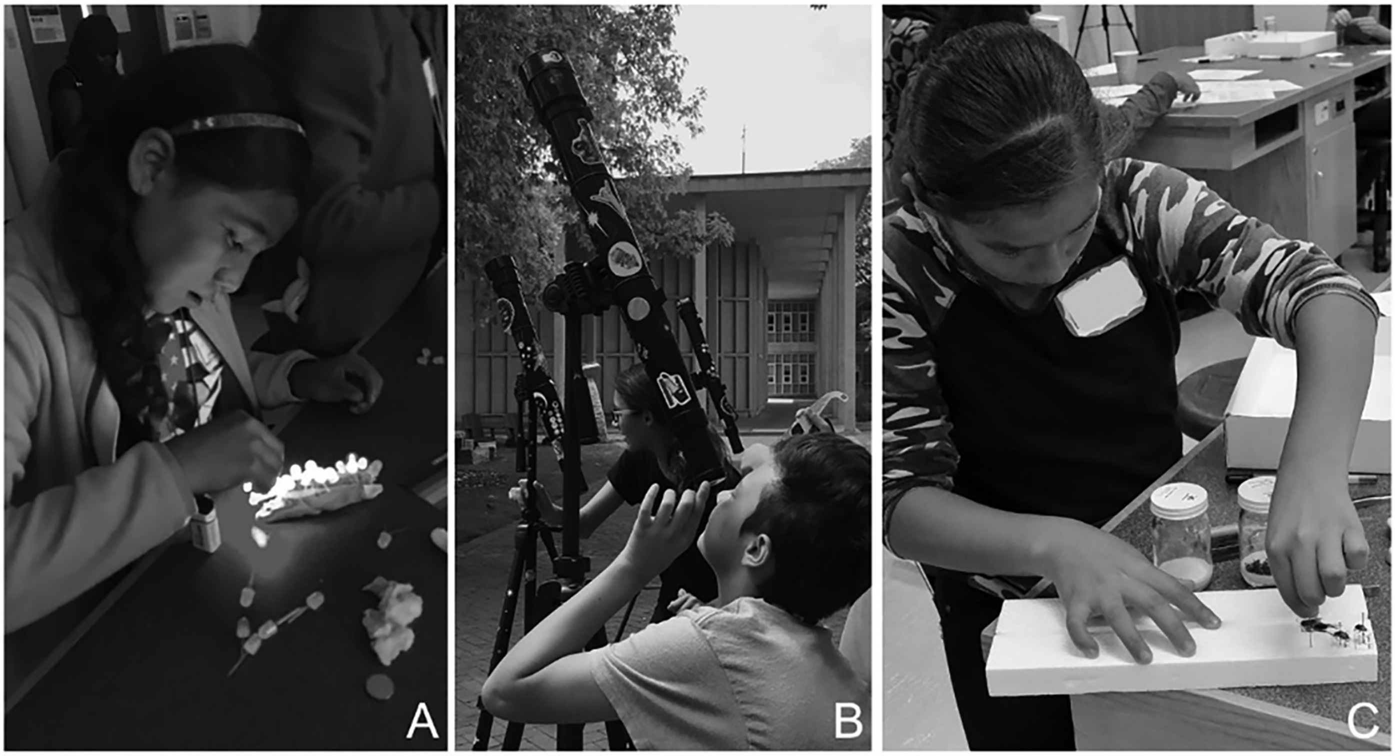

Figure 1. Camp participants completed a number of hands-on science, technology, engineering, and mathematics (STEM) activities such as (A) building circuits, (B) building and using telescopes, and (C) collecting, pinning, and identifying insects as part of a hypothesis-driven ecological study.

Table 1. An exhaustive list of responses that we categorized as reflecting either low, medium, or high self-efficacy.

Low Responses	Medium Responses	High Responses
• I cannot/can't • I'm kind of struggling • Probably not • I don't think I could because …	• I don't think … I mean yeah • I can … it depends • I think I can/might • I don't know • I might be able to sometimes … it depends • Possibly • Sometimes it can be confusing • I guess but it might be hard • I can kind of … it depends …	• I can … • I have completed • Yes I can … • Anybody can • I think I could … I'm really good • Yes, I am positive • I can do well • It might be difficult but yeah I can

○ Results

Relationship with Science

For questions related to *relationship with science*, students were more likely to respond "yes" to the question, "Do you know a scientist?" following the camp (8 students increased and 1 decreased; sign test, $n = 9$, $p = 0.02$; Figure 2). In response to the other four questions, only a few students changed their response from pre to post, resulting in low statistical power to detect changes, but responses to three questions increased: "Do you do science?" (3 students increased and 1 decreased; sign test, $n = 4$, $p = 0.312$), "Do you use science in daily life?" (5 increased and 1 decreased; sign test, $n = 6$, $p = 0.109$), and "Is science important to you?" (3 increased and 0 decreased; sign test, $n = 3$, $p = 0.125$; Figure 2). There was no change in response to the question: "Are you a scientist?" (2 increased and 2 decreased; sign test, $n = 4$, $p = 0.688$).

Many responses about students' relationship with science contained a school-related contextual phrase such as "in school," "only for school," or "when I am in science class." When asked, "Do you do science?" 40% of responses (pooling pre and post) contained one of these school-related contextual phrases. Similarly, when asked, "Are you a scientist?" 22% of responses contained a contextual phrase.

Scientific Self-Efficacy

We gauged *scientific self-efficacy* through a series of questions. Since self-efficacy is the belief in one's ability to succeed in a task, we first asked students to rate their ability to do science on a scale of 1–5. There was a significant increase in their self-reported ability to do science from pre to post ($F_{13,1} = 25.52$, $p = 0.0004$). We also asked a series of questions that reflect self-efficacy, and we coded responses as high, medium, or low (Table 1 and Figure 3). As with the questions about relationship with science, many students did not change in their responses, resulting in small sample sizes with

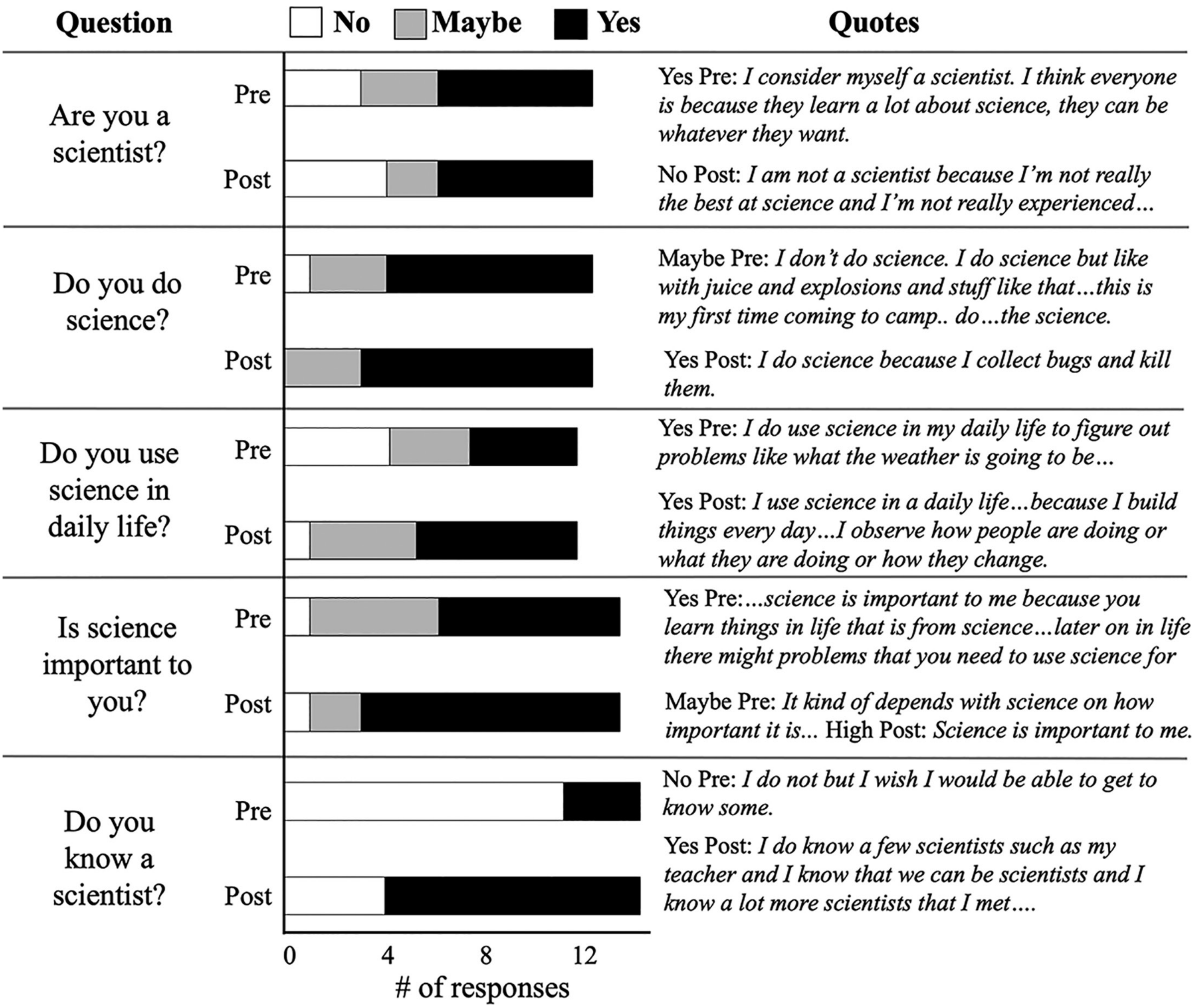

Figure 2. Summary of responses to questions related to relationship with science. Horizontal bar graphs summarize the pre- and post-responses (no = white, maybe = gray, yes = black) to each question listed in the left-hand column. Sample quotes for each response are listed in the right-hand column.

little statistical power for the sign tests. Responses to four of five questions increased: "Can you complete a science-related activity?" (5 students increased and 1 decreased; sign test, $n = 6$, $p = 0.109$), "Can you ask a scientific question?" (3 increased; sign test, $n = 3$, $p = 0.125$), "Do you think you could do well in a high school science class?" (4 increased; sign test, $n = 4$, $p = 0.062$), "Can you explain science to others?" (4 increased and 1 decreased; sign test, $n = 5$, $p = 0.188$; Figure 3). Responses to one question had more decreases than increases: "Can you make a hypothesis?" (2 decreased; sign test, $n = 2$, $p = 0.25$).

When we asked students to rank their ability to do science, we quantitatively measured responses, but we also describe select quotations below.

> *Participant 1: (pre) I'd say I'm around a 3 or 4 on a scale on my ability in science. And, because I'm in between, like I'm really good at it and I need help with it as well.*

> *Participant 1: (post) If I estimate my ability in science on a scale on 1 to 5, I'd probably be a 4 because I'm still learning and I don't know everything in science but I am very, I understand it enough to teach somebody.*

The student ranks herself at 3.5 because she is "good at it" but still "needs help." Following the camp, she ranks herself as a 4. She recognizes that she is "still learning" but is confident enough in her understanding to explain science to others.

> *Participant 2: (pre) I would rate my science on a scale from 1 to 5 a 2.5 because I don't think I'm that good but I think I am kind of good at the same time.*
> *Participant 2: (post) I think I can be a 3 in a half now because I learned more science and I'm better.*

This student recognizes that she is more confident after participating in the camp because she has learned more. She seems to base her scientific self-efficacy on content knowledge.

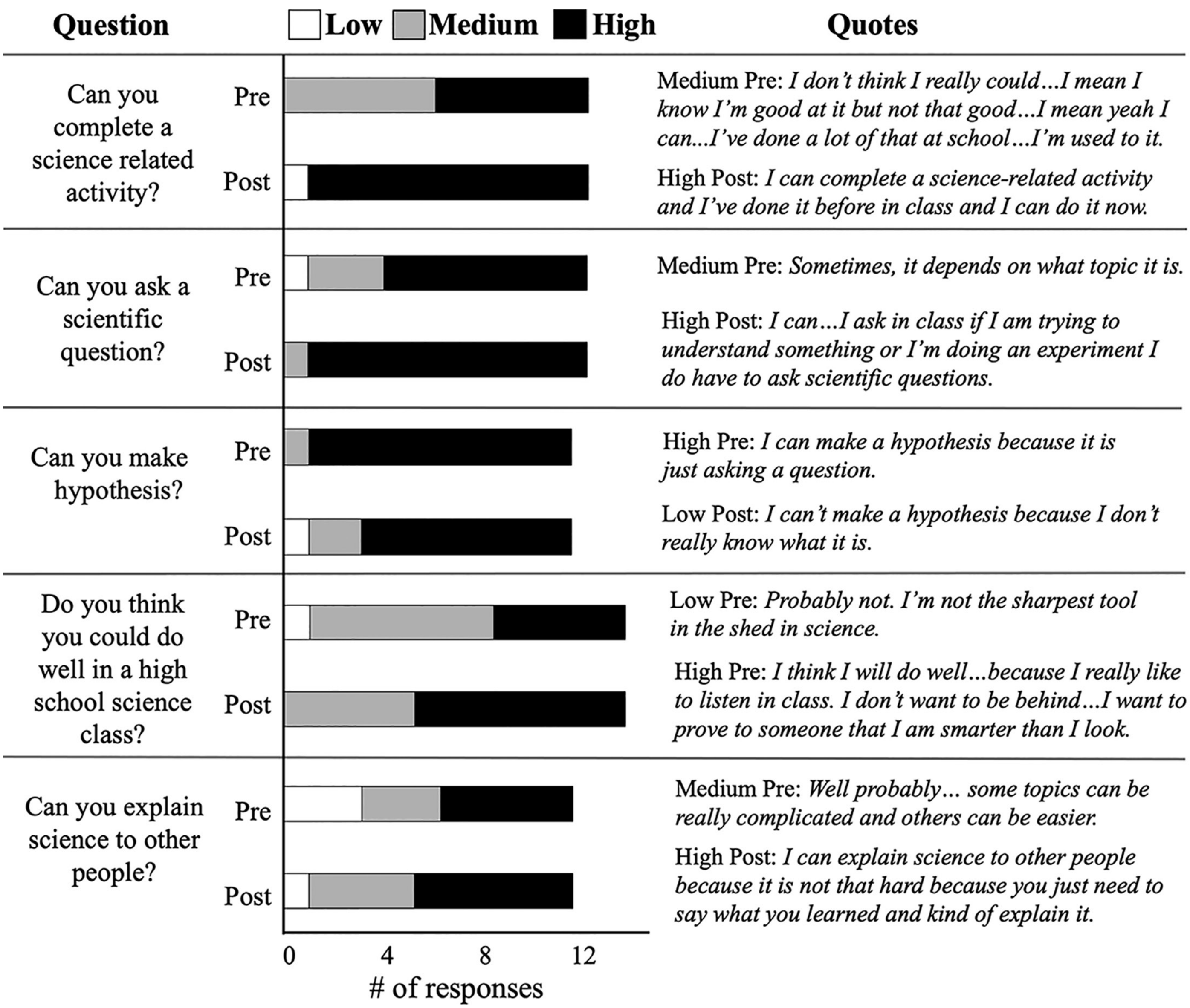

Figure 3. Summary of responses to questions related to self-efficacy. Horizontal bar graphs summarize the pre- and post-responses (low = white, medium = gray, high = black) to each question listed in the left-hand column. Sample quotes for each response are listed in the right-hand column.

Interest in a STEM Job

When students were asked if they could see themselves "having a job in a science field," their pre- and post-responses did not differ. There were eight "yes" responses, two "no" responses, and two "maybe" responses in both the pre and post. However, three students switched from pre to post with two increasing and one decreasing (sign test, $n = 3$, $p = 0.5$). Here are responses from the two students that showed an increase:

> *Participant 1: (pre) I do not see myself in a job in a science field.*
> *Participant 1: (post) I cannot see myself having a job in the science field but I can at the same time. I would be a zookeeper.*

This student changed from "no" to "maybe" since she appears to be more open to the idea of working in a science field after completing the camp. Notably, one of the visiting scientists at the camp was from the local zoo. A different student showed an increase from "maybe" to "yes" on her response to the same question:

> *Participant 2: (pre) I can sort of see myself in a science job, not really. I kind of want to be more of animator and use video tech and all that.*
> *Participant 2: (post) I could sort of see myself having a job in the science field and I may do computer science where I program or animate drawings and make them into a movie or something like that.*

This student did not recognize that computer science, specifically computer animation, is considered science. Her change from maybe to yes after completing the camp is driven by her new perspective of STEM as a broad area that includes computer science.

○ Discussion

We did not detect a change in interest in having a STEM job, but this is likely because most of the students (10 of 14) were interested in a STEM job before participating in the camp. A similar program also found no change in interest in STEM careers but a very high interest before participating in the program (Phelan et al., 2017). This highlights the importance of carefully considering recruitment strategies depending on the goal of the program (e.g., targeting students who are already interested in STEM vs. those uninterested). For the two campers who did increase their interest, one changed because she initially did not realize that her intended job, being an animator, counts as STEM. A lack of exposure to STEM in childhood and adolescence is a major obstacle to participation for girls (Dasgupta & Stout, 2014). We made an effort to expose campers to a wide variety of science fields including ecology, biology, astronomy, physics, and computers and engineering.

We detected measurable changes in scientific self-efficacy. Students significantly increased how they ranked their ability to do science after participating in the camp, and four of five open-ended questions showed a trend of increasing self-efficacy (Figure 3). We did see a decrease in the question about making a hypothesis. It is possible that the students did not understand what a hypothesis was before the camp; after learning the specifics of stating a hypothesis, they may have realized how challenging it is, something with which even senior researchers would agree. Taken together, our findings indicate an increase in scientific self-efficacy after participating in the camp. This result is critical since self-efficacy predicts student achievement and persistence in STEM (Bandura & Locke, 2003; Lent et al., 1994; Rittmayer & Beier, 2008). Additionally, though we did not detect a change in interest in careers in STEM, high scientific self-efficacy is a strong predictor of interest in a STEM career for girls (Larose et al., 2006) and among minoritized racial and ethnic communities (Chemers et al., 2011).

We found mixed results from the five questions assessing students' relationship with science. First, we found an increase in the number of girls who could name a living scientist after participating in the camp. At our camp, participants interacted with many female scientists at various career stages, increasing the students' awareness of living scientists through direct exposure to role models and building a new network for the participants. Additionally, we made students aware of the scientists that they already knew, changing the definition of a scientist from a celebrity, like Einstein, to an average person who uses science in their daily life. For example, one student did not realize that her science teacher would be considered a scientist (Figure 2). Our camp validates the importance of role models in effective out-of-school programming (Stout et al., 2011). The camp made several participants more aware of the fact that they do science (3 increased), use it in their daily life (5 increased), and that science is important to them (3 increased). While not statistically significant, taken together these results suggest that we helped students understand how broad a field STEM is and that they can and do use science in their lives. We did not see a change in the number of participants that identified as a scientist. It is perhaps not surprising that something as deep-seated as identity would not shift in a week.

There were several limitations with this study. First, the questions we asked were not part of a formal validated instrument, which limits the generalizability of these results. Second, because the camp was fully free of charge for participants (funded by grants and donors), we were limited to a small number of campers, which made it difficult to conduct quantitative analyses. A larger sample size would have provided more power to detect significant quantitative changes as a result of participating in the camp. We also had issues with missing data (when girls skipped questions) and incomplete responses. We designed our survey questions to be open-ended with the hope that the girls would fully explain their reasons for their answers; however, because students privately and anonymously answered questions, many gave one-word answers and ignored the requests to explain their answers. This could be avoided in future work by having more structured interviews conducted by a researcher. However, one advantage to the way we administered the surveys is that the girls were not influenced or led by the researchers, so may have responded more honestly than if they were speaking directly to one of us. Future work should consider including more gender diverse participants, as nonbinary and gender-questioning students are also underrepresented in STEM (Maloy et al., 2022) and would likely benefit from participating in out-of-school time opportunities like this camp. Another goal for future camps is to allow participants to act as conduits, bringing knowledge and skills from the camp back to their K–12 classroom through collaborations with teachers. Finally, in future camps we plan to use surveys validated for use with middle-school students (e.g., Wang et al., 2018).

This work explored the effects of a STEM summer camp on participating middle-school girls from minoritized communities in Colorado. While we are limited in our ability to extrapolate our findings, we add to the growing body of work suggesting that out-of-school time programs can increase scientific self-efficacy for girls and minoritized students (Larose et al., 2006; Chemers et al., 2011). Addressing the lack of diversity in STEM fields will require systemic changes and multiple diverse strategies.

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