

Exploring Black Undergraduate Students' Communication and Biology Education Experiences about COVID-19 and COVID-19 Vaccines During the Pandemic

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ABSTRACT

Effective communication about science is a core skill undergraduates should learn, but little research has explored how students communicate about culturally controversial science topics. In this study, we explored how Black undergraduate science students took on the role of science communicators in their communities during the COVID-19 pandemic. We interviewed 23 Black students about their experiences learning about COVID-19 vaccines and communicating about COVID-19 vaccines to their communities. We found that students' racial/ethnic and science backgrounds made them feel a responsibility to be effective communicators about COVID-19 vaccines as potential trusted messengers within their communities. However, students were using limited strategies when communicating and were unsure how to communicate about COVID-19 topics effectively to those who were vaccine-hesitant or doubted the severity of the pandemic. Finally, students described ways that their biology instructors could have helped them be more confident when communicating about COVID-19 vaccines with their communities. Findings suggest that biology instructors could teach science communication principles in addition to content knowledge about culturally controversial science topics in their undergraduate classes to build on students' developing science communication skills.

INTRODUCTION

Biologists and science communication experts have indicated that science communication training for undergraduate students in the sciences is important for promoting effective science communication to the public (American Association for the Advancement of Science [AAAS], 2011; Bray *et al.*, 2012). However, researchers have noted a lack of science communication education in undergraduate courses (Karikari *et al.*, 2016; Dudo *et al.*, 2020), which may negatively impact how undergraduates are communicating about science with their communities and how their communities perceive science. Effective science communication is especially important when discussing culturally controversial science topics for which there is consensus among experts but significant disagreement within the public like the causes of climate change and the safety of vaccines (Sylvester, 2021). Undergraduate science students may have the potential to be boundary spanners, which are individuals who can communicate information effectively between the scientific community and their own communities (Hawkins and Rezazade, 2012). Scientific communities include those directly involved with science including science students (Burns *et al.*, 2003). We know that many undergraduates are communicating about culturally controversial science topics to their communities (Couch *et al.*, 2022; Shah *et al.*, 2022), and that these undergraduates represent diverse

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identities in terms of political affiliation, religious affiliation, and race²/ethnicity (Couch *et al.*, 2022). Therefore, they could be potentially important communicators within their communities.

Black² undergraduate science students may be one population who want training in science communication about culturally controversial science topics due to their desire to address the unique roots of hesitancy about science within Black communities (Google *et al.*, 2023). We define community as a group of people with diverse characteristics who are linked by social ties, share common perspectives, and engage in collective action in shared places and/or settings (MacQueen *et al.*, 2001). Vaccine hesitancy in Black communities has unique roots in distrust in medical institutions that stem from historical and modern racism (Bajaj and Stanford, 2021). Given the strong emphasis of communal values among Black students, they may feel a strong desire to serve their community through being able to communicate about these important yet controversial topics (Luedke, 2020; Dasgupta *et al.*, 2022). However, it is not known how Black undergraduate science students conceptualize their potential role as science communicators within their communities when speaking about culturally controversial science topics. If students value and desire this role, it further exemplifies the importance of establishing undergraduate science communication education to empower these students. We also do not know whether and how these students are learning to communicate in their biology courses, or if there are ways that instructors can help them improve their communication.

In this study, we explore Black undergraduate science students' science communication and biology education experiences during the COVID-19 pandemic to 1) inform undergraduate science communication education efforts and 2) underscore the potential for us to empower students who desire such communication education. We explored this by focusing on how Black undergraduate science students communicated about COVID-19 and COVID-19 vaccines to their communities during the COVID-19 pandemic and how prepared they felt to communicate effectively. We also explored these students' experiences learning about COVID-19, including any experiences they had learning about how to effectively communicate about COVID-19 and COVID-19 vaccines. Finally, we explored the extent to which these experiences impacted their confidence communicating about COVID-19 and COVID-19 vaccines to their communities.

¹In defining race, we adopt the definition of the American Association of Physical Anthropology (AAPA): "Race does not provide an accurate representation of human biological variation. It was never accurate in the past, and it remains inaccurate when referencing contemporary human populations. Humans are not divided biologically into distinct continental types or racial genetic clusters. Instead, the Western concept of race must be understood as a classification system that emerged from, and in support of, European colonialism, oppression, and discrimination. It thus does not have its roots in biological reality, but in policies of discrimination. Because of that, over the last five centuries, race has become a social reality that structures societies and how we experience the world. In this regard, race is real, as is racism, and both have real biological consequences" (AAPA, 2019). In line with this definition, we refer to "race" throughout this article as a social identity (which can have negative consequences for an individual's experiences due to racism) and not a biological classification.

²In this article, we choose to use the term "Black" because our study population identified as Black/African American on our surveys and the term is "Black" can be more inclusive than "African American" alone; not all those who identify as Black have recent African ancestry and not all who identify as Black in our classrooms consider themselves American.

BACKGROUND

Science communication about culturally controversial science topics

Science communication, or communication of scientific information to promote interest, understanding, attitudes, or awareness of science (Burns *et al.*, 2003), impacts the public's attitudes towards contentious science topics (Scheitle and Ecklund, 2017; Unsworth and Voas, 2021). The way science is communicated can influence public discourse patterns on topics at the forefront of public-health officials' concerns like vaccines and climate change (Hart and Nisbet, 2012). However, people who are likely to have a strong interest in promoting science like professional scientists and undergraduate science students are not always effective science communicators (Couch *et al.*, 2022). For instance, while scientists have communicated to the public about the safety and effectiveness of the COVID-19 vaccines (CDC, 2021), COVID-19 vaccine hesitancy and rejection are widespread, with only half of adults in the United States intending to accept COVID-19 vaccines around the time that COVID-19 vaccines were first becoming available (Salmon *et al.*, 2021).

Historically, scientists have often highlighted and focused on deficits in scientific knowledge among the public and thus believed that communicating facts about scientific topics would improve the science literacy of the public (Nisbet and Scheufele, 2009). However, communicating using facts alone may not be an effective way to communicate about contentious topics because people's experiences and values can lead to different perceptions of what is factual (Kubin *et al.*, 2021). Further, communicating facts alone is a one-way approach to science communication that suggests scientists are the knowledge authority who merely transmit their knowledge to the public (Lewenstein, 2003; Ahteensuu, 2012). This one-way approach to science communication is known as a deficit approach (Wynne, 1989; Ziman, 1991; Lewenstein, 2003; Besley and Tanner, 2011) and its impacts have been studied in science communication research. For instance, popular science writer and evolutionary biologist Richard Dawkins is known for his deficit approach to science communication about evolution (Dawkins, 2006). In his infamous book, *The God Delusion*, Dawkins assumes that people who are religious are delusional and simply have not considered evidence sufficiently when deciding to believe in religion (Dawkins, 2006). His assumptions have often resulted in negative perceptions towards evolution among religious individuals; Muslims and Pentecostal Christians were more likely to experience a decrease in evolution acceptance if they knew of Dawkins' role as a scientist and his attitudes toward religion (Unsworth and Voas, 2021). Flaws in this deficit approach have led science communication experts to recommend other approaches to communicating science that build the credibility and trustworthiness of both the science content and the communicator (Wynne, 1989; Sturgis and Allum, 2004), which may be more impactful than facts alone when there is controversy surrounding the topic (Sauer *et al.*, 2021).

In contrast to a deficit approach, researchers have encouraged a dialogue approach for more effective science communication (Wynne, 1989; Miller, 2001; Burns *et al.*, 2003; Van der Sanden and Meijman, 2008; Nisbet and Scheufele, 2009). When using a dialogue approach, a scientist's communication is relational and often starts with understanding the

knowledge and opinions of their audience (Wynne, 1989; Miller, 2001; Burns *et al.*, 2003). This helps the communicator identify shared interests and values with their audience and helps them to connect their own knowledge and understanding to that of the audience's (Burns *et al.*, 2003; Nisbet and Scheufele, 2009). When scientists and the general public engage in dialogue, both can contribute to conversations in which they can inform each other about their concerns related to science and society (Borchelt and Hudson, 2008). Further, an important skill for communicating effectively is being aware that identity and culture may impact how people perceive science (Bray *et al.*, 2012), because certain scientific topics are seen as controversial in some communities. We refer to culture as shared attitudes, values, beliefs, and behaviors among a group of people within a community, but can be different for each person, communicated from one generation to the next (Matsumoto, 1996). For instance, rejection of evolution can be predicted by perceived conflict with religious identity and culture (Barnes *et al.*, 2021). So, when scientists talk about evolution to religious audiences, they could acknowledge areas of compatibility with religious identity and evolution to reduce perceived conflict rather than emphasize only areas of conflict with religious identity and evolution that maintain or increase levels of perceived conflict (Barnes and Brownell, 2017). Overall, scientists should communicate in a way that is personal, respectful, and empathetic to the audience's concerns (Bray *et al.*, 2012; Kubin *et al.*, 2021; Lewandowsky *et al.*, 2021). Doing so could establish more trust of the scientist and may help the public develop more positive attitudes towards science (Lewandowsky *et al.*, 2021). But what role do undergraduate science students play in communication efforts?

Undergraduate science communication

Undergraduate science students represent a large pool of diverse future scientists who will be communicating to others within their communities about culturally controversial science topics. The diversity of undergraduates exceeds the diversity of scientists in terms of religion (Pew, 2009, 2022), race/ethnicity (NSF, 2019), and political affiliation (Gross and Simmons, 2007; Gallup, 2022), meaning that these students are closer to communities with which scientists have historically been ineffective. Even as nascent scientists, undergraduate science students are already communicating with their communities. First-generation undergraduate biology students have described communicating about climate change and vaccines within their communities and have shown characteristics of being boundary spanners between the scientific community and their home community (Shah *et al.*, 2022). However, these students were sometimes seen as credible but also sometimes seen as not credible within their communities, indicating a need to better understand these students' experiences and how we can help them improve their communication ability.

Evidence suggests that undergraduate biology students may not be prepared to communicate about culturally controversial science topics. In a prior study, our research team found that students were serving as science communicators about COVID-19 vaccines during the pandemic but often did not use effective science communication principles (Couch *et al.*, 2022). When students described their strategies for communicating about COVID-19 vaccines they often used a deficit approach to

communication by only providing scientific facts. In addition, Biotechnology undergraduates did not value science communication to nonscientists and demonstrated a lack of understanding of science communication (Edmondston *et al.*, 2010). Therefore, undergraduate students may have the same deficit mindsets that some other scientists have when communicating science to the public and this could be a result of their undergraduate training. Undergraduate science communication education may be able to help students become effective communicators earlier, but we need to better understand their current experiences and needs.

Black undergraduate students' science communication about COVID-19 during the pandemic as a potentially important case of undergraduate science communication

Concerns about COVID-19 vaccines are prevalent across the United States. Even though scientists recommend COVID-19 vaccines to mitigate the amount of hospitalizations and deaths caused by COVID-19, only about 69.5% of the U.S. population are fully vaccinated against COVID-19 as of May 2023 (CDC, 2023). Vaccine distrust can be predicted by several factors such as political, religious, and racial/ethnic identities (Funk *et al.*, 2020; Sylvester, 2021). However, the reasons for vaccine hesitancy may be different for individuals of different groups. For instance, white evangelicals are among the most vaccine hesitant (PRRI, 2021) and most difficult groups to convince to receive the COVID-19 vaccine (Bokemper *et al.*, 2021). Based on prior literature, a common explanation for vaccine hesitancy among white evangelicals is belief in misinformation that suggests vaccines go against the morals of their religious ideologies (Lee Rogers and Powe, 2022; Nagar and Ashaye, 2022).

On the other hand, vaccine hesitancy in Black populations is largely due to historical and even more modern experiences of racism in the U.S. (Balasuriya *et al.*, 2021). These experiences have led to high concerns about the safety and effectiveness of vaccines or access barriers to getting the vaccine (Balasuriya *et al.*, 2021; Fernández-Penny *et al.*, 2021). Prior literature has documented that past unethical research that negatively impacted Black populations, such as the Tuskegee Syphilis Study, have led to a distrust in science among individuals in Black communities (Shavers *et al.*, 2000; Freimuth *et al.*, 2001; Jacobs *et al.*, 2006). However, more recent experiences of racism and discrimination also contribute to distrust in science and specifically COVID-19 vaccines in Black communities. For example, racial disparities in health outcomes and health care exist that could lead to distrust in medical fields (Bajaj and Stanford, 2021). One study found that Black and Hispanic women were less likely to be prescribed pain medications despite reporting more pain compared with non-Hispanic white women (Badrel-din *et al.*, 2019). In addition, Black mothers suffer the mortality of their infants at higher rates compared with white mothers (Heron, 2018), and Black women who experienced the loss of an infant described in interviews that they had negative experiences with their health care providers, and many described that these experiences were due to their race (Wallace *et al.*, 2017).

Because Black populations have been historically underserved in society, research has focused on empowering students in this population to address ongoing injustices (Harwood *et al.*, 2012; Karkouti, 2016; Walkington, 2017). These injustices may motivate Black students to want to make healthcare more

effective for their communities, which could include being effective communicators and increasing vaccination rates to reduce disease and death in their communities. One study found that the events of George Floyd and the COVID-19 pandemic together encouraged some Black graduate students in biology to communicate science to better their communities (Google *et al.*, 2023). However, very little is known about Black undergraduate science students' learning experiences or communication experiences about COVID-19, making it difficult for science educators and researchers to understand how we may build effective science communication education about this culturally controversial topic for these students.

Theoretical Framework: Boundary Spanners

To explore Black students' experiences communicating about COVID-19 and COVID-19 vaccines during the pandemic we use the theoretical framework of boundary spanning. Boundary spanners are individuals who belong to two different but overlapping social groups and can more effectively communicate information between these two groups than those who only occupy one group (Hawkins and Rezazade, 2012). This framework originated in industry studies (Tushman and Scanlan, 1981) but has extended to science – policy studies (Bednarek *et al.*, 2018; Goodrich *et al.*, 2020), health care studies (De Regge *et al.*, 2020), and more recently, undergraduate science communication studies in which first-generation college students were having meaningful conversations about science with their communities (Shah *et al.*, 2022). In this study we further extend the utility of the boundary spanning framework in undergraduate science communication research. We looked at a population of students who belong to both the scientific community and Black communities and can thus be potential boundary spanners when communicating about science. Boundary spanners can be effective because their association with a community affords them an assumed trust within their community that is not afforded to those seen as outsiders to the community (Hawkins and Rezazade, 2012). Boundary spanners have also been looked at in contexts such as sustainability science to help strengthen the relationship between science and policy (Goodrich *et al.*, 2020). In addition, Black scientists have been trusted messengers about COVID-19 vaccines within Black communities (Huang, 2020) and have thus already been shown to occupy boundary spanning roles when communicating science to their communities.

Positionality Statement

The authors acknowledge that our identities influence this work. For this research race/ethnicity, science identity, and beliefs about COVID-19 and COVID-19 vaccines are the most relevant aspects of this study. C.D.B and A.N.G identify as African American and A.R.S, M.G.A, and M.E.B identify as white. The research team are all currently enrolled in or are working in science degree programs, and all have attitudes that reflect the scientific consensus that COVID-19 vaccines are relatively safe and effective at preventing severe disease.

Research Questions

1. What were Black undergraduate science students' experiences when communicating about COVID-19 with others in their communities during the pandemic?

2. How did these students' science identity and their racial background influence how they communicated about COVID-19 during the pandemic?
3. What were students' perceptions of their community's attitudes, behaviors, and knowledge of COVID-19 vaccines during the pandemic?
4. What were these students' experiences learning COVID-19 communication in biology classes and how did these students think their confidence could have been improved for communicating effectively about COVID-19 to their community?

METHODS

Middle Tennessee State University's Institutional Review Board approved this study (protocol no. 0003571).

Recruitment and Participants

We recruited a national population of Black biology undergraduate students in the United States for interviews during the COVID-19 pandemic. In Fall of 2021, we recruited students from a pool of participants in an unrelated national study we were conducting among undergraduate students in biology classes. In that study we surveyed 11,995 students that were in undergraduate biology classes. Of these students, 758 identified as Black and 399 indicated they would be willing to be interviewed. We sent these students recruitment emails and asked whether they would be interested in interviewing about their experiences communicating about COVID-19 and COVID-19 mitigation. We offered a \$25 gift card as an incentive. In total, 23 Black biology undergraduate students from 13 institutions and nine states (Arizona, Tennessee, Texas, North Carolina, Florida, Michigan, New York, California, and Alabama) were interviewed. At the time of the interview, 60% of the sample identified as biology majors. 39% of the sample were nonbiology majors but were enrolled in science degree programs (including but not limited to athletic training, psychology, and public health). All students, including one nonscience major, were taking a college biology class during the COVID-19 pandemic. Most students were in their junior/senior years of college at the time of the interview.

Surveys

We gathered survey data from students before the interview to characterize and provide context for our interview sample. Because identification as a scientist might be an important driver of our participants' experiences communicating about COVID-19, we asked students to rate statements (strongly agree to strongly disagree, five-point scale) such as "I identify as a scientist." The questions were from a previously published science identity survey (Williams and George, 2014). We also asked students whether they themselves had been vaccinated for COVID-19. Almost all students (22/23) reported being vaccinated. Students' answers to these questions were used as a discussion point in each interview to probe how students' science identity was related to their science communication experiences.

We also collected students' demographic information (gender, race/ethnicity, religious affiliation, political identity, year in school, and college major) to track the diversity of students in our study. All questions used to gather these data can be

TABLE 1. Combined demographics of students interviewed in this study.

	% (n = 23)		% (n = 23)
Race/ethnicity		Career goal	
Black	82.60	prehealth	47.83
*multiracial	17.40	research scientist	26.09
Gender		other	26.09
man	8.70	Political Identity	
woman	87.0	liberal	78.26
nonbinary	4.30	moderate	17.39
Major		conservative	0
biology	60.90	decline to state	4.35
nonbiology	39.10	Religion	
Year in school		Christian	73.91
first/second	30.43	Muslim	8.70
junior/senior	69.60	nonreligious	17.39
Institution			
Doctoral	92.30		
Masters	7.70		
Baccalaureate	0		
Community College	0		

*multiracial students selected Black as one of their racial/ethnic identities

found in the Supplemental Material. The aggregated demographics of the 23 students interviewed are in Table 1.

Interviews

We developed interview scripts to explore students' experiences communicating about COVID-19 to their communities and how their biology classes may have prepared them to communicate. To thoroughly address each research question, we asked students to explain any experiences they had communicating about COVID-19 and COVID-19 vaccines outside of school, as well as, how often and with whom they discussed COVID-19 and COVID-19 vaccines. We further asked students how their identification with science or their racial/ethnic backgrounds influenced how they communicated about COVID-19 to their community. We also asked students to describe their conversations about COVID-19 and vaccines within their communities. Students were then asked to describe how their community experienced COVID-19, to what extent they feel that historical discrimination towards Black communities affected their communities' attitudes towards COVID-19 vaccines, and what they think would help their community be more comfortable adopting masks and vaccines. Finally, we asked students to describe their experiences learning about COVID-19 in their biology classes, how those experiences impacted their confidence communicating about COVID-19 to their communities, and to describe how their instructors could have helped them feel more confident communicating about COVID-19 to their communities. Because not all Black students consider themselves a part of Black communities, we asked students to describe their involvement in Black communities (see *Supplemental Material*) and confirmed that all participants considered themselves to be a part of Black communities. Students received a subset of interview questions before the interview so that they could

think about their answers before being interviewed and have time to recall any relevant information. A copy of the final interview script is provided in the Supplemental Material. The interviews were audio-recorded and were an average of 45 min long. All interviews were conducted by a single researcher (C.D.B.) to ensure consistency across interviews.

Interview analyses

While C.D.B. was interviewing, she wrote down detailed analytical notes on themes that she saw throughout the 23 interviews. M.E.B. listened to six interviews and discussed emerging themes from the interviews with C.B.D. to incorporate a second perspective. After all 23 interviews were complete, they were transcribed and each participant received a pseudonym used in the transcripts to protect their identities. C.D.B. read through the transcripts and used inductive content analyses (Cho and Lee, 2014; Krippendorff, 2018) with constant-comparison methods (Glesne, 2016; Glaser and Strauss, 2017) to determine themes that emerged in the interview data. A.R.S. used the same methods to independently identify themes after reading 12 interview transcripts because saturation of data is usually reached by 12 interviews (Guest *et al.*, 2006). The two researchers (C.D.B. and A.R.S.) then came together to discuss and combine the themes that they found. A.R.S. agreed on themes C.D.B. identified and identified new themes that C.D.B. did not initially identify. We used these themes to establish a final coding rubric. The researchers used the final coding rubric to independently code five new interviews they had not previously discussed together. When they compared codes, the Cohen's κ interrater score was 0.88 and at an acceptable level (Landis and Koch, 1977). They then both used the codebook to independently code the remaining interviews and met to resolve any discrepancies between their two codes (coded to agreement). A copy of the final coding rubric can be found in the Supplemental Material. Quotes are lightly edited for clarity.

RESULTS

In total, the researchers found 23 themes in the data that we grouped into four findings that provided insights into our research questions. We only report themes found in at least three student interviews. All reported themes, descriptions, and example quotes can be found in Tables 2–5. The frequency of a theme will not necessarily indicate its prevalence among a broader population of undergraduate biology students (Maxwell, 2010; Glesne, 2016). Our study design and data analyses were qualitative in nature and aimed at describing the landscape of experiences that exist among students rather than quantifying the prevalence of those experiences. We indicate when “most” students (two-thirds or more), “many” students (between one-third and two-thirds), or “some” students (less than one-third) reported on a theme. All themes that emerged from the data and the coding rubric used to analyze the data can be found in the Supplemental Material.

Finding 1: Students were communicating about COVID-19 to their communities but used a limited number of strategies

Even as nascent scientists, Black undergraduate students courageously took on the role of science communicators

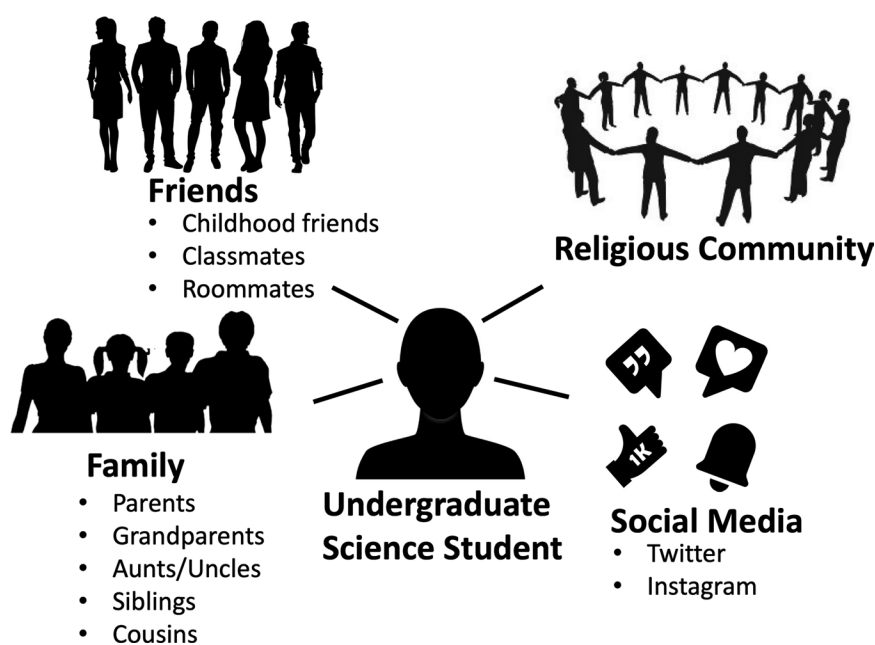


FIGURE 1. Study participants defined their communities in interviews as family, friends, and religious communities they encounter face to face as well as those they encounter online on social media.

about COVID-19 and COVID-19 vaccines within their communities. Students in this study defined their communities as their friends and family outside of academics, as well as other college peers (Figure 1) and described frequently communicating about COVID-19 and COVID-19 vaccines with individuals in their communities. These students also reported that there were times that they were able to convince others in their communities to get a COVID-19 vaccine. However, some students were not able to influence attitudes towards COVID-19 and COVID-19 vaccines among hesitant members of their community. Students avoided conversations when others had opposing views about COVID-19 to avoid conflict and because they felt that they wouldn't be

able to influence them. When asked how they communicated about COVID-19 and COVID-19 vaccines to their communities, students reported using a limited number of strategies. Participants in our study described that their methods of communicating about COVID-19 included using facts and showing care to emphasize the importance of receiving a COVID-19 vaccine. Students who communicated about COVID-19 using facts often described explaining the science of COVID-19 to inform their community or to convince their community that COVID-19 is a real issue and that COVID-19 vaccines are safe and effective. Students who showed care emphasized the importance of getting the COVID-19 vaccine by addressing the safety of the other person, which can be an effective communication strategy. See Table 2 for a summary of the themes we found and illustrative quotes from participants. Below, we expand on these findings and provide example quotes from participants.

Students used limited communication strategies

Most students said they communicated about COVID-19 with their “immediate” (Riley) or extended family because they were “most comfortable to talk to” (Gabby). In addition, Miranda explained “Most of my discussions have been with my family members to make sure that my family gets the vaccine.” Students such as Miranda described that they communicated the most with their family to ensure that they were protected against the virus.

Most students described communicating about COVID-19 by educating their community about COVID-19 facts. For instance, students discussed how COVID-19 affects the body and how vaccines work. For example, one student mentioned:

TABLE 2. Examples of themes from finalized coding rubric of interview transcripts for the research question “What were Black biology undergraduate students’ experiences communicating about COVID-19?”

Theme	Description	Quote	% (n = 23)
Friends and Family	Student mostly communicated with friends and family	“I definitely [discuss COVID-19 most with] family and roommates because I’m around them the most.”	70%
Presenting facts	Student communicated with facts	“[I told him] a lot about how the virus attacks your body, the mechanisms they use, and the vectors they transmit it through”	74%
Avoidance	Student avoided conversations	“It’s really limited who I decide to talk with about the COVID vaccine... sometimes I don’t want people to get angry with me.”	70%
Influence	Student influenced vaccine decisions	“One of my cousins got COVID. I told her that I got the vaccine and then she was really like willing to get the vaccine for herself.”	61%
Not an influence	Student did not influence vaccine decisions	“I have a little bit of insight about what actually the vaccine does so that helps me to reciprocate that information to them, but they still don’t get it.”	43%
Showing care	Students communicated by being more personal	“We’re like ‘You know you gotta stay safe. We love you. We don’t want you to catch COVID to be in a hospital and eventually die.’”	35%
Unsure what to say	Student was unsure how to communicate	“I don’t know how else to explain it other than the facts and the numbers.”	17%

"My thing is telling them the facts [...] I tried to explain to them how viruses work and how COVID-19 affects other parts of your body." – Miranda

Students such as Miranda described that their main COVID-19 communication strategy was to tell others the science behind COVID-19 and COVID-19 vaccines to remain objective. Students further described using facts to combat misinformation about COVID-19 vaccines, such as informing others how the vaccine was made. Megan explained "I reiterate how long it's been tested and build the credibility of the research behind it and the statistics." This indicates that students might have believed that communicating just facts was enough to change people's mind about culturally controversial science topics.

Many students also reported communicating about COVID-19 by showing care to encourage their community to receive a COVID-19 vaccine. Students such as Gabby described communicating about COVID-19 by making the conversations more personal.

"I say it's important to get the vaccine so that we can stay safe from other people...we've seen a lot of people who have gotten COVID and have ended up in the hospital." – Gabby

Students also showed care when discussing how the other person would feel right after getting vaccinated. Maya specifically told her roommate who was previously hesitant to receive the vaccine to "take it around a time where she's not in class, when she doesn't have anything else to worry about, and when she's able to take care of herself. [I wanted to] settle some concerns...make sure she's taking her vitamins and other medications."

The fact that we only found two themes of communication strategies may reflect that instructors rarely teach about basic science communication principles. Some students even recognized that they may not have been using effective strategies. Nia stated "Do I think I'm being persuasive when I'm (communicating about COVID-19)? Probably not. I just spit out facts at them." Nia didn't think that her communication strategy of only discussing facts was an effective way to change other's perception of COVID-19 and COVID-19 vaccines.

Although students described using limited communication strategies, many students discussed experiences in which they were able to influence their community's attitudes towards COVID-19. For instance, students such as Destiny described that they were able to influence others in their community to reduce their COVID-19 vaccine hesitancy and get a COVID-19 vaccine.

"One of my friends didn't believe in getting the vaccine. I sat down and had a talk with her and brought up all the research that I had done...and I think eventually.... after I educated her more about the topic, she was less weary and eventually decided to get a vaccine." – Destiny

Destiny was able to reduce her friend's hesitancy towards COVID-19 vaccines by discussing information about the vaccine and was even able to influence her friend's decision to receive the vaccine. This shows that with the proper rapport and credi-

bility established, information and facts were effective in this instance. Another student, Mary, described convincing others to get a COVID-19 vaccine by discussing their concerns. Mary mentioned that telling her aunts that she got a COVID-19 vaccine made them feel less worried about getting one. Mary explained, "Well I know my aunts when we told them that we got the vaccine...they can kind of trust it."

Students were not always effective in their communication

Many students described experiences when they were not able to convince others to receive a COVID-19 vaccine. For example, Haley mentioned:

"I let [my friend] know where they could find more information (about COVID-19), but some people you can't really get through to them. They weren't really interested in looking up the information. They just wanted to make their claim and stay there." – Haley

Other students described that even when explaining facts about COVID-19 with people in their community, it wasn't well-received. For example, Kristen specifically mentioned, "I tell people you just have to look at [COVID-19 vaccines] from a scientific standpoint [...] They don't really receive it". Shayla described, "I tried to explain how deadly the disease is, and I didn't convince [my family member]". In these instances, Shayla was not able to establish enough credibility or explain the information about the vaccines in a way that influenced her family to get a vaccine.

Some students further mentioned that not being able to make a convincing argument was disappointing. In fact, most students even reported that they avoided or stopped conversations about COVID-19 with others who didn't agree with their perceptions of COVID-19 and COVID-19 vaccines. For instance, students such as Jada described avoiding conversations about COVID-19 with others to avoid conflict.

"I just see it on my Twitter timeline, just some people sharing their opinions about [COVID-19]... I just see it and I just keep scrolling... I don't feel like getting into an argument" – Jada

Aside from just wanting to avoid potential conflict with others, students also avoided conversations because they believed that the other person wouldn't change their minds about COVID-19 vaccines. For example, Deja stated that she didn't discuss COVID-19 with her aunt because, "You cannot argue that woman down. She's not changing her mind." Similarly, Erica mentioned that some people in her community "have their own motive and their own philosophies... sometimes I just stay away from my friends about [COVID-19] and they just do their own thing." This indicates that students were most uncomfortable communicating with people who were hesitant to get vaccinated.

Some students discussed how in instances in which they had the opportunity to communicate about COVID-19 vaccines, that they felt unsure how to communicate effectively. For instance, Maya stated, "I don't know how to communicate this (COVID-19) to [my aunt]. How else do I approach this topic?" Further, James discussed that he was unsure how to address his community's concerns about COVID-19 vaccines. When asked how he responded to others who did not trust COVID-19

vaccines, James said, “I feel like I haven’t quite figured that out yet. It’s hard to tell them to trust it. I’m not sure what I would say.” So, although students like Maya and James wanted to be effective communicators, they were not taught effective science communication strategies that could help them improve their self-efficacy for communicating about COVID-19 to their community.

These findings suggest that Black undergraduate science students were communicating about COVID-19 and COVID-19 vaccines in their communities, but they used limited strategies for having these conversations effectively. However, they did describe using a strategy that is known to be effective, which was showing care to the other person. In addition, some students were able to influence others in their community to receive a COVID-19 vaccine, but they weren’t always able to have this impact on others. Students had negative experiences when they felt like the conversations were not productive and when they avoided conversations about COVID-19 and COVID-19 vaccines with others to avoid conflict. Students stated that they were unsure how to communicate about COVID-19 to their communities effectively. Next, we describe how students’ racial and science backgrounds affected their COVID-19 communication.

Finding 2: Students’ science and racial identities made them feel a responsibility as science communicators within Black communities

Students explained that their unique identities made them feel responsible for being effective science communicators within Black communities. All students in our study described their racial identity as Black and most students identified themselves as a science person. Almost all students reported receiving the COVID-19 vaccines. They often described how their racial and science identities influenced how they communicated about COVID-19 and COVID-19 vaccines in their communities. Students described their racial backgrounds as important in helping them communicate in a way that addresses the unique roots of vaccine hesitancy in Black communities. Students described their science backgrounds as helping them communicate about COVID-19 to those in their community who may not have sufficient evidence that the COVID-19 vaccines are safe and effective. These findings are summarized (Table 3) and reported in more detail below.

Many students in our study described that their COVID-19 communication was influenced by their racial background. Students considered the perceptions of those within their community when they communicated. They described being relatable or acknowledging medical racism and other unethical events that could have led to hesitancy among those in Black communities about the vaccines. For example, one student said:

“[My race influences my communication] because I know people [in Black communities] don’t have the best history with the medical field and the government. I try to keep that in mind when I do talk to people [...] I convince them that things are changing. There are people in the medical field who are helping us. There are more and more Black scientists who are out there creating this vaccine who can help them.” – Deja

Here, Deja recognized that because there has been institutional discrimination in medical fields and the government, people within her community may not have trusted things that come out of these institutions. When Deja communicated about COVID-19 to her community, she acknowledged that those who were hesitant toward COVID-19 in her community were hesitant for unique reasons compared with other communities and tried to encourage them to have positive perceptions of COVID-19 vaccines. Destiny explained that she felt a responsibility to communicate about COVID-19 to Black communities because “it’s important as someone in the Black community to be talking about the COVID-19 vaccine in the Black community where there’s a lot of health disparities.”

Students also described that their science identity influenced how they communicated about COVID-19 and COVID-19 vaccines. For instance, most students such as Mackenzie mentioned that they believed that being a scientist helped them to be more knowledgeable about COVID-19 and that this enabled them to be able to communicate about COVID-19 and vaccines with their community.

“I’m able to explain in layman’s terms how vaccines work and why this is important...I’m able to simplify things better for some people.” – Mackenzie

Mackenzie mentioned that having a background in science helped her acquire knowledge about COVID-19 and

TABLE 3. Examples of themes from finalized coding rubric of interview transcripts for the research question “How did students’ science identity and their racial background influence how they communicated about COVID-19 with others in their community?”

Theme	Description	Quote	% (n = 23)
Knowledge	Science background influenced communication	“I think having a little bit of background with my degree in biology has helped me understand a little bit more when reading up about certain things...so I feel like when explaining it to other people, I can break down some of the terminology that’s used.”	74%
Understanding	Racial background helped student understand their community	“I think [my race] has a major impact [on my communication] ...I try to be as vigilant as I can to encourage people because I do know that a lot of Black people are kind of on the fence about it (COVID-19 vaccine).”	39%
Responsibility	Student felt responsibility to communicate about COVID-19	“It made me feel better that I could at least rightfully inform someone that wasn’t completely educated on the vaccine. I felt like I was doing my part [as a scientist].”	26%

COVID-19 vaccines that made her more confident to educate others about COVID-19 in a way that is easier to understand for nonscientists.

Some students mentioned that as a scientist, they felt a responsibility to communicate science and specifically COVID-19 information to their communities. Students such as Miranda believed that discussing COVID-19 with their communities was important because they were fulfilling their role as science communicators.

"I felt like I was doing the role of what is expected of someone that does want to go into medicine of trying to convince people that they have an obligation to take care of themselves first and then take care of people around them." – Miranda

Similarly, Maya shared, "I have this information (about COVID-19), I feel like I shouldn't just keep it. All of my friends are not biology majors so there's not much opportunity for them to be hearing about these things as much as I do." For Maya, being one of the only science people in her friend group encouraged her to be a source of information about COVID-19 for them.

These results indicate that students' racial/ethnic backgrounds and science identities did influence how they communicated about COVID-19 and COVID-19 vaccines with their community. Students reported that their racial backgrounds informed how they communicated about COVID-19 because they understood their community's concerns about COVID-19 and COVID-19 vaccines and thus were uniquely positioned to communicate in a way that addressed their hesitancy and established trust. Students also mentioned that their science background allowed them to understand the science of COVID-19 and COVID-19 vaccines and this knowledge helped them communicate information more effectively to nonscientists in their communities. Students stated that they felt a responsibility as a science person to have these conversations about COVID-19 with others in their community. These findings align with the boundary spanners framework in that these students

can be conduits of information between both the scientific community and Black communities because they are a part of both groups (Hawkins and Rezazade, 2012). Next, we discuss how our participants perceived their communities' attitudes about COVID-19 and COVID-19 vaccines.

Finding 3: Students were aware of their communities' attitudes toward COVID-19 topics, but many students were understanding of these attitudes and believed they could be improved

Participants in our study discussed how they perceived their communities' attitudes towards COVID-19 and COVID-19 vaccines. Students described feeling frustrated that their community was misinformed when they encountered individuals who were hesitant about COVID-19 vaccines or COVID-19 mitigation. They often mentioned that those within their community were hesitant because they didn't trust the government and/or science. Other students were understanding of this distrust because they believed that historical discrimination towards Black communities influenced their attitudes. Students also mentioned that their community would be more accepting whether information about COVID-19 vaccines came from trusted messengers such as others in Black communities. Below we summarize (Table 4) and describe these results in more detail.

Students' perceptions of their communities' COVID-19 attitudes

Many students described feeling frustrated with their communities' attitudes toward COVID-19 and COVID-19 vaccines. For example, Alexandria described being disappointed when others were hesitant to receive a COVID-19 vaccine:

"It makes me feel a little disappointed because I feel like people have been getting vaccines for different things for a while. It's kind of wild that people have felt so defensive about this one. It just makes me feel a little bit disappointed because I want everyone to do the best for their health, and I think that the best for your health is definitely to be vaccinated." – Alexandria

TABLE 4. Example of themes from finalized coding rubric of interview transcript for the research question "What were students' perceptions of their community's attitudes, behaviors, and knowledge of COVID-19 vaccines and masks?"

Theme	Description	Quote	% (n = 23)
Distrust	Community did not trust science or government	"They just don't believe in Western medicine. They don't think that it'll be good for their bodies."	96%
Understands the hesitancy	Student understood why community is vaccine hesitant	"I completely understand why they would be untrusting...because they still teach medical racism in medical school."	87%
More informed	Student believed that educating community would improve COVID attitudes	"Being as transparently informed as possible [would make Black communities more comfortable]. Being presented all the benefits of it, but as well having access to the knowledge of the side effects."	70%
Frustrating	Student frustrated with community's perception of COVID-19	"I feel frustrated because I don't see why you wouldn't get [the vaccine]."	57%
Perceived lack of data	Student stated that community believes there isn't enough data on COVID vaccines	"The big thing was that [my friends] were unsure. They felt like the vaccine came out quickly. They didn't know if they could trust that it would be safe."	48%
Misinformed	Student believed community is misinformed	"A lot of misinformation is out there that had my parents scared"	43%
Role model	Student believed that trusted messengers would improve COVID attitudes	"If we had people go into Black communities, probably even Black people, I feel like that'd be more trustworthy."	39%

Another student Miranda explained, “I’m getting a bit angry with them. Do what you’re supposed to do to not be selfish... it gets me very angry.” Here, Miranda specifically described having negative feelings when encountering people in her communities who decided to not get a COVID-19 vaccine. This may have negatively impacted Miranda’s ability to be an effective communicator. As we found in Finding 1 when students are frustrated, it hindered their communication efforts because they would then avoid or disengage with those who had beliefs different from their own.

Most students stated that their community had negative attitudes toward COVID-19 and COVID-19 vaccines due to a distrust in the science and/or the government’s involvement with the vaccines. They often mentioned that members of their community believed that scientists or government officials have negative intentions regarding their decisions about COVID-19 and COVID-19 mitigation. For instance, Abby mentioned:

“Just how the health field deals with Black women or Black people in general...they don’t want to treat Black people as best as they treat white people. And that experience with the health field definitely has a directly proportional effect with COVID-19 because you can’t even barely trust your doctors with something simple like a routine exam. How are you going to trust them to give you something in your body?” – Abby

Likewise, many students mentioned that their community was hesitant about COVID-19 vaccines because they didn’t believe that there was enough data about COVID-19 vaccines. For instance, Destiny explained, “[My friend] didn’t think that there was enough research backed behind it and didn’t think that she would know what the effects would be on her body, so she didn’t really trust it.” Further, Alicia described that the timing of the release of the COVID-19 vaccines made her friend question the safety of the vaccines:

“I think the big thing was that [my friend] was unsure. They felt like the vaccine came out quickly. They didn’t know if they could trust that it would be safe.” – Alicia

Students were understanding of their community’s COVID-19 attitudes

Although some participants expressed frustration while communicating to those with different beliefs from them, most participants also expressed that they were understanding of their communities’ perceptions of COVID-19 and COVID-19 vaccines. These students understood why those within their communities were hesitant toward COVID-19 vaccines. Students said they had a unique understanding of how historical and modern discrimination towards Black communities has influenced vaccine hesitancy. For instance, Rose mentioned:

“I know that concern (about COVID19 vaccines) would just be like not trusting medical professionals and the medical field as much just because of like certain malpractice and you know history, with all that syphilis research and stuff like that. I know there have been concerns like that brought up...” – Rose

Another student, Jada, shared a similar feeling:

“I feel that a lot of people in the Black community are very hesitant about receiving the COVID vaccine. They always bring up the Tuskegee experiment as examples to not trust people in the government or people in the health field. So that’s a reason why a lot of Black people are not getting the vaccine because they’re not sure...So, I do understand the hesitance in which people are not getting the vaccine, especially in the Black community.” – Jada

Rose and Jada understood why knowledge of unethical research that negatively impacted Black populations led to high-vaccine hesitancy in Black communities.

Many students described that some people in their communities were misinformed and lacked understanding about COVID-19 and COVID-19 vaccines. The perception was based on conversations about COVID-19 they had with others who had misconceptions based on conspiracy theories, and they described these people as being misinformed. For example, Aaron stated, “There are others that are iffy about it (COVID-19 vaccines) because you know, the misinformation that they get from social media.” Aaron described that the reason why some people in his community were hesitant to receive a COVID-19 vaccine was because they were not getting COVID-19 information from reliable sources.

Many students mentioned that if people within their communities were more informed, they would be more willing to receive the COVID-19 vaccine. These students suggested that people within their communities were not knowledgeable and therefore didn’t believe that COVID-19 is real or that the vaccine isn’t to be trusted. For example, Haley stated:

“More education [would make Black communities more comfortable]...Just going into communities and helping them understand what the coronavirus is and how it impacts your body and help them understand how a vaccine will help that process.” – Haley

Haley believed that helping communities establish a better understanding about COVID-19 and COVID-19 vaccines would have helped reduce their hesitancy towards COVID-19 vaccines. Similarly, Alliyah explained, “Having people knowledgeable about vaccines and COVID just sitting down with people and discussing it [would make Black communities more comfortable].”

Many students recognized that not just education or understanding was needed within their community, but also building trust would be necessary. Students explained that Black communities would be more trusting of COVID-19 vaccines if they received information from other people that they can trust – including other Black people in their communities. For example, Gabby explained:

“Hearing experiences from other members of the Black community and why they’ve chosen to get the vaccine would probably help influence their idea of getting the vaccine.” – Gabby

Students such as Gabby believed that if members of Black communities discussed how they decided to get the COVID-19 vaccine themselves, it could have helped establish more positive attitudes towards the vaccines in those communities.

Megan further shared that her grandmother was more receptive of what her doctor said because they share similar backgrounds:

"I think if they heard more information from people similar to them or people they trusted within their communities, they would be more trustworthy to take in the information. I know my grandmother has a doctor who she loves because she's also Haitian and she speaks Creole sometimes. I think there's more of a connection so she's willing to trust her more and take her advice and go to her with problems." – Megan

These findings suggest that students were both critical and understanding of their communities' attitudes towards COVID-19, often describing frustration with their communities' attitudes and an understanding of why those in their communities were hesitant towards COVID-19 vaccines. Many students believed that simply educating people within their communities would establish positive-vaccine attitudes which may have indicated a misconception about effective communication. But students also said negative attitudes toward COVID-19 vaccines within their communities were due to distrust in science and the government, indicating an understanding of unique experiences of those within Black communities. Students believed that their communities' hesitancy toward COVID-19 vaccines would be reduced if they were educated by people who are like them, such as others in Black communities. Next, we discuss how students said their confidence communicating about COVID-19 vaccines could be improved.

Finding 4: Students recommended that biology instructors teach about the safety and effectiveness of COVID-19 vaccines in addition to core science communication principles to improve their confidence communicating

We asked students how biology instructors could have improved their confidence communicating about COVID-19 and COVID-19 vaccines to their communities. We found that

many students did not learn about COVID-19 or COVID-19 vaccines in their biology classes and students suggested that if biology instructors taught about COVID-19 and COVID-19 vaccines, it would have helped improve their confidence communicating. Some students did learn about COVID-19 and/or COVID-19 vaccines in their classes. Of these students, many said that it improved their confidence communicating, but some students said the instruction did not improve their confidence communicating. Students who said instruction on COVID-19 and/or COVID-19 vaccines improved their confidence said it helped them change their own misconceptions and made them feel more knowledgeable. Students who said instruction on COVID-19 and/or COVID-19 vaccines did not improve their confidence communicating said that knowing more about the science did not help them learn how to navigate discussing a controversial topic with others who may not believe the science. We expand on these findings below. Themes are summarized in Table 5.

Teaching about COVID-19 vaccines may improve students' confidence communicating

Most students described that biology instructors could teach about COVID-19 and COVID-19 vaccines in their classes to help improve their confidence communicating about COVID-19. Students often felt that if they knew more about COVID-19, they would feel like they would be more prepared to answer any questions or address any misconceptions people might have about COVID-19. For example, Riley suggested that instructors should teach more about the science behind COVID-19 to improve her ability to communicate:

"[Instructors] could provide the breakdown and all the processes that are involved in the virus. Then I could actually explain more about how it works and how a virus spreads." – Riley

Many students who did learn about COVID-19 and COVID-19 vaccines in their biology classes described that their learning

TABLE 5. Example of themes from finalized coding rubric of interview transcript for the research question "What were these students' experiences learning COVID-19 communication in biology classes and how did these students think their confidence could be improved for communicating about COVID-19 to their community?"

Theme	Description	Quote	% (n = 23)
Include COVID-19 in curriculum	Instructors should teach about COVID-19 to increase confidence communicating	"[Instructors] could relate [COVID-19] more to the concepts that are being learned in class and allow for questions to be asked about it."	83%
Learned about COVID-19	Student learned about COVID-19 in class.	"We would have these things called deep dives where we would go into the concerns of vaccinations and the history of vaccinations."	52%
Did not learn about COVID-19	Student did not learn about COVID-19 in class	"My teachers haven't really brought up COVID-19."	48%
Learning facts improved communication	Learning about COVID-19 helped improve communication	"[Learning about COVID-19] helped. It gave me more vocabulary to use when talking about it."	30%
Learning facts did not influence communication	Learning about COVID-19 did not improve communication because they did not learn communication principles	"[Learning about COVID-19 did not really help] because...I feel like at that time everyone was living regular college campus life, so everyone got to pretend that COVID wasn't a thing...I didn't really have anyone to talk about it."	26%
Changed perceptions	Learning about COVID-19 changed student's perceptions	"I decided to get the vaccine because my biology teacher was an influence."	17%

experience helped improve their confidence-communicating about COVID-19. For instance, one student stated:

"We definitely touched on it (COVID19) in my biology class last year...about how it functions [...] It definitely made me confident communicating it because I felt like I understood more about it than people normally do, and I feel like I can apply that information." – James

Students such as James mentioned that learning facts about COVID-19 in their biology classes helped them feel more confident communicating because it helped them feel more knowledgeable and they were able to apply that knowledge to their discussions. Some students also said that learning about COVID-19 in their biology classes was beneficial because it caused them to change their own perceptions about COVID-19 and COVID-19 vaccines. These students said that they were previously hesitant about COVID-19 vaccines but learning about it in their classes made them change their minds. For instance, Maya mentioned.

"I work very closely with certain professors in my school. We talk about COVID-19 in terms of the development, how the new variants will react to the drugs that come out. So, all of that has really influenced how I have looked at this...because I myself was skeptical about taking a booster dose of the vaccine." – Maya

Maya described that although she was previously hesitant about receiving a COVID-19 vaccine, it was learning about COVID-19 vaccines in her class that made her more comfortable to get vaccinated. Another student shared how learning about COVID-19 changed their perceptions of science and enhanced their interest in learning about COVID-19:

"[Learning about COVID-19] made me more interested in science in general. There was a time where I couldn't really apply science to the real world, and then when [my professor] was bringing up that COVID or PCR is related, it got me more interested in researching COVID and the vaccine." – Mary

These experiences suggest that teaching about COVID-19 and vaccines may help these students become better communicators by transforming their own misconceptions about the COVID-19 vaccines. Further, COVID-19 and COVID-19 vaccines are a personally relevant topic that could help students become more engaged in their learning of science. However, there were many students who did not learn about COVID-19 in their classes and felt like they would be more prepared to communicate if they did.

Learning facts about COVID-19 did not improve some students' confidence communicating

Among students who did learn about COVID-19, some of them did not think this helped their confidence communicating. These students said to feel more confident, they needed to learn how to communicate with others about controversial topics in productive ways. Students such as Megan mentioned that learning about science communication principles would help them feel like more effective communicators.

"I think including strategies for how to connect to a broader audience or possibly people who wouldn't be as open to learning about COVID [...] I think it would be a better way to contextualize information that's given to us." – Megan

Megan explained that if her instructors taught about how to communicate about COVID-19 to nonscientists and address hesitancy, she would have felt more confident communicating about COVID-19 within her community.

Even though these students wanted to learn about science communication principles, almost no students reported learning about COVID-19 communication strategies in their classes. Some students recognized that learning facts was not enough to increase their ability to communicate effectively and mentioned that although they learned about COVID-19 in their biology classes, it didn't improve their confidence communicating about COVID-19 to their community. For instance, Miranda stated, "It (learning about COVID-19) didn't impact my confidence in discussing it with people because...it doesn't really hit the main issue of people getting the vaccine." When Miranda learned about COVID-19 in class, she didn't feel that the discussion helped improve how she communicated about COVID-19 because the instructor didn't discuss effective ways to encourage others to get vaccinated.

These findings suggest that there might be ways that biology instructors could have helped improve students' confidence communicating about COVID-19 and COVID-19 vaccines to their community during the pandemic. Most students who learned about COVID-19 in their classes reported that their learning experience helped improve their confidence communicating to others about COVID-19 and even changed their own perceptions about COVID-19 and COVID-19 vaccines. Students who did not learn about COVID-19 mentioned that they would have been more confident communicating about COVID-19 if they had learned about it in their biology classes. Students recommended that biology instructors implement COVID-19 topics in their curriculum to help improve their confidence communicating about COVID-19 in the future. Further, they specifically mentioned that just teaching about COVID-19 and vaccines may not be enough to increase their confidence. They also recommended that instructors teach effective communication strategies.

DISCUSSION

We found that Black undergraduate science students we interviewed: 1) served as science communicators about COVID-19 within their communities during the pandemic, 2) recognized and felt a responsibility to adopt this role effectively within their community, and 3) received very little guidance for how to be effective communicators about COVID-19. We found that as Black science students, participants possessed insights and motivations for mitigating vaccine hesitancy within their communities. However, we also found that students' primary communication strategy was to communicate facts about COVID-19. These results are in line with prior research showing that undergraduates are significant science communicators (Couch et al., 2022; Shah et al., 2022) and that they may be learning to take a deficit approach to communicate about controversial science topics from the science community (Couch et al., 2022). However, the students showed nascent strategies

TABLE 6. Summary of recommendations for improving undergraduate students' science communication about culturally controversial topics.

Recommendation	Citation	Justification
Engage with audiences	Mercer-Mapstone and Kuchel, 2017	Engagement with the community is necessary to influence their perceptions of science.
Be respectful	Bray <i>et al.</i> , 2012	Experts agree that being respectful to audiences is important for building trust.
Listen to understand	Goodwin and Dahlstrom, 2014	Listening to the audience is important for understanding and addressing their concerns.
Consider the audience	Mercer-Mapstone and Kuchel, 2017	Experts agree that considering the social, cultural, and political context surrounding scientific topics is essential for effective science communication.

that could be strengthened further by science communication education that they themselves recognized would be empowering.

Collectively, this study and other recent studies are illustrating the potential importance of incorporating science communication instruction in undergraduate science classes (Mercer-Mapstone and Kuchel, 2017; Wack *et al.*, 2021; Couch *et al.*, 2022; Shah *et al.*, 2022). While instructors often recognize the importance of teaching about culturally controversial science topics in their classes (Pedersen and Totten, 2001; Saunders, 2010), we also need to start thinking about how to equip our students with the means to communicate effectively about them. This study adds to the growing body of literature showing how equipping students with communication tools can empower them as boundary spanners. This study and past research supports that Black scientists can be important communicators in their community because they are seen as trusted sources of information about medical decisions in Black populations (Alsan *et al.*, 2021; Pietri *et al.*, 2018); when Black and Latinx participants received messages about COVID-19 from various physicians, both groups experienced gains in their knowledge of COVID-19; however, when the physician shared the same race/ethnic identity as the participants, Black participants were more likely to seek out more information about COVID-19 compared with when the physician was not Black (Alsan *et al.*, 2021). In addition, one Black physician stated that Black women are willing to wait several months for an appointment with her in hopes that she will provide more care because they come from similar backgrounds (Bajaj and Stanford, 2021). These patients' claims are further validated by a study showing that infant mortality is halved when Black mothers are cared for by Black doctors (Greenwood *et al.*, 2020). Further, Black women, who are underrepresented in science, anticipated more feelings of trust and belonging at a science, Technology, Engineering, and Mathematics (STEM) company after viewing Black scientists' profiles compared with viewing white scientists' profiles at the company (Pietri *et al.*, 2018). So, Black scientists have often taken on the role of trusted messengers about science within Black communities and now we have documented that Black undergraduate science students are doing the same.

Students in this study recognized that to be effective communicators about COVID-19, they had to feel confident in their knowledge about the science and they needed to know about strategies for communication. Although they were often taught about the science of COVID-19 in their classes, they were rarely

taught how to communicate about COVID-19 effectively to nonscientists. But how can instructors incorporate science communication principles into their teaching about COVID-19? Recently, a set of science communication skills (Bray *et al.*, 2012) and principles for undergraduates (Mercer-Mapstone and Kuchel, 2017; Wack *et al.*, 2021) have been published. Below we describe these principles and their relation to our findings on undergraduate science communication and other current literature as a starting point for instructors. Table 6 summarizes these recommendations.

Science Communication Principles for Undergraduate Science Communication Training

Engagement is necessary for effective science communication. In this study and our prior survey study regarding undergraduates' COVID-19 communication (Couch *et al.*, 2022), we found that students weren't always effective communicators. They often avoided talking about COVID-19 vaccines with others to avoid potential conflict or because they felt like the other person would not change their minds about COVID-19 vaccines. According to prior literature from science communication, engagement with the community is necessary to have an influence (Mercer-Mapstone and Kuchel, 2017; Wack *et al.*, 2021). Therefore, when students do not feel confident in their communication and decide to avoid discussing COVID-19 with their community, they could be missing an opportunity to help lessen their communities' concerns about COVID-19 vaccines. However, it is important that students are engaging with their communities effectively. Students in our study discussed times when they did engage with their communities about COVID-19 but they did not feel effective, while many other students described times when they were able to help others feel more comfortable about COVID-19 vaccines. So perhaps we can encourage students to communicate once they feel prepared and have the necessary tools to do so effectively.

Effective science communication is respectful. Being respectful to others when communicating science is an important science communication practice (Bray *et al.*, 2012). In our prior survey study, we found that students were often overtly negative when communicating about COVID-19 to others who were concerned about COVID-19 vaccines during the pandemic (Couch *et al.*, 2022). Prior literature suggests that hostility during a conversation can cause the message to be miscommunicated and cause the recipient to experience negative emotions, influencing how the message is received (Pfeiffer, 1998;

Buarqoub, 2019). Since scientists may be communicating science with people who are more hesitant to accept scientific topics, being mindful of maintaining respect for the other person, their experiences, and their unique concerns could be a good way to build trust when communicating. Experts note that being respectful to others when discussing science is one of the most important skills to teach in science communication courses (Bray *et al.*, 2012). Students in this study did not explicitly mention being respectful or disrespectful in their conversations, so this population may be more advanced in their understanding of this principle as so far as they are not being overtly negative during their communication as seen in other populations of undergraduates (Couch *et al.*, 2022) but all students may benefit from instruction that emphasizes actively practicing respectful communication even when there is a disagreement on the ideas being discussed.

Effective science communication includes listening to understand. When communicating about culturally controversial science topics, science communicators should actively listen to the audiences and their concerns to understand their perspectives (Goodwin and Dahlstrom, 2014; Gagneur, 2020; Lewandowsky *et al.*, 2021). Although our participants did not explicitly mention listening in their communication, most students mentioned that they understood that people in their communities may be hesitant to receive a COVID-19 vaccine due to both misinformation and experiences of racism in science. Prior literature suggests that showing the audience that you are listening and understand their concerns could help build trust and may allow the audience to be more open to opposing perspectives (Goodwin and Dahlstrom, 2014; Lewandowsky *et al.*, 2021). Instructors can teach students to listen to the audience when communicating science to understand their concerns. Then, students may feel more confident that they are applying recommended practices.

Effective science communication considers the audience and cultural context. When communicating about culturally controversial science topics, it's also important to be aware of the audience and the social, political, and cultural context about controversial issues (Mercer-Mapstone and Kuchel, 2017; Wack *et al.*, 2021). For instance, the audience may not find the topic interesting or relevant. They may also have differing levels of knowledge or understanding of the topic. Further, their cultural backgrounds may influence how they perceive different scientific topics. One of the goals of this study was to explore whether and how Black undergraduate science students were taking on the role of being boundary spanners when communicating to their communities about COVID-19 vaccines. We found that both their racial/ethnic and science identities made them feel a responsibility as boundary spanners to discuss COVID-19 with their communities who may not be involved in science practices. Students in this study recognized that historical and modern racism in medical fields and the government that have significantly impacted Black populations was a major factor in the vaccine distrust that some of those within their communities experienced. In addition, students pointed out that the abundance of COVID-19 misinformation led some people within their communities to become more hesitant towards COVID-19 vaccines and that trusted messengers

could help their communities feel more comfortable about COVID-19 vaccines.

Potential applications of science communication education

Given the recent results of several studies, including this current study, it is becoming increasingly important for instructors to teach students which strategies are more appropriate for communicating with different audiences (Mercer-Mapstone and Kuchel, 2017; Wack *et al.*, 2021; Shah *et al.*, 2022; Couch *et al.*, 2022). Instructors could teach about science communication principles to build on the skills that students already displayed in this study and help them feel more prepared to have these conversations with their communities as trusted messengers. It is important to note that an increase in faculty of color who may have more experiences and awareness of these cultural contexts may help improve students' communication outcomes (Cherng and Halpin, 2016; Bristol and Martin-Fernandez, 2019; Cherng and Davis, 2019).

Students in our study mentioned that learning more about COVID-19 vaccines could help them be more confident communicating to their communities, but also recognized the need to learn effective communication strategies. These recommendations could be incorporated in biology instructor's courses in addition to teaching about vaccines to help better prepare their students to be more effective science communicators. For instance, introductory biology courses often cover immunology, and teaching about COVID-19 vaccines could be a way to incorporate discussion about COVID-19 with the immune system. Further, with the rise of mRNA vaccines, COVID-19 could also be discussed with common topics such as transcription and translation. When discussing these topics, instructors could also teach about these basic science communication principles to help students feel more prepared to discuss COVID-19 vaccines and other culturally controversial science topics including evolution and climate change. For instance, teaching students how religious and political ideologies may influence perceptions of evolution and climate change could help prepare students to discuss these topics with others more effectively.

Recommendations for instructors who want to implement science communication training

The research on undergraduate science communication education is still in its nascent state and there is much work to be done before we can make reliable recommendations for instruction. However, there are a few preliminary findings and resources that can guide instructors. First, instructors and students may struggle with adding science communication content to their classes due to perceived time constraints and a lack of value for science communication training (Edmondston and Dawson, 2014; Edmondston *et al.*, 2010; Gardner *et al.*, 2017). So, instructors will likely have more success if they incorporate science communication lessons that seamlessly integrate with the content as well as emphasize the value of science communication to nonexperts (Edmondston *et al.*, 2010). Further, there are published resources that may be able to guide instructors in identifying strategies that they can teach to their students, such as a COVID-19 communication handbook that outlines how to address misinformation (Lewandowsky *et al.*, 2021). Another important resource to consider includes studies

conducted by Mercer-Mapstone and Kuchel (2017) in which they publish 12 core concepts for effective undergraduate science communication education, including considering the social context of the science topic, promoting engagement, and understanding the target audience (Mercer-Mapstone and Kuchel, 2017). Importantly, Mercer-Mapstone and Kuchel (2016) also published an activity using some of these concepts to try to improve students' communication effectiveness; they show that after this activity, students perceived greater communication effectiveness and confidence (Mercer-Mapstone and Kuchel, 2016). However, more research is needed to understand whether this leads to more effective communication beyond just the students' perceptions. Another potential resource is a study published by Wack *et al.* (2021) in which students were assigned to plan, produce, and describe a science communication product based on the important concepts published in prior literature (Besley *et al.*, 2018; Mercer-Mapstone and Kuchel, 2017); the students had positive perceptions of the assignment and most students correctly identified some important aspects of communicating science to nonexperts such as increasing awareness and interests (Wack *et al.*, 2021). However, fewer students identified other goals such as conveying respect and openness (Wack *et al.*, 2021), which is especially important when communicating about controversial science topics such as vaccines (Lewandowsky *et al.*, 2021). Although this study did use a measure for gauging students' actual knowledge, the authors note that there is not sufficient validity evidence for the measure to be applied broadly (Wack *et al.*, 2021). So, there is still a need for a more robust and validated measurement to understand whether these lessons are effective in increasing knowledge of science communication and this should be a fruitful area of future research.

LIMITATIONS AND FUTURE RESEARCH

This study was conducted when the COVID-19 vaccines were first becoming available, which allowed us to explore how these students communicated about COVID-19 vaccines with others at a crucial time for pandemic mitigation. However, we may see different outcomes during other times in the COVID-19 pandemic or when discussing other controversial science topics. This study was an exploratory study meant to illuminate Black students' experiences communicating about culturally controversial science topics within their communities. However, this study only explored students' communication about COVID-19, and this could be a unique context that differs from communication about other culturally controversial science topics like climate change and evolution. For instance, research shows that Black biology students tend to be more religious than students from other race/ethnicities (Barnes *et al.*, 2020) and may be communicating about evolution to their communities (Google *et al.*, 2023) but we know very little about these communication experiences. More research needs to be done on Black student attitudes and communication about evolution and how their racial background may influence those attitudes and communication. Black students may also have experiences communicating about climate change that are different from communicating about COVID-19. Some polls indicate that Black youth may be more likely to be activists for climate change within their communities (Ballew *et al.*, 2020; Hatzipanagos, 2019), but little research has looked at

details of these students' communication about climate change. Future research can explore students' experiences communicating about other culturally controversial science topics and identify strategies to help them become empowered as effective communicators.

CONCLUSION

In this study, we documented that during the COVID-19 pandemic Black undergraduate science students were serving as science communicators within their communities about COVID-19 and COVID-19 vaccines. They felt a responsibility as scientists within Black communities to communicate effectively and described being both frustrated with and understanding of hesitancy towards COVID-19 vaccines within their community. Despite communicating often, wanting to communicate effectively, and displaying unique knowledge of the cultural context surrounding vaccine hesitancy in their communities, many students described feeling ineffective in their communication and mainly provided facts as their main communication strategy. Students indicated that their biology instruction could impact their confidence and effectiveness when communicating. Specifically, they recommended that biology instructors continue to teach about COVID-19 facts and concepts to bolster their expertise but also to teach them about basic science communication principles for discussing culturally controversial science topics so that they know how to leverage their expertise effectively in these conversations. This study, in conjunction with a series of recent studies (Mercer-Mapstone and Kuchel, 2017; Wack *et al.*, 2021; Couch *et al.*, 2022; Shah *et al.*, 2022), is highlighting the importance of developing undergraduate student science communication skills about culturally controversial science topics.

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