Talking Science: Undergraduates' Everyday Conversations as Acts of Boundary Spanning That Connect Science to Local Communities

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ABSTRACT
Biologists produce knowledge that can be applied to both global and personal challenges. Thus, communicating this knowledge to the general public is becoming increasingly important. One way information can move between different communities is through boundary spanners. Boundary spanners are individuals embedded in both communities who can communicate information known by one community to the other. We explore whether undergraduate biology majors can act as boundary spanners connecting their biology departments to laypeople in their personal networks. We conducted 20 interviews with upper-division first-generation college students at a large Hispanic-serving institution. These students were engaging in everyday conversations about science with people in their personal networks. They engaged in behaviors that characterize boundary spanners: translating scientific language into more common language and knowledge building, that is, providing background concepts that community members need to understand a topic. Finally, students were sometimes perceived as credible resources and sometimes were not. We explore some of the causes of this variation. The boundary spanning of undergraduates could help address one of the major challenges facing the scientific community: spreading the use of scientific knowledge in personal and policy decision making.

INTRODUCTION
Biology produces knowledge that can be applied to many global and personal challenges. For example, accepting the scientific research on the connection between climate change and human behaviors could influence both how people vote or lobby for policies and the choices they make in their daily lives. Similarly, rejecting the scientific evidence of vaccines may influence people to decline them or to not vaccinate their children. This puts their health at risk as well as the health of people around them, as illustrated by the re-emergence of measles in the United States (Phadke *et al.*, 2016). Thus, communicating science to the general public is increasingly important, and this importance is reflected in the prioritization of science communication by scientific societies and funding agencies (European Commission, 2002; Holt, 2015).

In general, public trust in science is high compared with other sources of knowledge (Eurobarometer, 2014; Besley, 2014; Castell *et al.*, 2014). However, this trust decreases when a person anticipates being personally impacted by the issue (Barnett *et al.*, 2007; Hendriks *et al.*, 2016). Thus, with respect to the most crucial, personally impactful issues, the public's trust in science is the lowest. Many factors might explain this distrust in matters of personal relevance. As laypeople, members of the public, by definition, have a limited understanding of science and rely on experts to communicate science. This trust in expert knowledge is challenged when laypeople see experts with conflicting opinions, illustrating a perceived lack of consensus in the scientific

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community (Britt *et al.*, 2014). Also, trust is influenced by people's perception of others' benevolence (e.g., others are doing their best by them; Mayer *et al.*, 1995). Communities who have been harmed by scientists in the past may find it harder to believe in the benevolence of today's scientists (Quinn and Andrasik, 2021). This lack of trust also can occur when individuals perceive that the ideologies of scientists do not line up with their own (Bromme and Beelmann, 2018).

Many biologists recognize the importance of science communication and are engaging in it (Liang *et al.*, 2014), but their expertise may be an additional barrier to effective communication with laypeople. Expertise in a discipline changes how experts understand and organize knowledge in their field (Rikers *et al.*, 2005). On the other hand, laypeople have knowledge and beliefs about topics (Becker *et al.*, 2008), but lack this expert framework. This difference can make it hard for experts to determine what laypeople need to understand a concept and can lead to misunderstanding of concepts in conversations. In addition, scientists know a lot about their fields, but often do not know much about their audiences (Carr *et al.*, 2017). Familiarity with their audiences is crucial for understanding what additional background information or examples would best build their audiences' understanding or persuade them to change a behavior (Bromme and Beelmann, 2018). A related challenge is that many scientists believe that they can fix a layperson's beliefs and behaviors simply by supplying more accurate information (Davies, 2008; Besley and Nisbet, 2013). However, providing better data has not been shown to change the beliefs of laypeople (Miller, 2001).

We propose that biologists have allies that span the expert–layperson divide: undergraduate biology majors who engage in everyday conversations about science. Undergraduates lie on the spectrum between laypeople and experts, so they may be in a good position to evaluate what laypeople need to hear to understand scientific concepts. When students engage in everyday conversations, they are often speaking with people whose backgrounds and beliefs they know. In some cases, these relationships have established trust between the biology major and the layperson. Thus, undergraduates have the potential to communicate in ways that support both trust and mutual understanding with laypeople. In this study, we explore the current role of biology majors as boundary spanners—connecting biology communities to laypeople in their personal networks.

Theoretical Framework: Boundary Spanners

Informational boundary spanners are individuals who enable the exchange of information between two communities (Hawkins and Rezazade, 2012). Boundary spanners are members of both communities, which provides them with access to information in one community that they can communicate to the other and vice versa (Van Meerkerk and Edelenbos, 2014). The concept of boundary spanners was first developed in industry to describe how information is taken up in novel contexts, such as how information developed in one discipline (or department in industry) is learned and used in another (Tushman and Scanlan, 1981). Researchers found that certain individuals, those connected to both departments, facilitated this exchange of information between different departments, especially when the two departments were working on a shared project (Tushman and Scanlan, 1981). The idea of boundary spanners has now spread to describe individuals at the university–community (Adams, 2014), science–policy (Bednarek *et al.*, 2018), and science–implementation interfaces (such as extension agents connecting agricultural research and farmers; Safford *et al.*, 2017). Boundary spanning has also entered the study of healthcare, as doctors and nurses spread information between the medical research community and the general public (De Regge *et al.*, 2020). Although many of the these boundary spanners are in formal positions requiring communication across communities, a formal position is not required (Tushman and Scanlan, 1981). Examples of informal boundary spanners include community members who refer others in "hardly reached" communities to health services (Wallace *et al.*, 2019) and bench scientists who are personally connected to other units in their companies (Tushman and Scanlan, 1981).

Research on boundary spanners has found several characteristics predict their effectiveness. First, because they are members of the communities where they are spreading information, they are perceived by community members as more honest and legitimate than those outside a community (Hawkins and Rezazade, 2012). They can, thus, serve as "trust ambassadors," building trust between the two communities they are spanning (Coleman and Stern, 2018). Trust is known to be critical for the uptake of new scientific information (Lacey *et al.*, 2018), and the politicization of science means that trust cannot be assumed (Barnett *et al.*, 2007; Hendriks *et al.*, 2016). Boundary spanners can decrease the chance that science is seen as pushing a particular agenda or point of view (Bednarek *et al.*, 2018). Someone already in a community can draw on existing familiarity to establish trust as they communicate new scientific ideas (affinitive trust; Coleman and Stern, 2018). In addition to affinitive trust, trust in an individual's knowledge or expertise, rational trust, is also critical and is derived from perceptions of competence in that particular area (Katz and Tushman, 1979; Stern and Coleman, 2015).

Effective boundary spanners also can translate ideas from one community into the language of the other (Hawkins and Rezazade, 2012). Because they are familiar with the community and understand the language and conceptual frameworks commonly used, they can fit the new information into the community's existing knowledge basis and select the most relevant information to share (Tushman and Scanlan, 1981; Van Meerkerk and Edelenbos, 2014). In addition to translating, some researchers describe an additional role for boundary spanners: knowledge building. Boundary spanners are aware of the current knowledge of individuals in the community and can incrementally build upon that knowledge to help community members understand particular scientific concepts (Hawkins and Rezazade, 2012).

In summary, boundary spanners can spread knowledge from one context into another through the acts of translating and knowledge building and through existing relationships that involve affinitive and/or rational trust.

The Current Study

We suggest that biology majors are in a position to become boundary spanners that spread scientific information. They are connected to both lay communities through their informal networks of family and friends and to the biology community through their classes and interactions with faculty. These students know the languages and knowledge bases of their

TABLE 1: Interviewee demographics

Gender	
Male ($n = 8$)	40%
Female ($n = 12$)	60%
Trans/genderqueer/other ($n = 0$)	0%
Age	
18–20 ($n = 11$)	55%
21–23 ($n = 7$)	35%
24–26 ($n = 2$)	10%
Parents'/guardians' highest level of education	
Elementary or middle school ($n = 1$)	5%
High school/GED ($n = 12$)	60%
Some college ($n = 5$)	25%
Technical or trade school degree ($n = 2$)	10%
Race/ethnicity	
Asian ($n = 1$)	5%
Black ($n = 3$)	15%
Hispanic or Latino(a) ($n = 11$)	55%
White ($n = 4$)	20%
Mixed race (Asian, Black, and White; $n = 1$)	5%

home communities and can communicate what they are learning in their classes to their communities. In addition, because of their existing connections in lay communities, they are more likely to be seen as trustworthy. Advanced undergraduates have developed knowledge and competence through their academic experiences and may be perceived by those in their communities as knowledgeable.

In this study, we explore whether undergraduates are playing the role of informational boundary spanners (bringing scientific knowledge into lay communities) and their experiences in conversations about science that they have with people outside the scientific community. We focus on what we call "everyday conversations": spontaneous casual conversations that can occur in the car on the way to the grocery store or at the dinner table, and so on. These conversations are distinct from what people often consider to be science communication, such as formal public presentations, written articles for the general public, or tabling at events.

METHODS

We interviewed first-generation undergraduate biology majors at a single Hispanic-serving institution (HIS) to identify their experiences with and perceptions of having conversations about science outside their university. At the time, these students were enrolled in upper-division courses. We define *first-generation college students* as the first in their immediate families to be working toward completing a college degree. It is possible that their parents started college or are currently enrolled in college but had not previously finished a degree program (Table 1). These individuals were chosen to explore boundary-spanning behaviors, because, as upper-division students, they were more likely to have developed biology knowledge to share and as first-generation students they were more likely to be part of communities that did not already have direct access to scientists (as most scientists come from upper middle-class backgrounds; Lee *et al.*, 2016). The biology majors were students at Florida International University (FIU), an HSI urban R1 institution in Miami, FL. FIU is primarily a commuter campus drawing the majority of students from the surrounding three counties. Thus, many of the students are living in close proximity to their families and lay communities.

Students were recruited through flyers posted around campus and via the biology department student Listserv. Before being selected for an interview, students completed a demographic questionnaire that included questions on the student's age, year in school, gender, race/ethnicity, and highest level of education completed by parents or guardians. These demographics were important to provide context for any variation in first-generation student experiences with conversations about science based on gender, age, or race/ethnicity. As part of this survey, they were informed about the study and consented to participate.

From this pool, we invited eligible participants who were first-generation biology majors currently enrolled in upper-division biology courses. All 20 invited students participated in the study (see Table 1).

Interviews

Participants were invited for individual interviews. Sixteen of these interviews were completed in person in a private room on FIU's campus and four were conducted over an online videoconferencing platform. The interview began with a review of the consent form for the study. We used a semistructured interview format, in which interviewees were asked 11 core questions, with the flexibility of additional follow-up questions. Follow-up questions were employed when clarification or elaboration on participant ideas was needed. The core questions focused on capturing students' experiences with conversations about science outside the university. This included topics discussed, with whom they spoke, with whom and why it was challenging to discuss science topics, emotions they experienced, and approaches used in these conversations. Finally, students also were asked to share any training they had received in communicating science. These questions were intended to explore the role of trust (affective and rational) in students' everyday conversations about science and the presence of boundary-spanning behaviors, including translation and knowledge building, in these everyday conversations about science. The interview protocol is available in Supplemental Material Section A.

All interviews were audio-recorded and transcribed verbatim. During the interview, interviewers (J.S. & H.S.) had the opportunity to take detailed notes on the context and content of the interview. These notes were used to formulate follow-up questions and verify the information being garnered. The interviews averaged 25 minutes in length. After the interview, students received a $30 gift card for their participation.

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Analysis

We conducted a cross-case pattern analysis to identify experiences and perceptions that were common across our participants' engagement in conversations about science outside the university (Patton, 2015). A cross-case pattern analysis allows comparisons of descriptions of actions, perceptions, and experiences to identify shared patterns across the cases. We used this approach because boundary spanning may manifest differently depending on the contexts of relationships of the students.

Each student's situation, including cultural contexts and family structure, makes that student a potentially unique case. The features of a cross case analysis include first constructing a case record for each individual to understand and characterize that individual's experience. Once all the case records have been constructed, researchers compared the cases to identify experiences shared across participants (Patton, 2015). These shared experiences and the nuanced differences among them helped us understand the boundary spanning of biology majors.

We began our analysis by developing a case record for each individual. In teams of two, researchers read each transcript individually and then collaboratively wrote a consensus case record that characterized each participant's experience with communicating science outside the university setting and recorded exemplar quotes that supported these characterizations. Case records included with whom students had discussions, ways that they characterized their relationships with these people, and details about the conversations. In the cross-case analysis (described next) we formalized these aspects as operationalized codes using concepts from the theory of boundary spanning, including behaviors and trust. Disagreements between the two researchers were resolved by revisiting interview transcripts and consulting with the third researcher.

Once case records were written for all cases, three researchers (H.S., J.S., S.E.) reviewed each record to code crosscutting experiences. Codes were derived inductively, based on the boundary literature, and deductively, based on emerging themes. Based on the boundary-spanning literature, we specifically looked for the relationships that students had with the people with whom they spoke. We characterized presence and type of trust that existed. For example, affinity trust was identified when students described the type of relationship they had with individuals they talked to. Rationale trust was identified when students shared whether someone accepted their knowledge or listened to them about science (i.e., saw them as a credible or not credible source). We also characterized students' experiences with core boundary-spanning behaviors of translating and knowledge building. Translating was identified by students describing having to change the words they use. Knowledge building was coded when students described sharing background information. Deductive codes included aspects of student experiences not specific to boundary spanning, such as the specific science topic discussed in their everyday conversations about science. Once crosscutting codes were determined, teams of two researchers coded each case and came to consensus on the codes present. Coders referred back to transcripts when necessary. Finally, researchers reviewed each transcript one more time to identify any additional codes not captured previously. The final set of codes along with representative quotes can be found in Supplemental Tables 1–3.

Three researchers (H.S., J.S., S.E.) reviewed the codes to categorize the crosscutting codes into themes that united clusters of codes. For example, researchers coded instances when students described the communication strategy of putting science in common language (translating), instances when they described this as challenging, and instances when it was a barrier to having these conversations under the larger theme of boundary-spanning behaviors (theme 2). In this way, researchers were able to describe a crosscutting, shared experience of boundary spanning as well as nuanced experiences within that theme of the individual students.

RESULTS AND DISCUSSION

We identified three themes around first-generation undergraduates' experiences as boundary spanners. First, students had everyday conversations with people in their personal networks who did not typically engage with the scientific community and thus have the potential to act as boundary spanners. Second, students engaged in boundary-spanning behaviors of translating and knowledge building. Students also found these behaviors challenging. Finally, students were sometimes seen as a credible knowledge source in these conversations and sometimes not. We explore these themes in more detail in the following sections.

Theme 1: These Students Had Everyday Conversations about Science with People in Their Personal Networks Who Did Not Typically Engage with the Scientific Community

All students interviewed engaged in conversations about science with people in their lives. Students described talking to a range of people both inside and outside the university setting (Figure 1). Outside the university setting, conversation partners included parents, siblings, aunts, uncles, friends who were not science majors, romantic partners who were not science majors, coworkers, and customers. Most of the people with whom students spoke about science were in established relationships with the students, with affinitive trust (i.e., existing emotional connections). For example, Student 14 described how they use trust to decide who to talk to: "I mean [whether or not I talk to someone] depends on the level of … trust or something, level of connection because I wouldn't talk about [science] with a random stranger." Student 11 also emphasized the importance of affinitive trust for making them comfortable talking to friends: "Because they're more understanding. I'm talking about mostly my friends, even if they reject or they try to roast me or something, I know they're my friends."

Strangers, as a group, were not mentioned as people most students were willing to talk to about science. Student 3 reported that the categorization of a person as a "stranger" discouraged them from talking about science: "[My decision not to talk] was more when I was surrounded by people that I don't know…. I just felt like I'd rather not give my input this one time. I'd rather just sit this one out." Several students provided reasons for this choice. Most of the reasons revolved around the lack of affinitive trust: Strangers were unpredictable in their reactions to the science conversations and did not necessarily have feelings of goodwill toward the student. The only people one student mentioned talking to who might be characterized as strangers were labeled as customers. This student described caution in engaging in these conversations and tactics such as asking questions and waiting to hear how people respond rather than leading with their science knowledge.

The topics they engaged in with people about were varied (see Figure 2). Some of the most common topics included climate change, vaccine use, and conservation of plants and animals. In conversations about science, students gravitated toward science topics related to their career goals or their personal passions. For instance, Student 7, whose career goal was to become a dentist, discussed dental health with family members: "So I was able to share that information with my sister who is not pre-health, anything like that. But I was able to tell her, okay, every

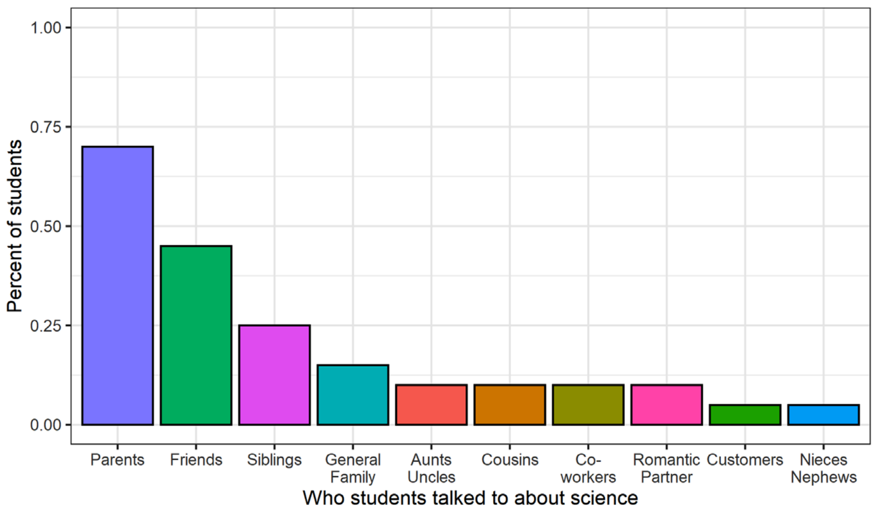

FIGURE 1: People who do not typically have contact with the scientific community with whom biology majors reported having everyday conversations about science. An additional 10 students reported talking with friends but did not clarify if friends were in science or not, so friends were not included in this figure.

six months you need a cleaning." Students' personal interests, beyond their chosen careers, included topics they were passionate about and topics related to recent events that impacted their family and friends. For example, Student 8 shared:

> I think [deciding whether to talk about the science you learn in your classes] depends on [a student's] interest really … If you're one of those people that just go to class to get the A and leave, then you're not going to talk about [topics in those classes]. But, if you're like me and … you actually care about what you're learning, then yeah it comes up.

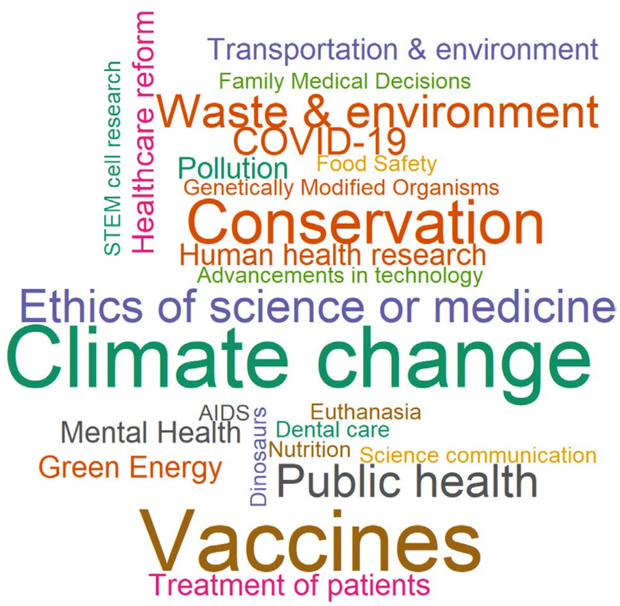

FIGURE 2: The range of scientific topics students brought up in their everyday conversations. The size of the topic indicates the number of students who mentioned it.

The importance of passion in decisions on what to share was echoed by Student 15: "So at the end of the day, [what drives whether you talk about something] is probably passion. If you're passionate about something … you're going to talk about it." Student 20 illustrated how passion can be translated into everyday conversations about food safety:

> Parasitology was super interesting to me … My dad likes sushi, so I was like "No, don't do that. There could be *Anisakis simplex* in there…. That's a parasite. If you get it, you have these symptoms …" I'll tell them. It's super interesting to me.

These students described conversations centered around biology topics about which they were passionate. For some students, this passion extended to the entirety of biology, while others focused on more specific topics that were relevant to what was happening in their lives or future careers.

Students introduced these interests into conversations in two main ways. First, sometimes students were seemingly spontaneously sharing their science knowledge. Student 8 illustrated this approach:

> I try to teach everyone along the way…. I always tell people interesting things about biology so that they can probably get interested … All those things are things I learned to appreciate and to talk [to] people about.

This student proactively shared science knowledge on topics that they found interesting. Alternatively, other students described talking about their interests after a conversation partner initiated the topic. This often took the form of questioning or correcting what the other person said to increase that person's understanding of the topic. For example, Student 18 described sharing knowledge for the purpose of correcting: "I feel like most of the time I can change their mind because I'm presenting them with facts. Like this new paper came out, this new study came out."

In summary, students had everyday conversations about science mostly with people with whom they had established relationships, and they were sharing ideas related to their passions. This sharing of passion is considered a best practice in science communication, because it is seen as less threatening than trying to change others' ideas (Besley *et al.*, 2016), although the same student could engage in both sharing and correcting behaviors. In addition, because students are more frequently around people they have relationships with, they are able to engage in conversations about scientific topics when people are possibly more receptive (i.e., when the person brings a topic up first). This is one advantage we found students had over scientists in communicating science.

Theme 2: Students Engaged in and Were Challenged by Boundary-Spanning Behaviors of Translating and Knowledge Building

Key boundary-spanning behaviors are translating knowledge from the language of one context to another (i.e., scientific jargon to plain language) and building up the knowledge base of conversation partners so that they have the necessary background for making sense of the information they receive. Both of these behaviors were demonstrated by the students; however, knowledge building was seen as much more of a challenge.

Participants commonly engaged in the strategy of translating science into common language that people in their networks outside science could understand. For example, Student 11 said: "Science can be very complex, it's like another language, so you really have to decrypt it for someone who's not a scientist." This quote shows that students are aware of the need to translate in these conversations to successfully communicate.

Some students described translating as a challenge in these conversations but still had the conversations. For instance, Student 16 shared an experience with learning when to translate:

> To you, if you're in bio every day, that's your field, yeah, [the science] is common sense. But to someone else, I guess, I don't want to say it's hard to do it, but sometimes you don't realize that you're saying a word and, like, "Oh, yeah," thinking the person knows the word, but it's, like, "Oh, no," you have to backtrack… [what we are sharing] is information that we know, I've taken so many tests on this information, but yet explaining it to someone else and especially children, it was 10 times more difficult.

This student struggled to identify what needed to be translated and how best to do it but persisted in the conversations.

Other students described the need to translate as a barrier to engaging in these conversations about science. For example, Student 5 seemed more pessimistic about their ability to translate science for their family:

> I feel like sometimes, it's hard to communicate these ideas…. Parents that don't have an educational background, they might not understand. And if we try to explain to them, we're just going to tell them our jargon then we're going to tell them things that they might not understand, and it's hard for them to get it.

This belief that people will not understand what they are saying could make this student less likely to talk about science with their parents.

The challenge of translation was exacerbated when multiple forms of translation have to occur at once in a conversation, such as when translating from scientific language to common language and English to Spanish. Student 11 described their experience:

> I have an understanding of [the science] that I wouldn't be able to explain to him in terms that he would understand. He doesn't speak English so there's a barrier…. So, I would have to try to learn it again and teach it to him in Spanish.

This student could not currently communicate with their father because of the double translation (scientific jargon to common language and English to Spanish).

A second boundary-spanning behavior is knowledge building. When it was mentioned, it was commonly perceived as a challenge. For example, Student 14 shared: "[Knowledge building] is an extra step for the people who I have to teach the basics of biology, that I just can't talk … with them understanding because they won't." This student's belief in their ability to successfully communicate in knowledge-building conversations was low. This could reduce their willingness to engage in such conversations.

Students specifically described engaging in two forms of knowledge building. One type was supplying the background knowledge that was necessary to understand the current topic a student wanted to discuss. Student 18 described this type of knowledge building:

> I think the most challenging people to discuss this information with is [*sic*] probably my family. They have absolutely no background in what I'm doing, so anytime I try to explain what's going on, how school's going, there's always a step before I have to do to explain all the background information that associates with what I'm doing, and then explain what I'm doing.

For this student, the extra step of explaining the background information makes these conversations more challenging than when they just had to translate jargon.

The second form of knowledge building was explaining the scientific process and how it is different from other ways of knowing. Student 4 described the need for this sort of knowledge building:

> I've noticed that people that are in science fields tend to look at [findings from scientific research] in a little bit of a different way and understand the process behind it and why studies say what they do because there's a whole year-long procedure leading up to them saying that one statement. But I feel certain people don't distinguish so much between, don't understand the idea that experiments are done, data is taken and such and it's not so much an opinion, as it is as close to fact as we can get. And they just think that it's a gray area when it's really not.

Some students viewed understanding the process of science as a necessary foundation for these conversations, because people in their networks were placing equal value on anecdotal evidence and hearsay as on scientific evidence. The students saw these equivalencies as a barrier to successfully communicating with others about science.

Some students related the challenges they faced with translating and knowledge building to how they have been taught science. These students described a focus on memorizing and testing in their classes. They identified how this limited their communication ability in two ways. First, they did not get opportunities to practice explaining what they learned. Student 2 described this: "I feel a lot of the times for people in the sciences and biology, we are supposed to take in a lot of information, just remember this, remember that. But we never get to actually express that information." They also were not exposed to strategies for communicating science effectively, as Student 5 points out: "I feel that now, whenever we have a class, we just focus on the subject and the subject and the subject, not how to communicate it." Memorizing information was not enough for them to feel comfortable explaining science to others. Students suggested various ways courses could address communication skills, including having faculty role model conversations and how to respond to common rebuttals, assignments or other opportunities for practice explaining course content to a lay audience, and being taught communication principles.

Combining some of the patterns from themes 1 and 2, we saw another way that students may be well positioned to effectively boundary span. In theme 1, we noted that students sometimes waited for others to initiate conversations about science. By allowing their conversation partners the chance to initiate topics, the students may be improving their knowledge-building ability (theme 2). They can use the initial information or context in which the scientific topic is brought up to tailor the knowledge that they highlight and share. However, when analyzing the students' perceptions of knowledge-building behaviors, it seems that they were still hesitant to knowledge build even when they knew the previous conceptions of their conversation partners. This hesitancy seemed to be related to their training in communication and expectations of being unsuccessful in building knowledge. Students were interested in incorporating practice with these behaviors into their science courses.

Theme 3: Students Were Sometimes Perceived as a Credible Source and Sometimes Not

Students experienced a range of outcomes in their everyday conversations about science. Sometimes the people they talked with accepted their knowledge, as illustrated in this quote from Student 16: "My mom…. She's not in science so most things that I talk to her about, she just listens. It's just like whatever I say is … she's going to believe that it's right." Other times people did not accept their knowledge. This variability in outcomes could happen with the same student: An individual student could describe experiences of successes and failures at sharing science. For example, Student 18 in an earlier quote described success at transferring information from scientific studies, but here described a failure:

> When I try to explain [scientific evidence] to them, they kind of just shut me out. They have decided that the information that they already have is the most correct version of it and they refuse to really put any more thought into that.

These quotes speak to the variability in credibility others saw in the students' knowledge and how this influenced the outcomes of the conversations.

Because the same student could experience successes and failures in conversations, the outcome seemed at least partially driven by the conversation partner. Credibility was particularly challenging to achieve when the conversation was with people who students described as older individuals. For example, Student 17 said:

> There are those, those people from work, they're around my age, they're like, they tend to be very open minded. But then there's some of the older individuals who are very like, "Well if I did it before, I can keep doing it again."

Students' definition of "older" individuals seemed variable. Although some students considered their parents to be "older," this was not always true. Student 13 did not consider their mother in the "older" category: "My mom's actually pretty young, so I can have some of those conversations with her." This suggests that students' definition of old was not necessarily tied to family roles.

Students did not directly address their lack of credibility with older people, but instead described types of prior beliefs these people held that they thought disrupted conversations about science. From the students' perspectives, three types of beliefs tended to arise more commonly when talking to older folks as opposed to other age categories. The first was personal experiences. Personal experiences were defined as experiences people have had in their lifetimes or experiences of others who were close to a person have had in their lifetimes and have told the focal person. For example, Student 12 shared: "[My parents] typically more often disagree. It comes more of their own experiences and their own opinions."

A second set of prior beliefs that made credibility challenging were cultural beliefs and folk knowledge. These were defined as concepts that are passed on from person to person in a culture that are believed to be true. Student 9 described the impacts of these cultural beliefs on learning new scientific information in conversation:

> Sometimes … you're raised on beliefs that are not right. And to be able to deviate from beliefs that you've been raised to think, even if they're wrong, it's hard. It's hard when you're raised to think something to then have science kind of tell you otherwise. It's very difficult to get out of that mindset.

A cultural belief that multiple students referenced was if you go outside with wet hair, then you will get a cold.

Religious beliefs were defined as beliefs about the world based on someone's religious orientation. When these conflicted with the scientific perspective that a student was trying to share, the student's point of view was more likely to be disregarded. For example, Student 14 shared that religious beliefs that conflict with science are such a barrier in these conversations, they do not even try to engage anymore:

> I … grew up in a really religious background. I guess they would say things that I know for a fact is not scientifically true. I'd rather not start that conversation because I know it's going to lead into a rabbit hole…. I don't want to start a polarizing conversation and not have a productive conversation out of it.

In addition to characteristics of their conversation partners, some students perceived their personal characteristics as working against them when they were in conversations with older individuals. Some students described experiences of being tokenized or dismissed for their age when they engaged in conversation. Student 18 described such an experience:

> A lot of the people who are in that community are very old and they're usually impressed that I'm just so young there, that I feel like they're listening to what I have to say because of my age and not because they are interested in the information I have to give…. There's some of the novelty of me just being a student and then saying, "Oh you're so cute, you're so small."

Some female students also experienced this because of their gender as described by Student 19:

> I actually hold back because as a woman in science it's harder to gain certain respect. So, when I talk to certain people it's like, okay well I can give my opinion, but it still may not be … Or I can give my information that I have but it can still not be considered enough.

Neither of these students was perceived as a credible source of scientific information in these conversations, although they were successful in others.

Some of the challenge of talking with older people also came from the students' hesitancy to engage in conversation. Students described being reluctant to confront older people's ideas. This was especially prevalent in conversations with parents. For some students, this hesitancy seems to come from a recognition of the power differences in their relationships. For instance, Student 3 shared how hard it can be to try to confront a parent's beliefs:

> I feel [sharing the science I know] is difficult, too, because I don't want to tell them all the time that they're wrong. I think a power sort of difference. But I'm not going to tell my dad, no, you're wrong. I don't know how to say that.

Other students refrain from the conversations out of seeming affection and concern for the older individuals. Student 11 described making such a decision to refrain from contradicting a parent out of affinity:

> I feel like I'm right, but my mom, the way she raised us was with that foundation, that background, that religious background. She's always been super good with us. So why would I want to tell my mom, "Hey, that's all [expletive]"?

It's important to note that not all conversations with older people were challenging. Two mediators seemed to improve the outcome of the conversations. First, if the older adult had a pre-existing interest in science, then engaging with that person was easier. The second was when student did not perceive older adults as old.

In summary, students sometimes were seen as a credible resource, a necessary component for boundary spanning, and their information was accepted. This was less likely to happen with people who students described as "older," although some had productive conversations about science with older individuals. Thus, students may be more successful at spreading scientific information among people in their same age group or younger rather than with people they perceive as older.

CONCLUSION

Do undergraduate biology majors serve as boundary spanners?

From these results, we see evidence that first-generation students are boundary spanners: They are having conversations with people who do not commonly interact with the scientific community about the interesting concepts that they are learning in their science classes. Even though these conversations may not be about controversial socio-scientific topics, students may be having an influence on listeners' receptiveness to science. By having positive noncontroversial conversations that involve scientific knowledge, students can engage in knowledge building and leverage the affinitive trust they have with people in their networks to build trust in the process of science itself (Coleman and Stern, 2018). Over time, this may shift people's receptiveness to the scientific perspective on controversial topics.

Boundary spanners play an important role of translating what they learned in one context into the vocabulary used in their other context and helping people acquire the background they need to understand new concepts. A common theme among the students interviewed is that both of these tasks were challenging. Students struggled both with explaining jargon and providing sufficient background knowledge for people outside science to understand their arguments. Differences in what was considered acceptable evidence between communities also challenged them in these conversations. These challenges could limit first-generation students' effectiveness as boundary spanners. However, the students in this study recognized their limitations with boundary spanning and were interested in getting better at it.

The challenges students have communicating with older individuals suggests that they may be more effective boundary spanners with individuals within or close to their own generation rather than for vertical transfer between generations. This is interesting, in light of the evidence that the people these students most commonly spoke about science with were their parents. The challenge of communicating science to older folks was moderated, however, if the student did not perceive the generational gap to be large, if older individuals trust in the student's science knowledge, or if the older individuals are interested in science. However, it is important to note that, even though these students find these conversations more challenging, they also reported successes when an older person was convinced of the scientific view the student presented. So, challenging does not necessarily mean students cannot be effective, but that students weigh additional considerations before deciding to engage, including the strength of an older person's prior beliefs and their own comfort pointing out that the older person is wrong.

In addition to thinking about how students acting as boundary spanners can help spread scientific ideas into novel community contexts, boundary spanning may benefit the students themselves. For example, a recent study on graduate students found that the more frequently they engaged in science communication, both formally (scientific talks, scientific writing) or informally (speaking in a poster session, asking questions after a presentation) the greater their intention to pursue a research career and the greater their science identity (Cameron *et al.*, 2020). Similarly, a study with first-year undergraduates found a correlation between frequency of talking about their science interests and their intent to pursue a science career. This relationship was strengthened for women when they received positive social recognition during these conversations (Jackson *et al.*, 2019). Recognition from others when they talked about science they learned in a physics class also predicted students' personal interest in that course at the end of the semester (Thoman *et al.*, 2012). Taken together, these studies suggest that recognition of their science interests can bolster students' science identity and interest in science. Thus, students' everyday conversations, when they go well, could bolster these first-generation students in their pursuit of science. However, the lack of recognition that some students described could limit or even harm their interest in science. Thus, finding ways for biology instructors to support students to have better conversations would benefit not only science but possibly the students themselves. This support should also help students understand how affinity and trust can support their efforts.

Limitations and Next Steps

Overall it seems that students in this study acted as boundary spanners, but with mixed effectiveness. However, the students represented in this study responded to an invitation to be interviewed on this topic, so they may be more engaged in these activities than those who did not respond. A broader quantitative study could determine whether this behavior is widespread. In addition, the majority of the students at this institution commute to campus and live at home, providing them more opportunities to engage with family members about what they are learning than a residential student might have. Additional studies on this topic at residential campuses and campuses drawing from a more rural population could shed light on how these students are engaging with people other than their science peers and professors.

Practical Implications

One area in which biology educators may be able to enhance student effectiveness as a boundary spanner is improving their ability to explain biological phenomena to a general audience. This could come through role modeling arguments or conversations or providing practice explaining biological concepts in the language of their home communities. It also could include analyzing the relationships they have with their audiences and learning how to build upon their audiences' prior knowledge. Practice could be as simple as short written assignments in which they explain a concept they learned to a layperson or could be as elaborate as engaging students with the local community through service learning or community-engaged research. Some example curricula that incorporate science communication include: a discussion-based course focused on reading primary literature and translating it for the public through writing (Brownell *et al.*, 2013); a three class–session unit using locally relevant topics to explore the value of science communication that can be incorporated into an introductory biology course (Lescak and Kelsey, 2021); and short classroom activities that can be incorporated across the semester in science, technology, engineering, and mathematics courses (Mercer-Mapstone and Kuchel, 2016). These curricula all resulted in increased student confidence or self-efficacy communicating science. In addition, a framework for effective science communication has been developed and can be used to develop novel lesson plans (Wack *et al.*, 2021).

Explaining concepts from one community to another community is a critical skill for boundary spanning and may be the easiest skill instructors can practice with their students to empower them to successfully spread scientific research beyond the academe. The boundary spanning of undergraduates could thus help address one of the major challenges facing the scientific community: spreading the use of scientific knowledge in personal and policy decision making.

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