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Data, discourse, and development: Building a sustainable world through education and science communication

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Dramatic expansion of distance learning during COVID-19 widened the digital divide and highlighted the importance of students' digital and data literacy skills. Simultaneously, science was playing out in front of the public as information and communication about the importance of COVID-19 protective behaviors and vaccines evolved. Yet within the global discourse, misinformation was rampant. The public questioned the validity of COVID-19 data. They did not know who or what to trust. Their concerns about the impacts of COVID-19 protective behaviors and the need for vaccinations rose. Some science educators were asked to avoid discussing the topic with their students. All of this is emblematic of an even larger problem—the inability of many people to understand and use data to make informed decisions to develop their communities. This article will use one example from the Smithsonian Science for Global Goals project: *Vaccines! How can we use science to help our community make decisions about vaccines?*, which invites students ages 8–17 to use data to change discourse and develop their own communities using inspiration from the United Nations Sustainable Development Goals (SDGs). This project encourages students to: (1) use investigations to gather and analyze data from their communities as they build data literacy skills (**data**); (2) communicate this information to others as a way of catalyzing and changing community conversations to make informed decisions (**discourse**); and (3) become active partners in creating more sustainable and equitable communities (**development**). These competencies of data, discourse, and development—integrated into science, technology, engineering, and math education for sustainable development (STEM4SD)—are aligned with a "data for learning" conversation that emerged during the pandemic. To expand students' data skills, educators must be grounded in a framework that holistically considers ethics, community impact, and science. Data must be contextualized to the problems that students face locally. Students must be given the tools to communicate scientific understanding to others in service of sustainable development. As such, an SDG-aligned approach to data for learning that promotes discourse drives learners to act to protect themselves, our societies, and our planet, while educating students on the underlying science and social science of sustainable development.

KEYWORDS

sustainable development, discourse, data, vaccines, STEM education

1. Introduction

Over the course of the COVID-19 pandemic the public has had an unprecedented view of the global scientific community at work as available information and communication about the safety and importance of COVID-19 protective behaviors and vaccines evolved. Many members of the public, unfamiliar with the dynamic nature of scientific discovery, mistakenly perceived the constantly changing data about COVID-19 as evidence that scientists were incompetent, or even worse, spreading disinformation. At the same time, within the global discourse about COVID-19, misinformation was rampant. The public questioned the validity of COVID-19 data and resisted taking steps to mitigate the spread of disease and protect themselves from serious illness. This challenge is ongoing as people continue to grapple with what sources of publicly available information to trust. Furthermore, as vaccination was politicized in the public discourse, decision-making about vaccination and other behaviors became increasingly tied to cultural or political identity (Herman et al., 2022). Some science educators were asked to avoid discussing the topic altogether (Divack, 2021). This is emblematic of an even larger problem—an urgent need to provide classroom resources that integrate civic discourse in science curriculum in ways that attend to the socio-political and value dispositions at the heart of decision-making about science-related topics.

This problem is not new. Tensions that arise when science educators are pressed to teach topics with political or religious implications are well-documented, notably in evolution education (Goldston and Kyzer, 2009; Pobiner, 2016) and climate change education (Zimmerman and Robertson, 2017; Walsh and Tsurusaki, 2018; Nation and Feldman, 2022). To address some of the tensions associated with teaching about COVID-19 vaccination, and other similar complex topics, the Smithsonian Science Education Center (SSEC) uses an approach that develops students' data literacy skills using local and global community data through transdisciplinary metrics and ideas (**data**); re-centers science as a tool for understanding and for informed decision-making in local and global discourse (**discourse**); and encourages students to develop into active partners in improving their communities through local and global development (**development**).

The United Nations' (UN) adoption of the Sustainable Development Goals (SDGs) was a global endorsement of the concept of building a better world through education (United Nations Development Program—UNDP, 2015). Through SSEC's Smithsonian Science for Global Goals project, students ages 8–17 have an opportunity to develop the knowledge and skills needed to understand the world's most pressing issues highlighted by the SDGs (O'Donnell, 2018b). However, knowledge and skills are not enough; students must feel a sense of engagement through relevant experiences and become agents for change in their own communities. Through a series of freely available community research guides developed by the Smithsonian in collaboration with the InterAcademy Partnership, students use their communities as their laboratory to investigate and communicate the science underlying the SDGs. They then define and implement their own sustainable actions to help solve these problems (O'Donnell, 2018b). This becomes an opportunity to take complex global problems and personalize them through localization. At the same time, because these problems arise on a global stage, students continue to interact with them in ways that attend to their global nature as well.

Science communication plays an important role in addressing the disproportionate effects of COVID-19 and vaccine resistance on vulnerable populations (NASEM, 2020). Thus, we draw examples from the Smithsonian Science for Global Goals' *Vaccines!* guide (Smithsonian Science Education Center—SSEC, 2021) to illustrate how students ages 8-17 can use **data** to change **discourse** and encourage positive **development** in their own communities. In pandemics, concerns and misinformation about vaccines have hindered progress in the fight against disease. However, students can be important partners in sharing information to help people make informed decisions. Through *Vaccines!* students are guided to build a scientific understanding of vaccines and vaccine development. They collect data to better understand concerns in their community. Students become localized science communicators, crafting communication action plans that integrate data while addressing community concerns directly. With the ability and agency to act, students can increase confidence in and address questions about vaccines in their communities.

The goal of all Smithsonian Science for Global Goals community research guides is to get students to act locally but think globally to build a just world. The guides integrate data, discourse, and development into science, technology, engineering, and math (STEM) education in what we call "STEM Education for Sustainable Development" (STEM4SD) (Pahnke et al., 2019). Sections below outline how the guides encourage students to use investigations to gather and analyze data (**data**), then communicate this information to others as a way of catalyzing and changing community conversations (**discourse**), with the aim of creating more sustainable and equitable communities (**development**).

2. Data: Quantity, quality, and use in education

The quantity of available data has increased exponentially and is used in a variety of ways. In 2020, 64.2 zettabytes of data were created, which is a 314 percent increase from 2015 (International Data Corporation, 2021). Businesses now routinely use data science techniques to forecast demand, detect fraud, and optimize transportation routes. STEM professionals use data to evaluate claims and drive decisions. Schools use student and teacher data for personalized learning, assessment, and certifications. Data is also used to evaluate global progress. For example, data sources linked to each SDG indicator measure progress toward the goals. Many data platforms now use data for social good, including measuring impact, managing resources, addressing climate change, and improving health and equity (Nikulski, 2021). Increasingly, organizations and businesses are also creating sustainability metrics and considering ESG criteria (environmental, social, and governance) in their decision-making (Friede et al., 2015). While the quantity and availability of data has certainly increased, data quality and basing conclusions on proper data analysis remains challenging.

Data quality issues include not only how the data is gathered, but also questions of data equity. Where is data being gathered, and how does this inform decision-making? If, for example, data is only being collected and aggregated at a global or national level, wide variation between localities may remain hidden. This has implications for metrics of sustainable development. Examining data at a global level may miss local progress or stagnation. When using data to drive

decision-making, applying data gathered from a different place or too broad an area may result in poor decisions for a specific community.

Data can also easily be misunderstood or misused. Understanding what conclusions can be drawn from specific data is still often problematic. Misinformation about vaccines is a prime example. Since 1990, anyone in the U.S. experiencing a reaction they think might be linked to a vaccine can share their data *via* the Vaccine Adverse Event Reporting System (VAERS, 1990). VAERS functions as an early warning system to establish potential correlations between specific adverse events and specific vaccines. However, since the database is publicly available, it can be misused or taken out of context. For example, if a few individuals are diagnosed with cancer after receiving a vaccine and report it to VAERS, someone seeking to misuse that information might share those stories and claim that a vaccine causes cancer.

As a result, it is crucial that we educate students not only on how to apply what they have learned from data to understanding real-world phenomenon and problems, but also on how to become informed consumers of data (i.e., analyze, use, and realize the limitations of the data). This section of the paper addresses traditional uses of data in STEM education (e.g., asking students to analyze and interpret data) and explores how STEM education in the future can help students apply data to address socioscientific issues of our time (e.g., use data science for sustainable development).

2.1. Defining data

Data is information derived from many sources; it is more than just numbers. Observations, ideas, and affect shared through drawings or stories, are all legitimate sources of data and are particularly useful when working with younger students (NSTA—National Science Teachers Association, 2022). Older students may collect and observe qualitative and quantitative data, including data sets related to diseases, poverty, hunger reduction, or climate change. Data can also include objects—such as the number of plastic bottles on a school ground collecting water and serving as breeding grounds for mosquito larvae. Computational and mathematical models can be used to analyze millions of data points. Photographs of animals captured by camera traps are also considered data and can be analyzed by citizen scientists working on conservation projects. Travel patterns of cars can be used to analyze transportation data to better understand sustainable communities. Social data includes demographic representation, age, gender, occupation, language spoken, and other parts of identity. To expand students' data skills, educators must be grounded in a framework that holistically considers ethics, community, and environmental impacts. When studying transdisciplinary topics that are embedded in the UN SDGs, many different forms of data are needed, and each of these is important to advance STEM4SD (Pahnke et al., 2019).

2.2. Using data in STEM education

Professional scientists are not the only ones who collect and analyze data. In the United States (U.S.), science standards for students ages 5–18 outline what students should know and be able to do in classrooms. The Next Generation Science Standards (NGSS Lead States, 2013), for example, have identified a series of science and engineering practices that are critical to students' learning, including *Analyzing and interpreting data*. Accordingly:

> Scientific investigations produce data that must be analyzed to derive meaning. Because data patterns and trends are not always obvious, scientists use a range of tools—including tabulation, graphical interpretation, visualization, and statistical analysis—to identify the significant features and patterns in the data. Scientists identify sources of error in the investigations and calculate the degree of certainty in the results. Modern technology makes the collection of large data sets much easier, providing secondary sources for analysis. (NSTA—National Science Teachers Association, 2022).

Analyzing and interpreting data is a skill that is developed over time. For young students, ages 5–7, the teacher or facilitator of the learning experience builds on students' prior experiences, progressing gradually to helping young students collect data, record data, and share observations about data (NGSS Lead States, 2013). Students might collect data firsthand or get data from media. Analysis of data might range from observing or describing patterns and/or relationships in the natural world (science) or designed world (engineering) to answer a scientific question or solve a problem. By ages 8–11, students may be introduced to quantitative data (numbers) and conduct multiple trials to compare results. Digital tools may be used to support students' data collection, graphical display of data, and data analysis to make sense of phenomena using logical reasoning, mathematics, and/or computation. Students might design a proposed object, tool, or process and refine it based on their analysis. As students get older (ages 12–14), they progress to extending quantitative analysis to investigations, distinguishing between causation and correlation, and use basic statistical techniques of data and error analysis. Finally, in secondary school (ages 15–18), students use more refined statistical analysis, compare data sets for consistency, and use models to generate and analyze data to make valid and reliable scientific claims or determine an optimal design solution (NSTA—National Science Teachers Association, 2022). How can we apply these traditional skills of analyzing and interpreting data to the teaching and learning of STEM4SD? Data must be contextualized to the problems that students face locally, and drawn from the opinions, thoughts, culture, and local ways of knowing.

2.3. Description and use of data in *Vaccines!*

Through the Smithsonian Science for Global Goals project, students take a transdisciplinary data-driven approach to STEM4SD learning focused on real-world problems (O'Donnell and Day, 2022). In the *Vaccines!* guide, students analyze the prevalence of specific diseases before and after vaccines became common (Smithsonian Science Education Center—SSEC, 2021). Students build data literacy skills by collecting their own local data to better understand the issue. They analyze data and apply their understandings to their local context. They take a critical approach to the data that exists and how it is used, which allows students to consider data equity and limitations. Students engage in problem-solving, using reasoning to understand and make complex decisions, and understand the interconnections among systems. Students grow to appreciate data from a more holistic perspective. For example, a full complete understanding of

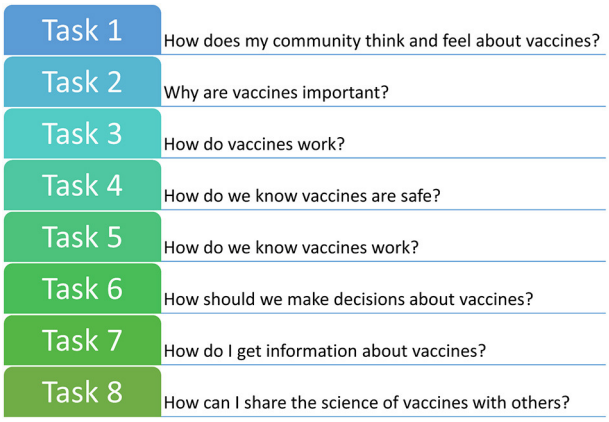

FIGURE 1
Progression of Smithsonian Science for Global Goals' Vaccines! guide.

a complex global problem might take a combination of quantitative, science-derived data, and qualitative approaches. These approaches can be place-based, uniquely tailored to local culture, and used as tools to understand the perspectives and constraints of a specific community.

Like all Smithsonian Science for Global Goals guides, *Vaccines!* features "tasks" (or lessons) that incorporate STEM4SD investigations and hands-on science to help students **discover, understand**, and **act** (O'Donnell, 2021). In *Vaccines!* students learn about the science of vaccines throughout history; understand the science of how vaccines work; explore how vaccines are developed; examine issues of equity, access, and misinformation; and develop an action plan for addressing vaccines concerns in their communities. The guide was designed for students across the globe and available in multiple languages to be used either at home with siblings, parents, or caregivers or in schools with teachers. In most cases, educators proactively download the free guide and facilitate it with the students they teach. Depending on the age of the students and the rigor employed in data collection and analysis, using the guide can take groups between several hours and several weeks. The eight tasks of *Vaccines!* lead students to progress through a variety of investigations, starting with their and their community's own knowledge and opinions, and culminating in taking self-determined action about vaccines in their local spaces. Figure 1 shows the full progression.

In *Vaccines!,* students analyze and interpret data to provide evidence for scientific phenomenon by asking questions, planning, and carrying out investigations (Smithsonian Science Education Center—SSEC, 2021). They also gather, analyze, and interpret data about patterns in how people in their community think and feel about vaccines. In Task 1, using a graph that shows Likert-like data from different countries on willingness to use a COVID-19 vaccine if available, students learn that people in the US have different thoughts, feeling, and opinions about vaccines than people in other countries. Students conduct a survey of their own community members to investigate how members of their community think and feel about vaccines. In Task 2, students obtain information from world maps, analyze data, and use models (e.g., graphs of measles cases from 1990 to 2020) to observe and gather evidence for how vaccines affect the prevalence of common diseases. They observe the scientific phenomenon that vaccines change the spread and effect of diseases. Graphs, charts, and other images are used to identify patterns in data. In Task 3, students use data to construct an explanation of how the body's immune system and vaccines work together to keep people safe from disease. They model the pathogenic antigen and antibody interaction as they learn about immune memory and then model the approach of different types of vaccines (e.g. weakened whole pathogens or genetic vaccines). In Task 4, students analyze the quality of data as they think critically about clinical trials. For example, students are given real-world data about the participant numbers and demographic makeup of specific COVID-19 clinical trials. They are asked to consider their own comfort level with vaccine safety information drawn from these trials, but also to extrapolate any limitations of the conclusions that can be drawn. For example, students are shown the age ranges of clinical trial participants and then asked to think about how that relates to the age restrictions of vaccine authorizations. Through this process students are given an opportunity to consider data equity as well as the limitations of conclusions that can be drawn from specific data sets. In Task 5, students build an understanding of comparison when considering data sets as they analyze real-world data from COVID placebo (control) and vaccine groups from a clinical trial. They learn how this data is used to calculate an efficacy rate for a vaccine and model probability of disease related to specific efficacy rates. In Task 6, students connect data with decision-making. They apply this knowledge to the scientific phenomenon that COVID-19 affects different populations in different ways. They use data from the U.S. Centers for Disease Control to engage in reasoning about vaccine access in the situation of a limited supply. In Task 7, students assess the credibility and accuracy of data from several sources of information about COVID-19 vaccines to identify accurate information. They use this information in Task 8 to connect what they have learned from data, the concerns they have identified in their community, and the actions they want to take. Throughout the guide, students are interacting with data in multiple ways. They are analyzing it, applying it, and collecting it. This multidimensional exploration into data can help students feel comfortable with data use and develop a critical lens for the limitations of existing data.

2.4. Why discourse about data is necessary

Data and the skills to interpret and collect data are necessary to advance STEM4SD, but data alone is not sufficient. We also need to help students engage in local and global community discourse about data to amplify science and help students make sense of complex socioscientific issues. By talking about data in ways that are place-based and relevant to students, we can help students understand how and why their values, identities, and histories might influence their perspective of data, and as a result, their perspective on the scientific phenomenon or problem. Concurrently, discussions about the links between local actions and global data can support students in navigating those connections. Discourse helps students apply their understanding of data to their social and cultural contexts at local and global scales.

3. Discourse: Productive public conversations

The need to encourage productive conversations around data related to important public topics is undeniable. Political polarization around the world is at an all-time high (Lee et al., 2021a). One need only look as far as the highly contentious conversations about vaccination and masking that have emerged throughout the COVID-19 pandemic to find a salient example that highlights how urgently we need to develop students' discourse, knowledge, and skills as active and engaged members of civil society. Actively acknowledging and engaging myriad discourses taking place across the public realm locally, nationally, and globally is a crucial step to engaging productively with these often-contentious public topics. Therefore, a central driver for the Smithsonian Science for Global Goals project is to equip students with skillsets and dispositions for engaging in discourse as a critical component of everyday knowledge construction with the expectation that doing so will increase student civic participation overall.

In addition to describing the role of data in science classrooms as discussed above, student discourse has also taken on an increasingly prominent role in science teaching and learning in the U.S., with newfound emphasis on student discourse as a form of knowledge construction (National Research Council—NRC, 2012). For example, two NGSS science and engineering practices promote student discourse: *Engaging in argument from evidence,* and *Obtaining, evaluating, and communicating information* (NGSS Lead States, 2013)*. Educational resources with a focus on discourse are needed to support teachers.

Discourse is essential to the production of knowledge, from everyday banter to experts engaging in the process of discovery (Kelly, 2010). Furthermore, discourse has foundational implications for how communities construct norms and expectations for engagement. In education, discourse is connected to students' epistemic processes and the types of knowledge they may find relevant at any given moment during instruction (Kelly, 2010; Berland and Hammer, 2012). Student learning is situated within the cultural practices and norms of a classroom community, which is itself situated in a broader community, one that changes over time as members "take action to change the social knowledge, norms, and practices" (Kelly, 2010, p. 62). Thus, discourse is often an important means for transforming social structures. Or as Philip and Gupta (2020, p. 196) point out, discourse is a means through which people "reify, nudge, perturb, alter, and/or transform existing relationships of power".

3.1. Data-driven discourse

Considering the powerful role discourse has in shaping society, it is sensible that we would want to make engaging in civic discourse a central educational aim. For decades, a primary goal of education for scientific literacy included efforts to support students in incorporating scientific data into discourse, especially when engaged in argumentation or group decision-making. The goal of such efforts has been to produce a citizenry reliant on scientific data when making informed decisions as members of a society (Roberts, 2007; Roberts and Bybee, 2014). But as Rudolph and Horibe (2016) points out, empirical studies have yet to support the claim that scientific knowledge and data alone are strong enough motivators for civic engagement related to science-based public issues. On the contrary, research has shown that even when equipped with substantial data on a subject, individuals often rely primarily on their lived experience alongside socio-moral, or value-centered beliefs when grappling with science-adjacent civic issues (Feinstein, 2011; Nielsen, 2013; Rudolph and Horibe, 2016; Emery et al., 2017). For example, Emery et al. (2017) found that even when presented with a substantial packet of evidence-based information about an issue, middle school students were rarely influenced by new data about a range of science-related civic issues. This was especially true for students who began the study with pre-existing positions. According to Emery et al. (2017, p. 117), their results indicated that "the majority of students made initial voting and purchasing decisions about the given issues based on prior knowledge and the brief scenario description". Furthermore, as Kim et al. (2014) found, the level of controversy associated with a particular science related issue had a direct influence on whether participants were willing to alter their pre-existing positions on the issue. Rather than integrating new data into decision making and using it to reconsider a previously held position, participants questioned the validity of data found in sources with conclusions that did not match their currently held positions (Kim et al., 2014). These findings beg the question, if scientific knowledge and data are not the primary drivers of civic engagement, how can we teach students to engage in meaningful civic discourse grounded in data about science-related issues, especially those that are politically wrought and therefore ripe for targeted misinformation campaigns?

3.2. Student agency to analyze discourse

One thing that is important to note when considering the studies discussed above is that those studies did not position students as embodied with the agency to seek new information about the issues at the heart of their studies. Instead, students were provided supplemental information that had been gathered and curated by a researcher or instructor on their behalf. Little room was made for students to reflect on their held beliefs about an issue alongside their peers, or to research the basis for community members' beliefs. As a result, students may interpret scientific discourse as divorced from their everyday ways of knowing and talking about the world (Tan et al., 2012). An alternative approach encourages students to act as epistemic agents, seeking and building knowledge about issues among themselves and through engagement with their broader community. One example of this model of learning is participatory action research (PAR).

Research has shown that a youth participatory action research approach can help build students' skills in information gathering and utilizing that information to make decisions and position youth to act as experts within their community (Barton and Tan, 2009; Bang and Vossoughi, 2016; Morales-Doyle, 2017). As Ozer and Piatt (2017, p. 5) point out, "Youth-led participatory action research seeks to engage adolescents in addressing issues that matter to them while identifying root causes that create and perpetuate the manifestations of those problems." Thus, as students begin to understand how people are thinking and feeling about a topic, that understanding becomes a tool for creating social change. This means creating opportunities for

students to not merely engage in discourse equipped with data that has been handed to them by an authority, rather to position students so they may authentically conduct the work of social scientists seeking to understand discourse taking place among multiple groups across and within communities. This type of analysis of discourse has largely been left to professional social science researchers. However, a shift to providing students with a more community-centered approach encourages multiple sources of knowledge and expertise. Youth are too often wrongfully dismissed as unknowledgeable and denied the agency to act as authentic information seekers when making decisions. However, under a PAR approach, professional gatekeeping gives way to opportunities for youth to become meaning makers of the discourses generated by their communities. Informal discourse analysis can be an important tool when engaging with students in youth participatory action research. As Koirala-Azad and Fuentes (2009) write:

> PAR attempts to redefine what counts as valid and relevant knowledge. In so doing, it demystifies the role and definition of the "expert." Instead, it transfers the power to create and use new knowledge to those who have been systematically abandoned or denied access to what has traditionally been accepted as legitimate spaces for knowledge acquisition and production (p.2).

Students can use de facto discourse analysis to identify topics relevant to them and their community. Although this analysis may lack the features of a formal discourse analysis conducted in a higher academic setting, youth may still analyze the community discourse to identify areas of concerns. For youth participatory action researchers, these areas of concern may act as a roadmap: identifying issues that need further attention and beginning to establish locally grounded, civic discourse about challenging topics.

3.3. Teaching civic discourse using *Vaccines!*

Recently, the National Academy of Education has offered guidance on teaching civic discourse, describing it in the following way:

> Civic discourse concerns how to communicate with one another around the challenges of public issues in order to enhance both individual and group understanding. It also involves enabling effective decision making aimed at finding consensus, compromise, or in some cases, confronting social injustices through dissent (Lee et al., 2021b, p. 1).

Conversations about challenging public issues are not solely, or even primarily, confined to classroom spaces. Yet, educational experiences can play a valuable role in teaching students how to engage in productive public discourse. Thus, the need for civic discourse requires both skills related to receiving information such as open-mindedness and active listening, but also sharing information such as communication and consensus building. Effective decision-making requires both receiving and sharing information.

In the *Vaccines!* guide, students are prompted to reflect on their own experiences and concerns about vaccines. They also conduct community interviews and survey-based investigations to better understand the knowledge, opinions, and cultural-historical contexts within which community members grapple with the wide range of information available about vaccines. Analyzing the myriad discourses about vaccines they find becomes an important frame for learning more about vaccines. Students are guided to analyze discourse *as data*. This disrupts the notion that data is something gathered by professional scientists; demystifying data as something students are fully capable of gathering and analyzing. Through this analysis students systematically identify "community concerns" in preparation for the remainder of their research. Some common themes might include concerns over how vaccines work, the timeline and scale of clinical trials, vaccine side effects, negative personal histories with vaccination, and general mistrust of the medical establishment. Discourse analysis of their class discussions and community dialogue creates an opportunity for students to take a productive and empathetic approach to understanding and confronting sources of vaccine hesitancy.

Thinking about these sources of hesitancy allows students to search for causes, by helping students identify various socio-moral factors at the root of them. As Ozer (2017, p. 175) discuss, students prepare to become active participants when they practice using civic discourse to share information with others. By properly identifying the root cause of concern about vaccines, or any other public issue, conversations can become much more targeted and have a greater potential for productivity. For example, if there is a common concern in the community that the vaccine trials were rushed, sharing information about the immunological basis for why vaccines work will not address that concern and may even backfire if people feel their concerns are not being heard or respected. Alternatively, discussing the design and timeline of clinical trials opens the possibility for a productive conversation. Beginning with community listening, data collection, and discourse analysis has the potential to build students' skills in effective communication and create positive experiences with civic discourse.

Students are also prompted to use community discourses about vaccines as learning experiences. For example, in the *Vaccines!* guide, students collect oral histories about vaccines and disease from people in older generations. Through this process, they gain a better understanding of what life was like when diseases such as polio, measles, mumps, and diphtheria were more widespread. The lived experience of adults they know can help make these past realities more concrete. Intergenerational conversations of this sort may play a key role in developing robust civic discourse, as Booth (2021) explains within the U.S. context:

> By embracing the practice of civic intergenerationality, we can address America's ongoing civic crisis. We can create a community of lifelong, reciprocal learners that uplifts our youngest civic agents while leveraging the experiences and wisdom of older generations (p. 4).

The bewildering array of information and discourses freely available through social media and other virtual sites highlights the critical information literacy skills students must draw on when trying to navigate issues, particularly politicized ones, online. In addition to being able to engage in communication, critical consumption of public speech in local, national, and global spaces such as that employed by politicians or the media is an important component of civic discourse (Lee et al., 2021a). Recognizing this need for information literacy, Task 7 of the *Vaccines!* guide provides

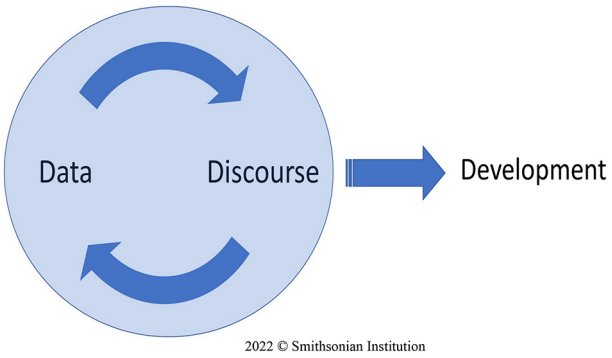

FIGURE 2
Data, discourse, and development framework.

activities for students to bring a critical lens to their own sources of information and those frequently used in their community. These communications are often national or global in nature, creating an opportunity for students to connect broader vaccines data and dialogues with those found locally. Understanding the bias introduced through news is necessary for students' informed decision-making about vaccines and to share with their community.

Civic discourse requires students to go beyond detached research. Students use what they have learned to become participants in and shapers of the community discourse, consensus-building, and decision-making. Students communicate their own ideas and knowledge as a way of moving their communities in directions they view as desirable.

In the *Vaccines!* guide, students are encouraged to utilize their positions within their community to become "trusted messengers" to help push forward and incorporate scientific data into community discourses about vaccines. By utilizing a neutral, empathetic approach to a topic that has become politicized, students can productively engage in public conversations that have become stuck in "us" vs. "them" ossified binaries. In the *Vaccines!* guide, students are encouraged to consider the best way of communicating with their own community. For example, they may use direct conversations, creative means like songs, visual communication tools like posters, or online tools like memes. A variety of options means a higher likelihood of students using a communication tool that resonates with their community.

4. Development: Combining data and discourse for a more sustainable future

The intention of developing student skills, abilities, and attitudes toward data and discourse is to develop students as active citizens to develop a more sustainable future for the communities to which the students belong (as shown in Figure 2). Students, with their local knowledge and perspectives, can become important assets in defining a sustainable future within their local context and joining in civic action-taking to make that vision a reality.

4.1. Defining development

Development can be a hotly contested term. In some contexts, development implies two problematic ideas. One, the idea of unrelenting economic development with the accompanying heightened drain on natural resources and deleterious impacts on natural systems. Discussing how this is unsustainable is beyond the scope of this paper (sf. Chomsky, 1998; Misiaszek, 2019). In certain contexts, economic development is certainly desirable. Yet, examining economic development in a vacuum or as a sole or privileged indicator of success, ensures an imbalance that largely excludes social, environmental, and ethical concerns. Considering a broader set of perspectives and goals is more complex than just pursuing economic development, but this balance, especially when locally defined, is more likely to lead to sustainable outcomes (Wanner, 2015; Mensah, 2019; Misiaszek, 2019).

The second problematic aspect of development arises from an implied sense of singularity of the final goal, essentially that a "developed" society or person should have a defined set of characteristics. Which people or cultures should determine this set of characteristics is generally not explicitly stated. However, in practice, the dominant voices of governments and institutions of the Global North often drown out alternative ways of conceptualizing a sustainable future and how to achieve it (Vásquez-Fernández, 2020).

Gough (2008) cautions that although specific types of knowledge may appear universal, all knowledge is tied to the culture and system that produces it. This highly contextualized and culture-specific knowledge can be an important source in generating localized sustainable alternatives to the one-size-fits-all globalized vision of an ideal sustainable future. Knowledge produced in one location cannot necessarily be transferred to another context without losing its meaning, as Redvers et al. (2022) explain:

> Traditional knowledges are collective, holistic, community-based, land-informed ways of knowing that are inherently interconnected with people and the environment. In other words, traditional knowledges are contextual… attempting to globalize these knowledges can cause them to lose their meaning, purpose, and focus on understanding the relationships between knowledge making and knowledge applications regionally (p. 156).

Despite the way the word "development" is employed in service of approaches centering economic development and dominant cultural constructs, the term "development" itself should not be tarnished by the ways it has been used. The difficulty lies not in the idea of development as improvement over time, but rather in the narrow nature of where development has been applied, such as in the sense of economic development, and the rigid outcomes which it has been used to measure, often defined by global institutions. There is opportunity to create space for a shared local and global conversation about what would constitute an improvement over time and how it should be measured. It is precisely this conversation—linking the present situation with future hopeful imaginaries—that is so critical for students to have as they engage in defining and working toward a better future.

4.2. A shared global and local definition and vision

When the UN created the SDGs, it did so after engaging in an extensive process of consultation (United Nations Development Program—UNDP, 2015). Although specific aspects of the goals can be critiqued, they provide a useful vision of medium-term desirable outcomes at a global scale. Yet, enacting this vision at a local scale requires more than just shrinking the size of the desired outcomes (Reddy, 2016). This decentralization must allow for the fact that an ideal sustainable future may look very different in different locations or to different cultures. Values related to boundaries between an individual and the collective, how to guarantee people behave in a responsible way to preserve the social fabric, and how people manage their relations to nature and the social world are all ways in which cultures differ widely (Schwartz, 2006). It therefore follows that the vision of a sustainable future and the methods of how to achieve that future would also vary widely. Rather than take the global vision of the SDGs and apply it in a local space, the SDGs can serve as a source of motivation and inspiration for a locally determined vision of a sustainable future.

Noteworthy in this more holistic, complex approach to development is the need for broad participation from community members, such as students, to help define what sustainable development could and should be for their local space and context. Under this approach, the definition of development shifts from a top-down, economic-focused neoliberal approach to an approach rising out of community identities and discourses and using localized data to provide a sustainable, shared community vision. Students can be an integral part of this visioning process, as they gather local data and begin and accelerate discourses about community identities and goals.

4.3. *Vaccines!*: Localized community-led development in practice

Students can make a valuable contribution by helping their communities develop their own localized ideas of a sustainable future. This localization can begin in relatively small ways. For example, students can take time to understand the concerns and ideas of people in a place through data gathering techniques such as surveys, interviews, and oral histories. Students are themselves part of a local community and their knowledge, feelings, and opinions are both valid sources of data and valuable.

In the *Vaccines!* guide, students start by considering their own identities using an Identity Map activity. They are prompted to think about their identity not as it specifically relates to vaccines but using a more complete series of open prompts to think about their roles, their interests, the groups they belong to, and the aspects of themselves essential to their sense of self. Framing the guide in this way allows for students to more explicitly examine how their identities are related to their beliefs (Blanchard et al., 2019). Students can interrogate the relationship between their identities, perspectives, and the types of vaccines discourse they engage in.

Users draw upon their own knowledge of themselves, their place, and their community throughout the guide. In addition, students naturally bring their own cultural value orientations, unconsciously

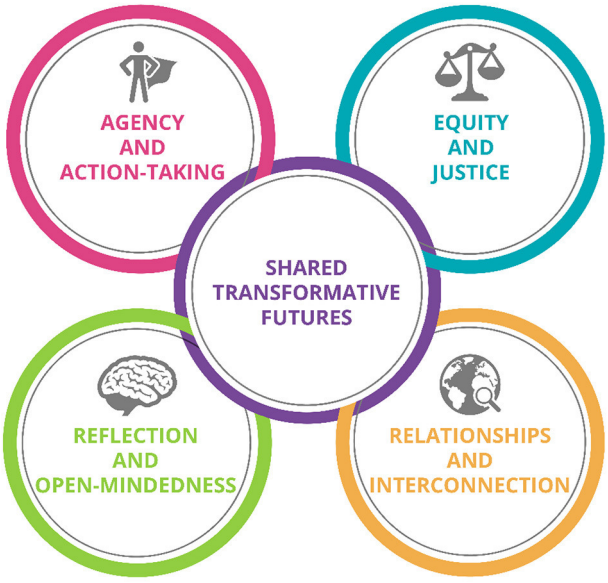

FIGURE 3
Sustainability mindsets.

shaping conversations and proposed solutions (Schwartz, 2006). This means that solutions developed this way through local data, and discourse are already integrated with localized knowledge and values. This knowledge is not limited to the personal knowledge and attitudes about vaccines, it includes topics such as the best way to engage in civic discourse, how widespread misinformation is, and the role history and current cultural movements have in shaping attitudes.

Using this type of diverse and localized approach to development may have bi-directional impacts, potentially impacting both the personal development of students as well as the development of the community.

4.4. Developing sustainability mindsets

Shifting toward a true focus on a shared community vision for a sustainable future requires certain mindsets for individuals and the community. Developing students' "Sustainability Mindsets" (shown in Figure 3, adapted from Gibson, 2021) is an explicit goal of the Smithsonian Science for Global Goals community research guides.

First, there is a need to have an approach that centers *Agency and Action-taking*. Students and communities must feel a sense of power, being able to do something about the problems they notice. Communities and individuals develop through iterative and reflective action-taking (Gibson et al., 2020). To create change in their communities, students must learn to define specific actions to improve problems they identify and then plan and implement those actions.

In the *Vaccines!* guide example, agency is supported not only through active information gathering and decision-making, but also

by putting ideas into actions. Students are prompted to think about what they should do and then implement those actions, encouraging a sense of agency (O'Donnell, 2018a). They are given the opportunity to connect their learning to actions they take in their community, such as sharing what they have learned either informally or using outreach methods relevant to their local community.

Second, there is a need for *Reflection and Open-mindedness*. The ability to listen to other's perspectives in an open-minded way and to engage in self-reflection has deep ties to the ability to create a sustainable, balanced vision. The need for perspective-taking is well-documented within socioscientific constructs (Sadler, 2004; Zeidler et al., 2005, 2011). When engaged in practices of science communication using discourses and data, this need for perspective-taking is particularly acute (Newton and Zeidler, 2020). Failing deeply to engage with the perspectives of others and critically examine our own perspectives makes it difficult to engage in productive community dialogue and find consensus in a sustainable, shared community vision (Colucci-Gray et al., 2006).

In the *Vaccines!* guide example, specific activities prompt students to consider their own perspectives and the perspectives of others. In Task 6, as an illustration, students consider their own perspective on who out of a group of people with different identities should get access to a vaccine first, if the vaccine supply is limited. They then reorder using scientific data, as well as social, health, economic, and ethical perspectives. This reordering is deliberate to support the development of the idea that different people can reasonably make different choices because of their priorities and values. Students must critically examine their own set of assumptions and are given the opportunity to reflect and change their mind in response to their analysis.

Third, communities and individuals must focus on *Relationships and Interconnection*. This encompasses many relationships, for example, developing the relationship between individuals, their places, and how that relationship is embedded in the natural world (Duhn, 2012; Di Fabio and Tsuda, 2018). Also crucial are the interpersonal relationships within members of a community (Christens, 2010; Thakhathi and Netshitangani, 2020). Furthermore, students need to explore and be mindful of the relationship between global systems, dialogues, and goals and their local counterparts. The interconnections between and within all these relationships highlights the systems that make the world the way it is.

In the *Vaccines!* guide example, relationships within the team of students working together are continually emphasized as students are prompted to develop collaboration skills. In addition, the relationship with their local community is developed through a reciprocal give-and-take of information. As students use PAR tools such as surveys and oral histories, they learn more about the people around them, their values, and experiences. They are guided to listen closely, such as with this quote in the guide:

> Growing up in a community, the community molds us. If you want to change people's behavior, you need to be aware of where people are coming from, from a cultural standpoint. The first thing you have to ask is, "What is the concern?" Talk to the community to understand what the concern is. Don't make an assumption. First hear the community. Then align the communication to the concerns of the community. —Dr. Panagis Galiatsatos, MD, MHS (Smithsonian Science Education Center—SSEC, 2021, p. 11).

In addition, they attend to global dialogues through their interrogation of information sources. Then, as they create communication vehicles to share information with their community, students are giving back to the people around them.

Fourth and finally, the lens of *Equity and Justice* must be applied as an interrogative tool to all aspects of sustainability. Rather than reinforcing existing inequalities, a truly sustainable path attempts to shift toward a just future (Gibson, 2022). This includes inequities and injustices arising from environmental, social, economic, and ethical sources.

In the *Vaccines!* guide example, prompts encourage students to embed equity and justice into their activities. For example, when conducting a survey, students are told "Think about the categories in your identity map. Use those categories to try to pick a diverse group of people to survey to get a more accurate idea of what your community thinks and feels. For example, you may want to survey people of many different ages or of more than one gender." (Smithsonian Science Education Center—SSEC, 2021, p. 12). Or later in Task 2, they are asked to think about collective responsibility to contribute to herd immunity. In Task 4 they think about the importance of equity and inclusion in clinical trials, considering how that relates to community trust. In Task 6, they think specifically about inequality and COVID-19 and explore the causes and impacts of that inequality. Embedding equity and justice themes in many tasks may help to encourage students to see it as a rightful part of every conversation, rather than a supplemental or final additional lens to choices or conversations.

4.5. Developing communities

As students develop their own Sustainability Mindsets and contribute to the development of a vision for a sustainable future in their community, they are playing an important role in developing their community. Data and discourse become tools for students who take an active approach to engaging in current and future civic life.

5. Discussion: Data, discourse, and development

Developing a shared vision for and achieving a sustainable future is a substantial challenge for both local and global communities. The public health challenge of COVID-19 can serve as a useful exemplar for the role education can play in addressing complex global issues, such as the ones highlighted by the UN SDGs. The COVID-19 vaccines became a highly politicized issue and misinformation about vaccines spread widely. Although correct **data** about vaccines is and was easily available, it was not convincing to many people who were vaccine hesitant, possibly because the data did not speak directly to their concerns—thus, the need for **discourse** to help chart productive paths forward for community **development**. The *Vaccines!* guide encourages trusted local community members (students) to use what they have learned through local and global data and engage in localized civic discourse on an issue with global implications. This discourse can in turn become a source of data itself, allowing for a process of continually customizing the conversation to be most relevant to the hopes and fears of a local community.

There is an obvious need to shift conversations about controversial global issues, such as how to address climate change

or pandemics, to more productive paths. Students can be a vital part of this shift, contributing to the development of their communities. As embedded members of a local community they are perfectly placed to lead and contribute to discourses about sustainable ways forward. However, this shift does not magically happen, it is the result of specific educational experiences, both formal and informal. The approach of the Smithsonian Science for Global Goals guides is designed to create the types of experiences that encourage productive development of ideas and actions for a sustainable future in local communities. One of the major ways it attempts to do so is in the interplay between data and discourse.

Understanding scientific data, how it is collected, and what it means is undeniably useful. However, developing an understanding using other sources of data is also essential, such as data drawn from the opinions, thoughts, culture, and ways of knowing localized to a space. Without this data, proposing and developing sustainable solutions would be impossible. To expand students' data skills, educators must be grounded in a framework that holistically considers ethics, community, and environmental impacts. Data must be contextualized to the problems that students face locally. And students must be given the tools to communicate scientific understandings to others in service of sustainable development.

Understanding data and what it means within local spaces requires knowledge and meaning constructed through discourse. It is not enough to know what data means in the abstract, the meaning must also be understood within the context of a local community. Through discourse and discourse analysis, students can bring highly subjective pieces of themselves and their communities to the surface, to truly see and understand their values. After this process, engaging with meaning-making and data becomes different. It can now be seen through the lens of personal and community values.

The relationship between data and discourse is iterative, with one informing the other. In the *Vaccines!* guide, students gather and analyze community discourses as they engage in activities such as reflecting on their own opinions, surveys, and oral histories (Smithsonian Science Education Center—SSEC, 2021). This discourse analysis leads to a Community Concerns list, which they continually return to, matching the data they collect to the discourses they found. This churning process between data and discourse helps ensure that the solutions coming forward, and the investigations themselves, are grounded in the discourses and need for data present in the local community.

When students start with data, they gather information about themselves and their communities and examine their own and civic discourses using a critical lens drawn from their values, morals, and identities. They use these experiences to develop their community's vision about future and sustainable solutions. This data for learning, customized and shared with others by engaging in civic discourse, provides the opportunity for students to develop their ideas and actions to protect our societies and planet.

Author contributions

CO'D was invited to submit a paper to Frontiers: communications, submitted the proposal, wrote the abstract, introduction, and data section. CO'D and HG conceptualized the paper topic, outlined the structure of the paper, and wrote the proposal. MS wrote the discourse section. HG wrote the development section and discussion. All authors contributed to the final review and edits of the paper.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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