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Promoting Science Literacy and Awareness across the Globe: the Role of Scientists as Science Ambassadors

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Science literacy has many personal and societal benefits that allows for better informed decision-making. Although the importance of science literacy is recognized globally, there are many challenges associated with its promotion. Scientists are more frequently engaging with nonscientific audiences through public outreach activities and with increasing support from institutions and professional societies. This is especially true regarding microbiologists and other related professionals since the start of the global 2019 coronavirus disease pandemic heightened the need to convey novel and rapidly evolving scientific information to lay audiences. The means by which professionals engage with these audiences affect the efficacy of the relay of scientific information. One method of engagement is the "ambassador approach," which aims to establish dialogue among different groups of people and scientists. In this perspective article, we discuss this approach, highlighting activities for the promotion of science literacy organized by the American Society for Microbiology Ambassador Program and similar programs of other scientific societies. We discuss the benefits and challenges of implementing an ambassador approach, propose potential improvements that could be made to existing programs promoting science literacy, and ultimately advocate for increased implementation of science ambassador programs.

KEYWORDS American Society for Microbiology, science literacy, science outreach, science communication, science ambassadors, public engagement with science

PERSPECTIVE

Scientific literacy is essential as it helps individuals make well-informed decisions across a wide array of topics, including personal health, nutrition, and natural resource use (1). Indeed, science education is considered an important part of a young person's education across the globe (2–8). Despite widespread agreement on the importance of science literacy and its personal and societal benefits, there is a lack of consensus regarding its definition (1). One definition, derived from the Program for International Student Assessment, defines competency in science literacy as the ability to (i) explain scientific phenomena, (ii) evaluate and design scientific enquiry, and (iii) interpret data and evidence scientifically (9). Another simple definition, from the National Academies of Sciences, Engineering, and Medicine, describes science literacy as "familiarity with the enterprise and practice of science" (1). Other definitions are more specific. For example, some authors define science literacy with a focus on specialized skill sets required of scientists for the development of curricula for science students (10, 11). In this article, we refer to science literacy

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broadly, applying to all people, as a general understanding of scientific concepts and the ability to engage in critical discussion around these concepts.

With increasing frequency, there have been calls for greater engagement of scientists with the general public for the promotion of science literacy and education (12–15). Surveys show that scientists are also motivated to engage with the public and policymakers (16–20). Within the microbial sciences, and biology more broadly, there are many important scientific concepts that the public should be aware of. These include long-standing concepts, such as Koch's germ theory of disease, to more contemporary ones like the importance of 2019 coronavirus disease (COVID-19) vaccines, antibiotic resistance, issues around climate change, and the increasing prevalence of genome editing technologies. Scientific outreach and engagement are important tools for promoting science literacy and educating the public and policymakers (15, 21). There are challenges associated with these practices though. Among them are cultural, religious, and political polarization of important scientific topics (22–24). Moreover, most outreach programs focus on content knowledge, ignoring other dimensions of individual science literacy, such as identifying and judging scientific expertise and information reliability (1). The spread of misinformation and a lack of accessibility to reliable information can further compound the issue (25). Additionally, language barriers exist, since most resources are only available in English (26). In the promotion of science literacy globally, best practices need to take equity into account, being inclusive of marginalized and underrepresented audiences (27–30).

Early-career scientists have an important role in science outreach and the promotion of science literacy, as they can often more effectively engage with younger audiences (31). They also tend to be more engaged online than older scientists (19, 32), which can be helpful in reaching wider audiences in virtual spaces (e.g., social media) where people already are receiving information (33). Furthermore, science communications skills are important for scientists to develop, and it has been argued that formal communication training should be incorporated into science curricula at the undergraduate and graduate levels (34). There are several examples of pedagogical practices encouraging students to communicate with the general public and lay audiences, leading to greater competence in this skill (35, 36).

One strategy that may be employed in public engagement and the promotion of science literacy is an "ambassador approach," where dialogue between scientists and nonscientists can occur outside of traditional educational settings (37). This may be particularly important when considering diverse groups of people to help build relationships between scientists and the public. Here, we discuss some existing programs that take advantage of this approach for the promotion of science literacy. We focus our discussion on programs established by the American Society for Microbiology (ASM), while also taking note of similar programs from other scientific societies and groups. Although data assessing the impact of these programs remain limited, we argue that these programs are valuable for the promotion of science literacy and advocate for their increased adoption and development.

THE ASM AMBASSADOR PROGRAM AND YOUNG LEADERS CIRCLE

ASM is one of the largest life science societies in the world, with more than 30,000 members around the globe. This large and increasingly international membership base inevitably creates challenges in meeting its diverse needs. In order to address these needs and promote communication and awareness among local and global communities, ASM has established two programs: (i) the ASM Ambassador Program, which is composed of ASM Country Ambassadors as well as International and U.S. Young Ambassadors, and (ii) The Young Leaders Circle (YLC) (38).

The goal of the ASM Ambassador Program is to assist ASM in advancing its mission of promoting the microbial sciences globally. Ambassadors provide an official local presence on behalf of ASM and play significant roles in identifying and communicating national and regional issues, needs, and opportunities to ASM. The role of Ambassadors is multifaceted and includes interacting with scientists at international meetings and other venues as well as with the public, often through Ambassador-driven public outreach initiatives. As of 2022, the ASM Ambassador Program spans 112 countries across the globe, as well as 33 U.S. states (Fig. 1). Considering its broad reach, this program serves to foster a global network of individuals working to promote accessibility of the microbial sciences across the world. Stemming from the ASM Ambassador Program, the YLC is an international advisory group that is composed of current and former ASM Ambassadors and student chapter representatives. YLC members work to empower early-career microbiologists' voices, increase gender diversity in the field of microbiology, foster global networking, and support education and professional development (39). They also provide strategic direction for the ASM Ambassador program, setting priorities and assisting its governance. While much of the work undertaken by ASM Ambassadors and the YLC involves engaging with students and early-career scientists, public outreach and education is another major area of focus. Many activities designed and implemented by ASM Ambassadors are aimed at promoting science literacy within their local communities. In the following sections, we provide some examples of these activities and their impacts.

Promotion of science literacy by ASM and its ambassadors

ASM Ambassadors are highly dynamic early-career leaders who speak on behalf of ASM in their regional scientific communities, promoting networking, career development, and teamwork to advance science internationally. As ASM Ambassadors come from diverse regions of the world, they can often more effectively communicate with their local communities than would be

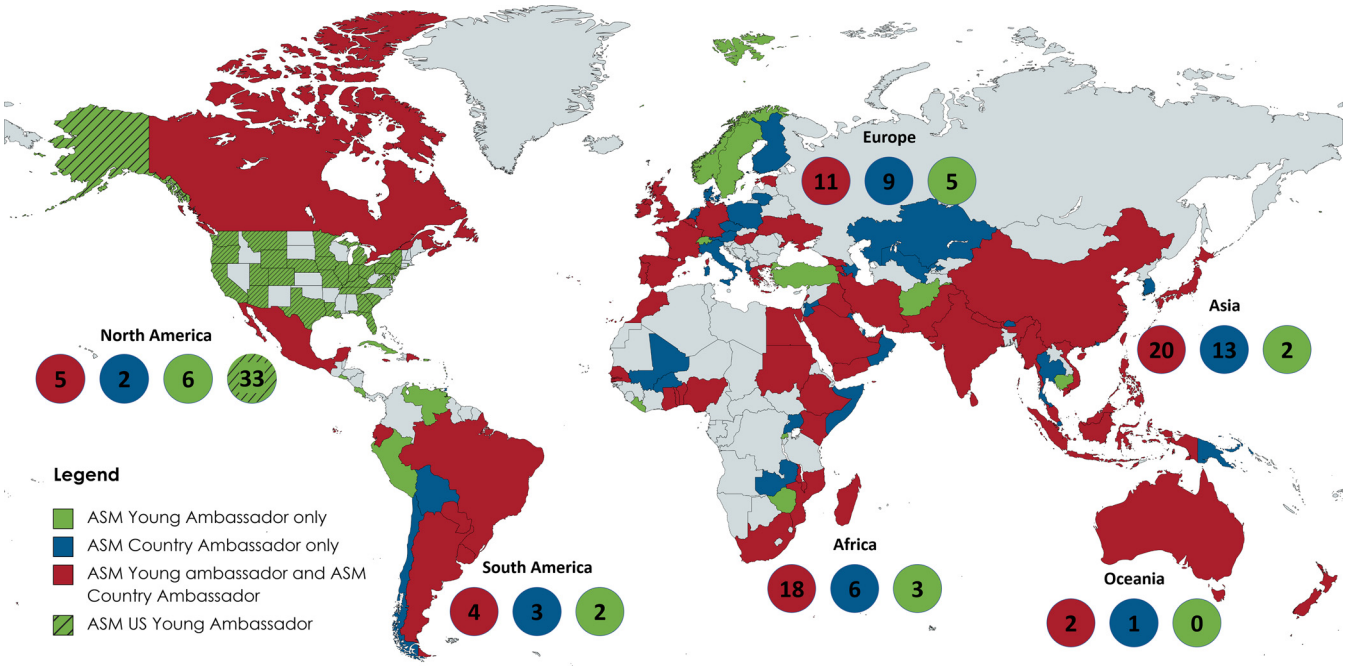

FIG 1. World map depicting countries in which the American Society for Microbiology Ambassador Program has a presence. Numbers within circles indicate the number of countries on each continent that have an ASM Young Ambassador (green), ASM Country Ambassador (blue), or both (red). For the United States, individual states with a U.S. Young Ambassador are depicted (green with black stripes). These data are current as of 2022.

possible by ASM alone. The intersection of different identities with their scientific identity opens the possibility for increased connections between Ambassadors and nonscientific audiences. Shared identities and cultural values can help instill trust in scientific professionals, as self-identity and cultural values influence how individuals perceive information (40). Furthermore, being integrated in their local communities, ASM Ambassadors are much more in tune with their local communities and their needs. They can more easily navigate nuances of their local cultural, political, and religious landscape, leading to increased acceptance of their outreach programs than might be achieved by outsiders.

Table 1 describes some examples of activities for the promotion of science literacy that have been funded by ASM and implemented by ASM Ambassadors in recent years. These programs are as diverse as the people organizing them and vary widely in their goals and audiences. Some of these activities work to break down language barriers. For example, the team behind the DivulgaMicro program has translated many ASM resource materials into their local languages (41). Through numerous workshops, they have also trained hundreds of early-career scientists in best practices for science communication with general audiences. Feedback on the DivulgaMicro program has been very positive, with participants praising the interactivity and usefulness of content presented in workshops (41, 42). While DivulgaMicro does not necessarily interact with lay audiences directly, it has been successful in giving more people in the region skill sets that will allow them to engage with locals more effectively. Other ASM Ambassador activities involve connecting with scientific and nonscientific audiences more directly. For instance, one recent activity organized by the Ambassador to Cameroon involved traveling to the northern part of the country to interact with the Maroua community. Working with public health professionals in the region to communicate in the local dialect and respect the religious culture of the area, a team of microbiologists connected with many individuals in this community to discuss public health issues with them. In doing so, they worked to promote awareness of hygiene practices that may be implemented to reduce disease incidence in this region. These efforts were positively received, and benefits of hygienic practices were acknowledged. However, for many, poverty and socioeconomic status were cited as drivers behind unhygienic practices. Many other great initiatives are being led by ASM Ambassadors. These are compiled into the yearly newsletter from the YLC (entitled "Your Leadership Communication: Your Pathway to the ASM Young Ambassador's World"), covering topics pertinent to ASM Ambassadors as well as student and postdoctoral members of ASM. Theses newsletters, as well as other relevant information regarding the ASM Ambassador Program, are available on a dedicated website (https://asmyoungambassadors.wordpress.com/).

COVID-19 pandemic influences on science literacy activities

Soon after the World Health Organization declared COVID-19 a pandemic in March 2020, quarantine and physical distancing led to the suspension of face-to-face activities in almost all countries (43). COVID-19 brought microbiology

TABLE 1
Examples of activities carried out by ASM Ambassadors that work to promote science literacy and engagement[a]

Activity	Yr	Description	Target audience	ASM young ambassador
ASM workshops at Women in Science STEAM camps	2016	This workshop took place in Lima, Peru, and was aimed at girls from different countries across Latin America. They gathered to learn about STEAM, working with microscopes, and culturing of bacteria using petri dishes. This and subsequent workshops were in part facilitated by the United Nations Girl Up Program, which aims to address gender disparities in scientific fields.	Secondary school girls from around the world	Uruguay
	2018	This workshop took place in Tbilisi, Georgia. It worked to teach girls about health through the lens of microbiology and presented information about the role of microbiology in the One Health approach.		Republic of Georgia
	2019	This workshop took place in Tallinn, Estonia, and was cross-cultural with 100 students from Eastern Europe and the United States. Together, they explored the invisible world of organisms that live in, on, and around us through hands-on educational activities.		Estonia
DivulgaMicro	Since 2018	The DivulgaMicro project is an initiative with the goal of enhancing science communication skills among early-career scientists in Brazil. It maintains a website dedicated to providing online resources for scientific outreach and also organizes workshops across Brazil. These workshops teach best practices for scientific writing and presentation as well as communication techniques for interacting with general audiences.	Brazilian scientists interested in public engagement	Brazil
Smithsonian Outbreak DIY Exhibits	2019	In 2018, the Smithsonian's Museum of Natural History launched its "Outbreak: Epidemics in a Connected World" program, for which a DIY version consisting of a series of posters was developed. This exhibit works to educate the public about emerging infectious diseases and the concept of One Health. ASM Ambassadors presented this exhibit at science outreach events and in public venues across the world.	Communities across the world	Various
Science communication through social media in Latin America	Varies; increased activity since 2020	Partially spurred from the Brazilian DivulgaMicro project, a social media campaign was started in Latin American countries at the beginning of the COVID-19 pandemic. Through posts and video series, these social media channels worked to distill academic information down into simple language that could be understood by all people. Topics of videos included antimicrobials, zoonotic diseases, beneficial microbes, hospital-acquired infections, and antimicrobial resistance, among others. Brazil: @divulgamicro (Instagram, Facebook) Argentina: @microbestory (Instagram, Facebook) Uruguay: @microbiouy (Instagram) Paraguay: @microbeclubpy (Instagram, Facebook) Mexico: @Micuorum (Instagram)	Latin Americans	Various
COVID-19 webinar series	2021	In a collaboration between Houston Taste of Science (a national science communication organization) and the Texas Medical Center Student and Postdoc Chapter of ASM (ASM-TMC), a two-part webinar series was developed to educate the public on COVID-19 and debunk myths and misinformation. This webinar was	Houston, Texas residents	Texas, USA

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TABLE 1 (Continued)

Activity	Yr	Description	Target audience	ASM young ambassador
		hosted by graduate students and postdocs from the Texas Medical Center, who had live conservations with virologists, infectious disease experts, and epidemiologists from Baylor College of Medicine, UT Health Science Center at Houston, Houston Methodist, and Harvard MGH. This series was later adapted to a shorter webinar tailored towards high school students, young adults, and their families in collaboration with the ASM-TMC Young Biologist Program at the Alief Independent School District. All webinars were recorded and made available to the public via Youtube (https://www.youtube.com/@asmtmc8094/videos).		
Workshop on biorisk assessment	2021	During the COVID-19 pandemic, a risk assessment workshop was conducted to educate professionals and early-career scientists working in laboratories about biorisk assessment. The workshop was based on WHO scenarios on biorisk assessment and used hands-on exercises related to waste management and shipping of biological substances.	Professionals and early-career scientists	Pakistan
K-TESST	2022	K-TESST is a citizen science project that aims to educate Tennessee residents about soil and water quality. By distributing soil and water testing kits, this program will collect and map data across the region and educate people about the environment by getting them involved in the process of science (https://sites.google.com/vols.utk.edu/k-tesst/home?authuser=0).	Tennessee residents	Tennessee, USA
Bacteria Grub at the Library	2022	This outreach activity is aimed at getting children excited about science and learning about the ubiquity of bacteria. Participants were taught how to perform environmental sampling using agar plates and simulated bacterial growth using icing to decorate sugar cookies.	School-aged children	Louisiana, USA
Community Sensitization on Good Hygiene Practices in Cameroon	2022	A team of six microbiologists led by the Young Ambassador to Cameroon traveled to the Maroua community to connect with them. This community is burdened by waterborne and foodborne diseases. Working together with local health district professionals, this team entered the community and discussed public health challenges with them. Community individuals included roasted meat sellers, street drug traders, and individuals using unclean water for drinking, washing juice bottles sold in the community, and washing animals.	Maroua community of northern Cameroon	Cameroon

[a]STEAM, science, technology, arts & design, and math; K-TESST, Knoxville-Tennessee Environmental Soil and Stream Testing project; DIY, do it yourself; WHO, World Health Organization.

and epidemiology closer to the general community. With this came opportunities as well as challenges. On one hand, people were primed to become more scientifically literate, as they wanted to learn more about viruses, disinfectants, and vaccines. This made public engagement on scientific issues easier. However, it also came with a significant rise in disinformation and a lot of unknowns in a rapidly changing landscape (44). With new discoveries happening daily, information from reliable sources evolved quickly, potentially sowing confusion. Additionally, with the rapid transition to online portals, all outreach events and public engagement activities began to rely on virtual communication tools (45). Across the globe, the effects of these shifts varied. Online meetings improved reach and accessibility for many regions, but decreased accessibility was seen in others where home Internet and computers were limited (46).

In the wake of the pandemic, many scientific societies and organizations established COVID-19 public outreach campaigns (47). Public engagement by ASM included development

of freely available public outreach tools, a shift in focus to COVID-19 on the "This Week in Virology" podcast, and increased advocacy for pandemic-related policy that is rooted in science. ASM Ambassadors helped put together some of these public engagement resources as well as organized webinars and virtual workshops. Many were tailored for specific audiences to help meet the communication needs of diverse communities. Ongoing activities were also adapted to virtual formats. For instance, in Latin America, social media presence increased during this time, as a series of accounts was created that worked to promote science literacy in this region (Table 1). As another example, the in-person DivulgaMicro workshop, developed by a former Young Ambassador to Brazil, was adapted to be given remotely (41, 42). Originally, the DivulgaMicro Workshop was 1 day long and was carried out at universities and at scientific conferences across Brazil. The online version of the DivulgaMicro workshop was modified to a 3-day format (8 h per day) and used a combination of short lectures and active-learning activities. This online workshop was adapted successfully; participants felt that sessions focused on teaching strategies for effectively communicating with the public were the most useful. Difficulties participants faced were limited to mainly technological issues, such as Internet connection instability.

PROMOTION OF SCIENCE LITERACY BY SCIENTIFIC SOCIETIES BEYOND ASM

In addition to ASM, many large professional societies engage in public outreach to promote science literacy. For instance, the American Society for Cell Biology (ASCB) has established the Committee for Postdocs and Students (COMPASS), analogous to the Young Leaders Circle of ASM. COMPASS not only represents trainees and creates opportunities for professional development but also creates opportunities for public outreach (48). This is best exemplified by the COMPASS outreach grant program, which awards $1,000 for projects or events that engage the public (www.ascb.org/grants-awards/compass-outreach-grants). The American Chemical Society (ACS) promotes professional development and public outreach by supporting institutional ACS Graduate Student Organizations (GSOs). Similar to ASCB members, students in these GSOs are eligible to apply for an ACS Student Communities engagement grant (www.acs.org/content/acs/en/education/students/graduate/graduate-student-organizations.html).

Other professional organizations have focused more on providing structured training for early-career scientists who wish to engage in public outreach. For example, the Society for Developmental Biology science communication internship program gives graduate students and postdocs an opportunity to learn how to communicate science through social media and society newsletters (www.sdbonline.org/science_communication_internship). Furthermore, organizations such as the Federation of American Societies for Experimental Biology and Geological Society of America have launched science policy fellowships that provide hands-on experience interacting with public officials and intensive training in science communication skills (www.faseb.org/awards/science-fellowships; www.geosociety.org/GSA/Science_Policy/GSA_Science_Policy_Fellowship). Similarly, the American Association for the Advancement of Science (AAAS) has established the Leshner Leadership Institute for Public Engagement with Science to train fellows in science communication and prepare them to pursue their own public engagement projects at their local institutions (49).

Finally, several organizations have established ambassador programs. One program launched by AAAS, the IF/THEN Ambassador program, focuses specifically on promoting women in science, technology, and math (STEM) with ambassadors serving as role models, sharing their experiences in STEM careers (ifthen.aaas.org/Home/About). Another program, supported by the National Science Foundation, is the STEM Ambassador Program (STEMAP) at the University of Utah. STEMAP trains and supports students, postdocs, and faculty members in carrying out public outreach activities outside of traditional venues such as schools and museums (50). The program has trained over 100 STEM ambassadors to date, reaching out to thousands of members of the public in various communities. Importantly, the program has also performed surveys and case studies of participants and disseminated the findings in peer-reviewed journals (37, 50). Both scientists and members of focal groups have responded positively to their implementation of an ambassador approach, reporting benefits in its use.

PROGRAMMATIC STRATEGIES FOR PROMOTION OF SCIENCE LITERACY

Today, many critical challenges we face, such as climate change, increased incidence of disease, and famine, require science and science-backed policy to solve them. Programs that work to promote science literacy via outreach and engagement by scientists are important tools for educating the public and policymakers (15, 21). Science is not static; facts change over time as new discoveries are made. Therefore, science literacy must include a component that instills understanding of scientific practices, how to judge scientific expertise, and how to assess the reliability of information (1). The goal in doing this is to mitigate the spread of misinformation, as well as limit cultural and political polarization of key scientific issues. Clearer definitions of what engagement with the public means and its goals are also needed (51, 52). This should help inform the design of outreach activities and lead to more positive outcomes.

In designing programs and activities for the promotion of science literacy, pedagogical practices such as backwards design can be helpful. With backwards design, desired learning outcomes of an activity are identified first, followed by a determination of what evidence can be used to assess results (53). Only after these are established are activities and assessments designed. Formal training of scientists in pedagogy and scientific communication for outreach should be supported by more institutions. Adequate communication skills are a prerequisite

for effective public engagement, and a lack of such skills severely hampers science communication efforts (18, 54). Communication training can help those involved in outreach to set clearly defined objectives that are tuned to particular audiences, fostering greater engagement and achievement of desired outcomes (55).

While many programs tend to focus on one-way dissemination of scientific facts (56, 57), there are strategies that may be implemented for more effective public engagement (15). More two-way communication between scientists and the public through outreach should be implemented to promote public trust and interest (37, 57). This ambassador approach to public engagement has benefits to both scientists and nonscientists alike and leads to positive societal impacts (37). Active engagement and dialogue between science ambassadors and nonscientists helps build relationships and promote learning for all parties by moving away from the deficit model, where scientists engage in one-way communication to a public perceived to be adequately informed about science (15, 58). This deficit model is largely considered flawed and is recognized as an ineffective engagement strategy (37, 55, 59, 60). Studies assessing the outcome of the ambassador approach implemented by STEMAP have indicated that scientists value this approach and see benefits in its implementation (37, 61). Given the accomplishments of ambassador programs, such as those of ASM and STEMAP, we argue that more programs like these should be developed and supported by scientific societies and universities.

Improvement of programs and their activities over time will require better protocols for assessing their efficacy and impact. More research is needed in these areas, including on the benefits and drawbacks of different engagement practices such as the ambassador approach. Publishing formal assessments of science outreach activities and their outcomes should be encouraged and become more commonplace (62). This allows for the establishment and refinement of best practices. Unfortunately, much of what has been published related to science outreach and the promotion of science literacy is spread across many different fields of literature (63). Use of a common set of keywords in papers can help combat this (62). Through learning about the experiences of others, engagement practice can continually be improved over time and the short- and long-term impacts better understood.

WAYS TO GET INVOLVED IN PROMOTING SCIENCE LITERACY

Given the many forms that science outreach and the promotion of science literacy can take, there are many ways in which scientists at any level of their career can begin to get involved. Starting local can be a great first step. As more and more scientists are recognizing the importance of outreach (16–20), it is likely that peers and mentors may be able to point out what opportunities exist locally. Museums and zoos often have volunteer opportunities that involve engaging with the public. Universities may have connections with primary and secondary schools or local science fairs with which there are opportunities. Those at academic and research institutions may be able to reach out to an institutional office of education and outreach or a student association that participates in outreach. At institutions that lack these resources, scientific societies may provide the opportunity to establish them. ASM, for instance, has a student and postdoctoral chapter program. ASM members can form chapters at their local institutions and host a range of events aimed at advancing the microbial sciences. Chapters benefit from their association with the society, as it permits access to ASM funds and resources that can kick start or help grow science literacy and outreach programs. ASM members can also apply for funding through community science grants to organize public science engagement events in their local communities. Programs such as these are a facet of many scientific societies and can provide support that may not be available locally.

Joining a scientific society can be a great way to engage in science outreach. Many societies have science communication courses and workshops. These programs provide instruction on effective communication for public engagement. Scientific societies also commonly have active outreach programs and activities where individuals can volunteer their time. Ambassador programs are one example of these. For societies lacking such programs, individuals can work to establish them by reaching out to society leadership and making it known that members want and would benefit from such programs. Implementing training programs for science communication best practices can be key, as this has been shown to be beneficial for scientific outreach outcomes (64, 65). Furthermore, allocating funding toward running science outreach activities can be crucial. As an example, much of the success of the ASM Young Ambassador Programs may be attributed to the Young Ambassador Project Fund. ASM Ambassadors apply for this funding by submitting proposals and budgets for projects they would like to run. ASM then reviews these proposals and grants funding based on their merit and potential impact. The availability of these funds fosters innovative ideas and permits flexibility of activities in different regions across the world.

CONCLUSIONS

The personal and societal benefits of promoting science literacy cannot be understated. Scientists, through outreach and engagement, can remove barriers to access of scientific information for many different targeted audiences, including the general public. Promotion of science literacy across the globe requires scientists to bridge language, cultural, political, and religious barriers. Access to reliable scientific information remains a challenge globally. ASM, through its large global network of programs, has demonstrated how valuable they can be in establishing dialogue among different groups of people and scientists. Although more work is still needed to optimize its efficiencies, an ambassador approach to public engagement is

well-suited to foster communication and connection among diverse groups of people. Programs that incorporate these practices into their activities are apt to benefit from this approach and see positive outcomes as a result.

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