Perspective

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Talk To A Scientist: a Framework for a Webinar-Based Outreach Program for Scientists to Engage with K–12 Students

Shreeya Mhade,[a] Snehal Kadam,[b] and Karishma S. Kaushik[a]
[a]*Department of Biotechnology, Savitribai Phule Pune University, Pune, Maharashtra, India*
[b]*Hull-York Medical School, University of Hull, Hull, United Kingdom*

Science outreach programs that enable real-time interactions between scientists and school-aged children are known to positively impact learning gains and students' perceptions of scientists. To expand K–12 outreach by scientists, it is important to build structured outreach programs which offer scientists well-defined opportunities, while providing school students regular and diverse interactions. We describe Talk To A Scientist, a science outreach platform in India, where scientists use a webinar-based approach to share their research with K–12 students (6 to 16 years). Running weekly for nearly 3 years, Talk To A Scientist has hosted over 100 live interactions, with a wide reach to participants across the country. Here, we outline the framework used to build Talk To A Scientist and discuss key gains, considerations, and challenges in the development of the program. We also suggest potential adaptations with which this framework can serve as a guideline for the implementation of similar K–12 outreach programs across diverse country- and context-specific settings.

KEYWORDS science outreach, webinars, K-12 students, children, scientists, informal science education

PERSPECTIVE

School students typically engage with science as a subject of study through a curriculum prescribed in textbooks, with almost no real-life interactions with scientists during the process (1). For students, this not only presents science in a limited and often outdated manner, but also offers minimal insights into the process and people behind scientific endeavors. Science outreach is an effective means to introduce novel and current scientific concepts to K–12 students and to do so in an interesting and engaging manner (2, 3). Importantly, outreach platforms offer the opportunity for school students to directly interact with working scientists and science professionals. This is important, given that face-to-face interactions with scientists are known to positively impact learning gains and students' perceptions of scientists (4–7). However, despite its need and relevance, several factors hinder scientist participation in K–12 science outreach (8, 9). Despite a strong desire to contribute, scientists report significant challenges related to time constraints and access to information on outreach opportunities, along with concerns of outreach involving large preparation and administrative obligations (8–11). Given this, scientists are more likely to be inclined toward outreach engagements with limited and well-defined time commitments and those that allow them to bring forth their own research or domain expertise (9, 11). Along these lines, there has been a growth in formal science outreach programs to enable extracurricular interactions between scientists and school students. These K–12 science outreach programs have typically involved in-person interactions, where different scientists are invited to schools, camps, or learning centers for talks, demonstrations, or hands-on activities (2, 3, 12–15). However, given the substantial logistics and limited reach of in-person events, there has also been a growth of online programs to support scientist-led K–12 outreach (16–18). In the science, technology, engineering, and math (STEM) enrichment program entitled, "I'm a scientist, get me out of here," school students interact with working scientists via live chats (16). The Skype a Scientist platform enables online matching and real-time interactions between classrooms and scientists (who talk about their research work) via videoconferencing (17). Importantly, these programs demonstrate that even via a virtual interface, science and scientists' can be made accessible and interesting to school students. Taken together, formal programs offer scientists the opportunity of brief (one-time) outreach engagements in line with their area of expertise, while providing school students regular and diverse interactions with a range of science topics and scientists. However, despite these established gains, there are very few such formal outreach programs, especially those that are tailored to country- and context-specific interactions between scientists and K–12 students (19, 20).

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Address correspondence to Hull-York Medical School, University of Hull, Hull, United Kingdom. E-mail: snehalgkad@gmail.com or karishmaskaushik@gmail.com.
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TEXT BOX 1 Features of the Talk To A Scientist platform

- **Live webinars:** Interactive science webinars (via Zoom) for K–12 students (ages 6 to 16 years) on alternate weeks for 60 min
- **Archived video content:** Session recordings edited for privacy (by a freelance editor) and posted on YouTube on alternate weeks
- **Online activities:** Science activities (puzzles, crosswords) sent on alternate weeks; participants can have their responses featured on the TTAS website
- **Summer family quizzes:** Three quizzes per year in which K–12 students can participate with their families as a team
- **Repository of materials:** PowerPoint slides for each session are uploaded to the website for free use and circulation
- **Website and social media:** Website hosted on Google Domains and social media accounts include Twitter, Facebook, Instagram, and YouTube
- **Scientist-led sessions:** Scientist-founders or guest scientists prepare content for the sessions; guest scientists include undergraduate and Masters' students, Ph.D. researchers, postdoctoral researchers, science communicators, and academic faculty
- **Diverse range of topics:** A range of contemporary scientific topics, such as COVID-19, dengue fever, and climate change, as well as classical scientific phenomena and techniques, such as black holes, bioluminescence, organs-on-chip, and cell culture
- **Hands-on sessions:** Each 10-episode season ends with a hands-on experimental session for K–12 students to perform with simple and easy-to-obtain materials

In March 2020, we started Talk To A Scientist (TTAS), a science outreach program that uses a webinar-based approach for scientists to share science with K–12 students in India (21). Given pandemic-related school closures, TTAS was built to enable K–12 students to join the weekly program from home, and it has since then grown to include a large and diverse community of regular participants. Over 3 years, TTAS has hosted a range of scientists from across India and has expanded to include archived video content and online science activities. Here, we outline the framework used to build the TTAS outreach platform and discuss key gains, considerations, and challenges in the development of the program. We also suggest potential adaptations, by which the TTAS framework can be used to build similar initiatives for K–12 outreach by scientists in other country- and context-specific settings.

THE TALK TO A SCIENTIST FRAMEWORK FOR SCIENCE OUTREACH FOR K–12 STUDENTS

TTAS was cofounded by an independent investigator and a Ph.D. researcher in India, with combined expertise in microbiology and medical sciences. The platform uses webinars to host live science discussions between scientists and K–12 students. The engagement is in English, and the program is structured over consecutive seasons, with each season based around a scientific theme and comprising 10 sessions. Each session topic is discussed using PowerPoint slides developed by the scientists or scientist-founders, with continuous interactions via the chat window. The final episode of each season is a hands-on session, designed to be done at home, using simple and easy-to-obtain materials. At initiation, TTAS conducted weekly webinars, which after 100 consecutive weeks was changed to alternate weeks of live webinars and archived video content or an online activity. Given this history, TTAS currently hosts two seasons per year that run on a weekly basis, each with 10 live sessions and 10 video releases or online activities. Further, the team expanded to include an outreach manager (funded via an extramural grant). The key features of the platform are shown in Text Box 1, and the framework of the platform is shown in Fig. 1.

FEATURES AND EVALUATION OF THE TTAS PROGRAM TO SCIENCE OUTREACH FOR K–12 STUDENTS

The regular features of TTAS include live webinars with scientists, archived video content, and online science activities. As special features, the platform also includes summer science family quizzes, age-specific webinars, and partnerships with national science initiatives (Fig. 2). Across nearly 3 years, TTAS has conducted over 120 live webinars, with 12 hands-on sessions and 65 guest scientists. Participants can register via a Zoom for each session, following which they receive a joining link. Participation is open and free to all, with no prior selection process. Based on our experience across 3 years, the average number of participants per session is ~20 to 30, with more than 4,000 K–12 student engagements across the program. During pandemic-related school closures, sessions hosted ~40 to 50 participants, including select sessions with over 100 participants. Based on our experience, participant turnout varies with the session topic and expertise of the guest scientist, as well as school and holiday schedules in India. Apart from these unavoidable variations in participation, there have been no challenges in recruiting participants, with session information being sent via weekly e-mails and hosted on the TTAS website. While teaching and learning strategies vary across K–12 age groups, the TTAS platform aims at an age group of 6 to 16 years of age to ensure wide participation. To account for varied learning levels, the content delivery follows a structure of 20 to 25 slides that start with the basics of the topic under discussion (e.g., the size and types of microbes in a session on antibiotic resistance), which is followed by more complex aspects. The

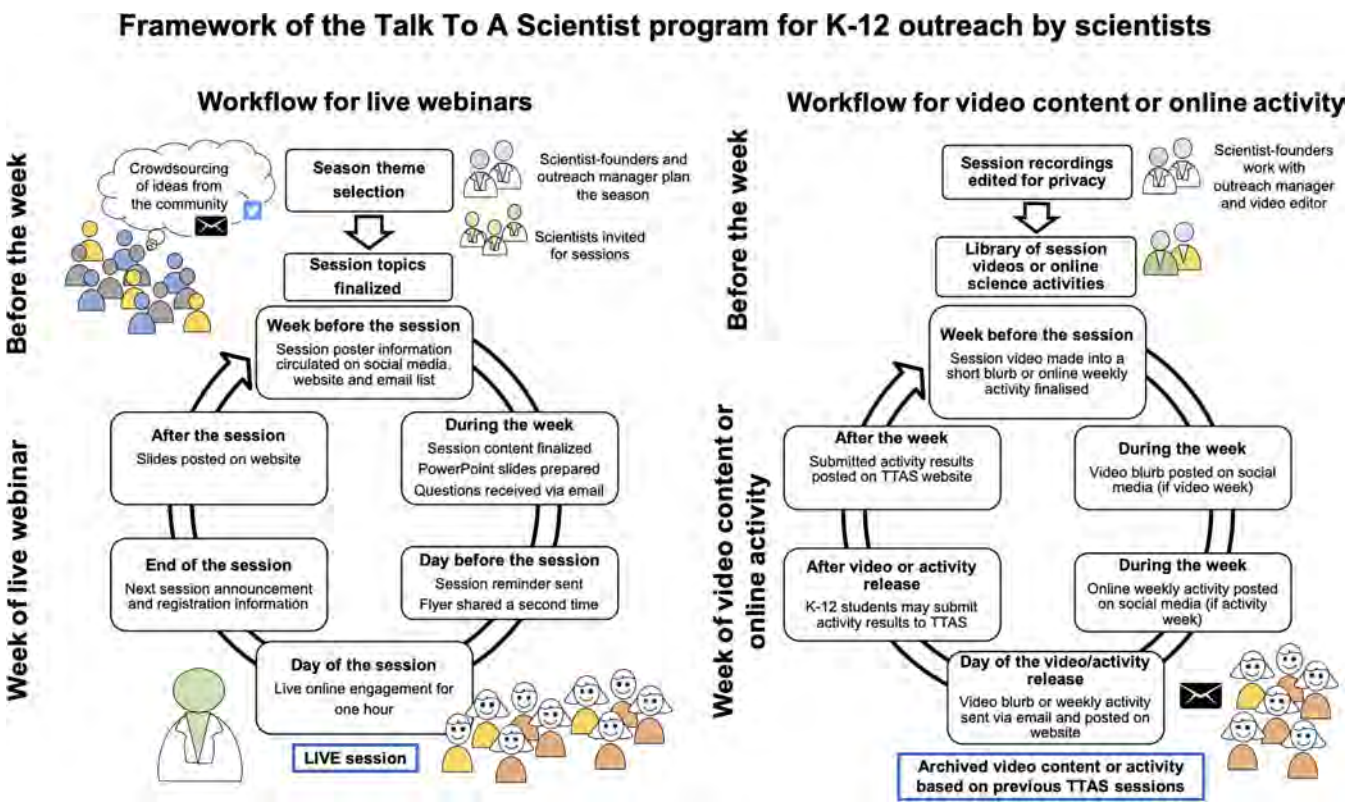

FIG 1. Framework of the Talk To A Scientist K–12 outreach program. The TTAS framework is built around a cycle of alternate weeks of live webinars and archived video content or online science activities. The TTAS live webinars follow a season format, with each season having a theme and comprising 10 sessions. The final session of each season is a hands-on session.

content delivery is regularly paused for participant questions and discussions (via the chat window). While the K–12 students are not divided into age groups, TTAS has conducted an age-specific webinar for 13- to 18-year-olds as part of a special program in which the content could be scaled up in complexity (22). However, given that the majority of TTAS participants are in the age group of 8 to 13 years, we continue to keep the age group wide and structure the content to support engagement across age groups (Fig. 2). At the end of initial seasons, participant feedback was collected related to the understanding of the science and the use of graphics and analogies in the sessions. Based on feedback, the sessions were fun and engaging, with the content and delivery fostering the understanding of science (Fig. 2). In the current season (season 13 on microbes), pre- and postsession learning gains are being analyzed after each session using word clouds and interactive questionnaires. The platform also has an expanding e-mail list and social media presence, including a YouTube channel, and has raised several extramural sources of funding.

IMPORTANT GAINS OF THE TTAS PROGRAM

Exposure to advanced scientific concepts and research

Across several TTAS sessions, K–12 students have been exposed to advanced research beyond standard school curricula and textbooks. These have included fundamental areas of science, such as DNA and heredity, development of multicellular organisms, biofilms, and vaccine development. Sessions have also discussed current research areas, such as wound infections, organ-on-chip systems, behavior of free-ranging dogs, and brain plasticity. Further, session topics have also included scientific methods, such as cell culture, immunology in the diagnosis of infections, and genome sequencing. Finally, the hands-on sessions, with simple and easy-to-obtain supplies, include topics such as chemistry of pH, building a table top model of climate change in glaciers, and extracting DNA from a banana, to name a few. Select examples of live feedback during the sessions indicating the understanding of the science are shown in Table 1. All previous session content can be found on the TTAS website (23). Further, session recordings are edited (to ensure participant privacy) and uploaded on the YouTube channel and website (24).

Exposure to a range of science role models

The TTAS program has hosted a range of scientists across biology, chemistry, astrophysics, and ecology, as well as science communicators (Fig. 2). In doing so, the platform showcases the breadth of science to K–12 students, including interdisciplinary and collaborative science, and highlights the application of scientific practice and principles across various careers. Further, it serves to build contemporary science role models, living and working in present times, for K–12 students to relate to and

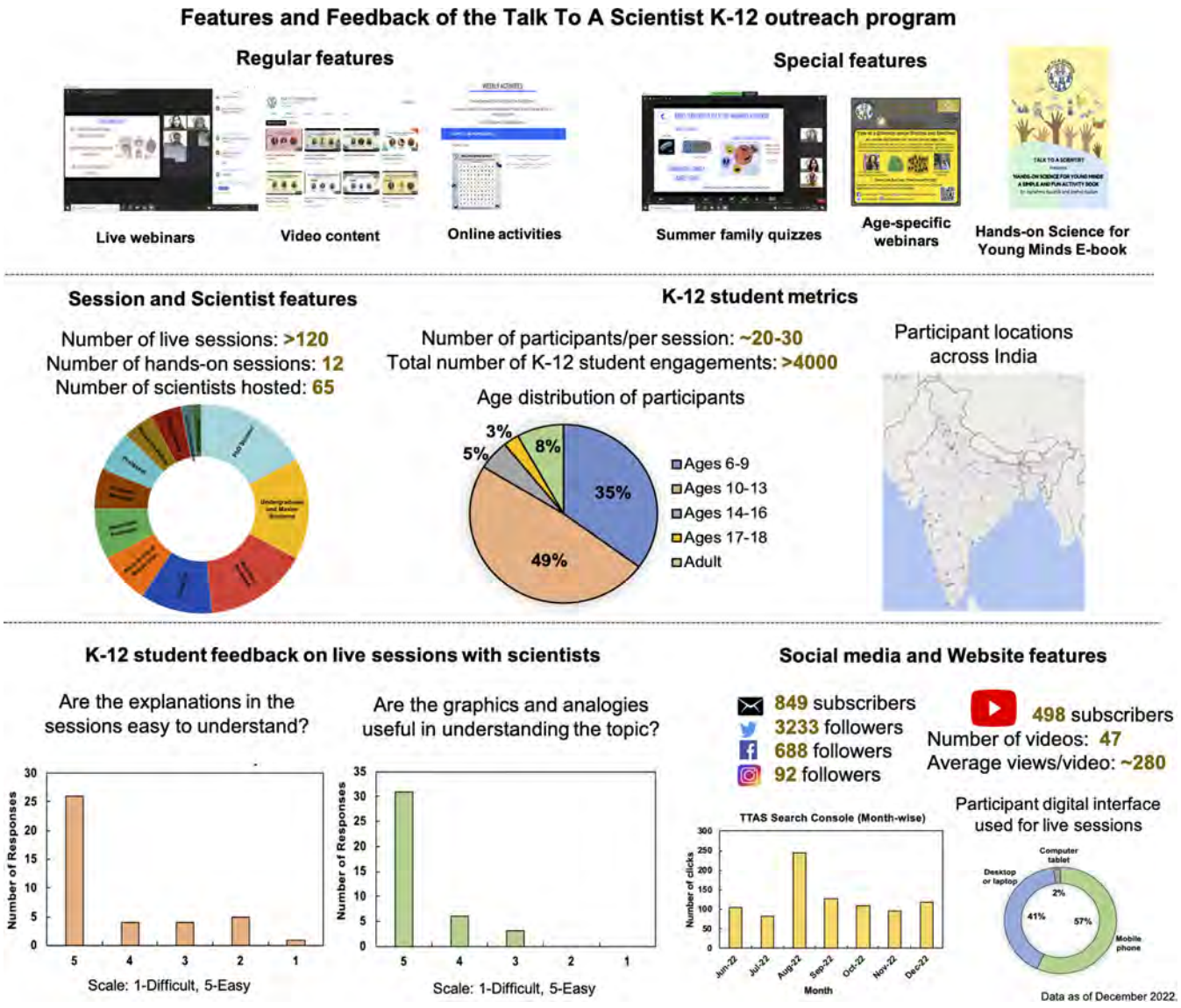

FIG 2. Features and feedback of the Talk To A Scientist K–12 outreach program. The TTAS program offers a diverse range of features for K–12 students to interface with science and scientists. The platform has run for nearly 3 years with over 120 sessions, 65 scientists, and more than 4,000 K–12 student engagements across India. Participant feedback indicates that the live webinars foster the understanding of science, and the content and delivery is well-supported by the graphics and analogies used. The platform has a large e-mail list and social media presence, including a YouTube channel. Participant feedback was obtained via Google forms (with informed consent from parents or legal guardians) and represents data from 40 participants.

identify with. In one example, after viewing a session recording, a participant e-mailed the guest scientist, which led to a visit to the laboratory of the guest scientist. In another example, a participant had an opportunity to review a manuscript for a scientific journal for school children with a guest scientist (25). Finally, regular participants across the TTAS sessions have often recollected the names of previous guest scientists and research areas and connected their relevance to subsequent sessions.

Learning science in an engaging and fun manner

Based on experience across 120 live webinar sessions over 3 years, the TTAS program has fostered regular engagement from K–12 students. This is based on a steady number of participants each week, followers and queries on social media, an expanding e-mail list, and returning participants (Fig. 2). Select examples of live feedback during the sessions indicating the understanding of science and style and delivery of content are shown in Table 2. It is important to note that the platform was initiated during pandemic-related school closures in India, during which the online engagement was critical. However, we have observed sustained participation and engagement even after the reopening of schools in India.

Community and society building

Through the science discussed, TTAS sessions enable the introduction of matters of community and societal relevance.

TABLE 1
Examples of live feedback during sessions indicating the understanding of the science discussed on Talk To A Scientist

Feedback from K–12 students	TTAS session
"Bacterial biofilms are like chocolate sprinkles in sticky caramel sauce!"	Talk To A Scientist about Biofilms
"DNA is the HTML code of living organisms!"	Talk To A Scientist about Molecules in the Lab
"Small genetic changes can lead to a revolution!"	Talk To A Scientist about DNA and Heredity (the hereditary transmission of hemophilia was discussed from the historical perspective of royal families in Europe and the Russian revolution)
"Animals are not same as humans"	Talk To A Scientist about Mini-Organs in the Lab (the organ-on-a-chip field was discussed in the context of replacing animals for scientific studies)
"Omnis cellula e cellula"	Talk To A Scientist about Developmental Biology (with a scientist who studies animal evolution using Hydra as a model organism)
"Why do we use only 70% (and not 100%) ethanol?"	Talk To A Scientist about Cell Culture in the Lab

In "Talk To A Scientist about Human Cells in the Lab," the structure of the skin was discussed, and the fact that skin color is a function of the pigment melanin was highlighted. In "Talk To A Scientist about Science Hoaxes," several common science myths (eating food during an eclipse, using papaya leaf juice to treat Dengue fever) were discussed using a scientific line of questioning. The sessions on fatty liver disease and how food makes you discussed the roles of balanced nutrition for childhood growth and development and highlighted the consequences of imbalanced diets, including childhood obesity. The hands-on session "Understanding Water Filtration with a Simple, Easy-to-Build Setup" was built around the theme of the participants being civic officers in rural India, tasked with the job of building and testing a portable water filter for the local community.

Benefits to scientists

Scientists can express their interest in being guest speakers on TTAS via the online sign-up form (26). For the scientists, preparing session content is an opportunity to deconstruct their advanced scientific research or practice for K–12 students. This involves building relatable analogies, connecting concepts with everyday life, and explaining in simple terms the why and how of their work. For early career scientists', this is also an opportunity to develop their science communication skills, with guidance from the cofounders and questions from the participants. Further, the edited session recordings (on YouTube) provide archived material for the scientists to use in their subsequent outreach efforts. In doing so, the TTAS platform provides scientists an opportunity to engage with K–12 students, through an organized platform and with well-defined time and content commitments.

Benefits to science education

By introducing concepts and approaches that go beyond standard school and undergraduate curricula, TTAS live sessions and archived video content can complement formal science education and serve as science resources in informal settings,

TABLE 2
Examples of live feedback indicating engagement and fun components of Talk To A Scientist sessions

Feedback from K–12 students	TTAS session
"It was paw-some"	Talk To A Scientist about The Private Lives of Animals (with a scientist who studies free-ranging dogs)
"So, we need to take care of these cells like we take care of a baby!"	Talk To A Scientist about Human Cells in the Lab
"It gave me goosebumps!"	Talk To A Scientist about Life in Antarctica (with a scientist who was part of an India-led Antarctica expedition)
". . .only it is a *Bin Bulaye Mehman*" (a popular idiom in Hindi that means an 'uncalled for guest')	Talk To A Scientist about Immunology in the Lab (in the context of differences between commensal and pathogenic bacteria, alluding to pathogens as "uncalled-for visitors in our body")
". . .more antibodies mean more valiant than *Ravana*"	Talk To A Scientist about Immunology in the Lab (the strength of the antibody response was compared to that of the mythological character *Ravana* from the Sanskrit epic *Ramayana*)
"Can I grow up to become the Principal Scientific Advisor of India?"	Talk To A Scientist about A Day in the Biology Lab (science careers, administration, and leadership in India were discussed)

such as after-school care centers and learning centers. The platform also develops weekly online science activities for K–12 students, such as puzzles, crosswords, and word searches. The TTAS age-specific webinar "Biofilms and Beehives" for 13- to 16-year-old participants was evaluated and published as an analogy-based instructional tool to introduce biofilms in high school and undergraduate curricula (22). Further, the hands-on session "Building a Biofilm" developed and implemented by TTAS (with India Science Festival) was published as a science outreach tool, with accompanying feedback (27). Finally, a compendium of 10 hands-on activities developed by TTAS was recently published as *A Hands-On Science for Young Minds* e-book (28). With step-by-step guidelines and interactive graphs and trivia, the book is well-suited for science education across schools, home schooling, and science camps (28).

Science outreach tailored to regional settings

While webinar-based science outreach for K–12 students is not particularly novel, an India-centric science outreach program has enabled the inclusion of science topics relevant to the region. For example, previous TTAS sessions focused on scientific challenges relevant to India, such as malaria, tuberculosis, and dengue fever. The platform has also showcased national science endeavors, for example, by hosting a guest scientist who shared his experience on an India-led expedition to Antarctica. In another example, a guest scientist conducted a virtual tour of the government-funded zebrafish facility at a national institute in the country. Further, as an India-centric platform, TTAS has been able to foster engagement with participants via common social and cultural phrases and elements of humor (Table 2). Finally, TTAS has also partnered with a national science festival, conducting a two-part webinar series "Microbes for Kids," including a live hands-on session to build and test a biofilm model for antibiotic tolerance (27).

KEY CONSIDERATIONS AND CHALLENGES OF THE APPROACH AND PLATFORM

A team initiative

TTAS was started as an outreach arm of a research group; the cofounders were the independent investigator and a researcher in the group (29). Given the weekly nature of the program, two cofounders and an outreach manager (part-time position) are essential to manage the platform and session delivery. The team members divide different tasks, which include planning the sessions, managing the website and social media accounts, creating publicity features, and hosting the sessions with the scientist.

Privacy and ethics concerns during online engagement

To ensure the privacy and safety of the students, the TTAS platform is set up such that the Zoom meetings require prior registration (with a valid e-mail address), the waiting room feature is enabled (so participants are let in and cannot enter automatically), and chats between participants, participant screen sharing, and screen annotation are disabled (30). While participants are on mute (to limit background noise), they can interact via the chat window and do have the option of turning videos on. If required, participants are unmuted briefly, so they can directly ask a question or express an idea. Registration lists are never shared, and if session screenshots are used, participant faces are obscured.

Archived video content

The webinars are recorded following informed verbal consent (via the Zoom meeting feature), and edited by a videographer to ensure privacy of the participants. The editing includes blurring of names and faces, in addition to any other identifying information, following which the videos are posted on the YouTube channel. The YouTube channel is marked as "made for kids," which follows YouTube's policy for data collection and content curation for young viewers.

Accessibility to the online interface

A major consideration with a webinar-based outreach approach is the participant requirement of a device such as a computer, laptop, iPad, or smart phone (Fig. 2) and an Internet connection. This selects for K–12 students with resources and environments that support this type of engagement and is therefore inaccessible to students from underserved communities. Recognizing this, the archived video content feature was initiated, which ensures the long-term availability of content to students and educators.

Funding for the platform

At initiation, TTAS was funded from personal costs, which included a Zoom subscription (up to 100 participants, ~$160/year) and a Google Domain license (hosting the website, ~$15/year). Subsequently, the platform received extramural funding from the IndiaBioscience Outreach Grant, American Geophysical Union, and the Microbiology Society, UK (31, 32). This funding supports a stipend for the outreach manager, Zoom and Google Domain costs, video editing (paid to a freelancer), and summer family quiz prizes.

CONCLUSIONS

TTAS is a successfully running webinar-based outreach platform that allows live interactions between scientists and K–12 students, with value and relevance to the scientific and student communities in India. Notably, the TTAS framework provides an organized platform for working scientists to engage in K–12 outreach, where they can share their scientific research with well-defined time commitments and guidance on session content and

TABLE 3
Potential adaptations and modifications to the Talk To A Scientist platform

Potential adaptation	Relevance
Language of outreach	While TTAS outreach sessions are conducted in English, occasional discussion in the sessions do include phrases and words in Hindi (also an official language). Potential adaptations of the TTAS program can consider enhancing language accessibility to the platform, by subtitling archived video content or hosting scientists with fluency in regional languages (33–37).
Age-specific webinars	Anecdotal feedback from a few participants indicated the need to increase the complexity of the content for older students ("...cover the same topic in depth for age groups to 10+ or 12+") (38). Based on this, TTAS conducted an age-specific webinar explaining the concept of biofilms, with analogies to beehives, both superorganisms (22). While having a wide age group of 6 to 16 yrs has enhanced participation and fostered a range of questions in the sessions, regular age-specific sessions can help sustain the interest of older participants and lend themselves well for formal evaluation of pre- and postsession learning gains.
Expansion to STEM fields	While TTAS sessions have had a significant biology or life science focus, the platform has hosted sessions on Science of the Internet, Science in Space, Black Holes, and Science of Cartography; guest speakers have included food entrepreneurs, science artists, and forest conservation officers. With the inclusion of scientists with a range of expertise, the TTAS framework can be adapted or expanded across STEM fields such as physics, chemistry, and math and subareas such as astronomy.
Inclusion of international guest speakers	While so far the majority of guest scientists on TTAS have been working in India, the platform has also hosted scientists from the Indian diaspora (working outside of India). With linguistic and time zone considerations, adaptations of the TTAS program can include international guest speakers. This will highlight the global nature of science and showcase diversity among science professionals (39).
Adaptations of the TTAS model to country- and context-specific initiatives	The structure of the TTAS platform, including the features, modes of evaluation, broad gains to the community, considerations, and challenges, lends itself well for adaptations to build similar initiatives tailor-made to other country- and context-specificities. For example, for country-specific relevance, the TTAS program in a certain country could focus on discussions relevant to scientific achievements and challenges in the region, host national scientists as role models, and be delivered in the local language. Further, for context-specific relevance, scientific topics relevant to K–12 students from indigenous, underserved, or underrepresented communities could be the focus.

delivery and without logistic and administrative obligations. We believe that the TTAS framework, including the considerations, challenges, and suggested adaptations (Table 3) could be used to build similar initiatives to expand K–12 outreach by scientists across diverse country- and context-specific settings.

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