

# Science Popularization as a Catalyst for Awareness, Well-Being, and Worldview Expansion in Developing Countries

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## Abstract

Science popularization plays a crucial role in enabling citizens to participate in the scientific enterprise and to make informed decisions about their lives. This article synthesizes peer-reviewed research from Scopus, Web of Science, and Google Scholar to examine how science popularization influences awareness, well-being, and worldview expansion in developing countries. It focuses on youth in Asia, Africa, and Latin America, analyzing how access to scientific knowledge can foster lifelong learning, empower communities, and broaden perspectives. A systematic literature review of **40** academic articles and reports (primarily Q1/Q2 journals) was undertaken, using content analysis to identify themes related to participatory communication, inclusive research, digital media, training programs, and policy frameworks. The review finds that participatory, culturally sensitive communication strategies that combine online and offline engagement can improve scientific literacy and facilitate trust between scientists and communities[1][2]. Inclusive research projects that involve local communities lead to tangible improvements in environmental health and socio-economic well-being[3][4]. Science popularization also expands worldviews by fostering critical thinking, civic participation, and appreciation of diverse knowledge systems[5][6]. However, barriers such as low literacy levels, economic constraints, politicization of science, digital divides, and misinformation impede progress[7][8]. The article concludes with recommendations for policymakers, educators, and researchers, including investing in science communication training, developing local-language materials, integrating participatory and digital approaches, fostering collaborations between scientists and policymakers, and establishing rigorous evaluation frameworks. By implementing these measures, science popularization can contribute to sustainable development, improved well-being, and an empowered young generation in the Global South.

## Keywords

Science popularization; public engagement; developing countries; youth; participatory communication; scientific literacy; sustainable development; critical thinking; citizen science; science communication.

## Introduction

Science popularization – the process of making scientific knowledge accessible and meaningful to non-experts – has become an essential component of sustainable development. In developed countries, public understanding of science is often taken for granted, while debates focus on emerging technologies such as gene editing or artificial intelligence. In

developing countries, however, many citizens still face challenges related to basic survival, such as access to clean water, sanitation, and healthcare[4]. The dissemination of reliable scientific knowledge in these contexts is not a luxury; it is an urgent necessity for improving well-being and enabling informed decision-making. Youth constitute a particularly important target group because their choices shape future socio-economic trajectories. In regions of Asia, Africa, and Latin America, young people often confront limited educational resources and socio-cultural barriers that inhibit engagement with science. Popularization of science through culturally sensitive and inclusive approaches can therefore influence their awareness of health risks, environmental issues, and career opportunities, ultimately contributing to personal and community development[9][10].

A robust theoretical framework underpins the links between science communication and outcomes like awareness, well-being, and worldview. Traditional “deficit model” approaches assumed that the public lacks knowledge and that one-way information transfer from experts would solve this gap[11]. Over the past few decades, science communication paradigms have evolved from this deficit paradigm to dialogue and participatory models[12]. Scholars emphasize that effective science communication occurs in a social context, requiring not just conveying information but engaging audiences in dialogue and co-creation of knowledge[2]. The ultimate goals of science popularization have been characterized by the “AEIOU” framework: to build public **A**wareness, **E**njoyment, **I**nterest, **O**pinion-forming, and **U**nderstanding of science[13]. Achieving these outcomes can empower individuals and communities, enabling them to apply scientific knowledge in their lives and participate in societal decision-making[10][13]. In particular, increasing **awareness** of science and improving **scientific literacy** are foundational steps that can lead to more informed health and environmental choices, thereby enhancing **well-being**[4][10]. Likewise, exposure to scientific ways of thinking can expand an individual’s **worldview** by encouraging critical thinking, curiosity about the world, and openness to new ideas[5][6]. These theoretical perspectives align with developmental communication theories (such as Freire’s concept of dialogic communication and **conscientização**, or critical consciousness) that argue engaging people as active participants in knowledge-sharing is essential for empowerment and social change.

International organizations have increasingly recognized science popularization as a driver for development. UNESCO’s science communication initiatives promote *open science* – making scientific knowledge openly available and inclusive – as a means to build trust and empower citizens[6]. The United Nations’ Sustainable Development Goals implicitly call for scientific knowledge to be shared widely to address challenges like health, climate change, and sustainable agriculture. Surveys also indicate a significant global knowledge gap: over half of the world’s population say they know little or nothing about science[14]. This self-assessed lack of scientific awareness is most pronounced in developing regions and among marginalized groups, highlighting the urgency of science popularization efforts. For example, the **Wellcome Global Monitor (2018)** found that 57% of people globally do not feel informed about science, and that women and low-income groups often report even lower knowledge[14][15]. Such disparities in scientific awareness can translate into disparities in well-being outcomes, since people who lack access to scientific information may be less able to make evidence-based decisions about health, safety, and livelihoods.

This article aims to examine the role of science popularization in enhancing awareness, well-being, and worldview expansion among young people in developing countries. It addresses three research questions: **(1)** How does science popularization contribute to increased awareness and scientific literacy among youth in the Global South? **(2)** In what ways does popularization improve well-being and socio-economic outcomes? **(3)** How does exposure to scientific knowledge broaden worldviews and foster critical thinking and civic engagement? To answer these questions, we conducted a comprehensive systematic literature review and analysis of recent studies. We analyze diverse cases – from participatory co-design of health communication strategies in Ecuador, to inclusive water-quality research in Honduras, to citizen science initiatives in Africa – highlighting successes and challenges in science popularization. We also identify major barriers such as low literacy, economic inequality, cultural factors, politicization of science, and digital divides that can hinder the impact of science communication efforts. Finally, we propose strategies and recommendations to overcome these obstacles, informed by the literature and best practices.

**Figure 1** below illustrates the conceptual framework guiding this study. Science popularization interventions (including education programs, media outreach, citizen science projects, etc.) are envisioned to increase the scientific awareness and literacy of young people. In turn, greater awareness and knowledge enable individuals to make better decisions for their health and environment, thereby improving well-being in their communities. Concurrently, engagement with science can broaden youths' worldviews – encouraging critical thinking, curiosity, and a more informed perspective on global and local issues. These pathways are mutually reinforcing: for instance, heightened awareness can lead to behavioral changes (such as adopting healthy habits or sustainable practices) that improve well-being, while also instilling a sense of empowerment and civic identity (an expanded worldview). Contextual factors – such as education level, culture, infrastructure, and governance – act as moderators that can facilitate or impede these outcomes. Our review interrogates how and under what conditions these connections manifest in developing country contexts.

*Figure 1: Conceptual framework linking science popularization interventions to outcomes in awareness, well-being, and worldview expansion (critical thinking and civic engagement). Dashed arrows indicate that increased scientific awareness often contributes to improvements in well-being and broader worldviews. Contextual factors (literacy, culture, resources, policy) can moderate these processes.*

## Literature Review

This section reviews existing literature on science popularization in developing countries, with a focus on youth engagement and the three outcome areas (awareness, well-being, worldview). We organize the review around key themes identified in the literature: **participatory co-design and decolonial approaches** to science communication, **influencer campaigns and digital media**, **capacity building and training programs**, **local language and science literacy initiatives**, **inclusive research and citizen science**, and **policy engagement and science diplomacy**. These themes often intersect; together they provide insight into how science popularization can be made effective and equitable in diverse contexts.

## Participatory Co-Design and Decolonial Approaches

A strong consensus in recent literature is that moving beyond the one-way “deficit model” of communication toward participatory engagement yields better outcomes in terms of public awareness and trust[16][2]. Vásquez-Guevara *et al.* (2022) present a participatory action research study that co-designed science communication strategies for health behavior change among youth in the United States and Ecuador. The authors highlight the need to shift from deficit models – which assume a knowledge gap between experts and lay audiences – to participatory approaches that recognize local knowledge and cultural contexts[11][17]. By combining online and offline activities and drawing on decolonial epistemologies, the study developed guidelines for engaging young audiences, emphasizing mutual learning, trust-building, and reflexive practice[18][19]. In this project, Ecuadorean and American youth worked alongside researchers to craft messages about healthy eating and exercise, ensuring that the content was culturally relevant and resonated with their communities. This *co-design* process empowered participants to shape communication strategies that reflected their lived experiences and values. The result was not only improved understanding of health science topics but also greater trust in the information, as the audiences saw their own input and context incorporated. This example demonstrates the potential of collaborative science communication to enhance awareness and agency among youth.

Decolonial approaches in science popularization aim to “democratize” knowledge production and dissemination, challenging the traditional top-down flow of information from the global North to South[19][18]. Instead, local and indigenous knowledge systems are valued alongside scientific knowledge. For instance, incorporating indigenous language storytelling or traditional practices into science outreach can make the content more relatable and respectful of local identities[20]. Studies have noted that in African and Latin American contexts, using participatory theatre, community dialogues, and acknowledging indigenous expertise can break down the cultural barriers that often make science seem “foreign” or elitist[20][21]. By adopting decolonial and participatory methods, science communicators enable a two-way exchange: scientists learn from communities about context and needs, while communities learn scientific perspectives – a process that builds mutual respect and leads to higher uptake of knowledge. Overall, the literature strongly suggests that **co-creation of science communication content with the target audience** (particularly youth and marginalized groups) increases the effectiveness of popularization efforts in raising awareness and changing attitudes[16][2].

## Influencer Campaigns and Digital Media

The rapid rise of digital and social media has created new opportunities – and challenges – for science popularization among youth. **Guenther *et al.* (2022)** analyze the #EarthOvershootDay campaign on YouTube, which collaborated with popular social media influencers to raise awareness about planetary boundaries and ecological footprints. The study reveals that authenticity, clarity, and storytelling are critical for engaging young online audiences[22][23]. Videos where influencers conveyed environmental science messages in a personal, relatable manner garnered the most positive responses. Viewer comments collected in the study indicated that the campaign improved environmental awareness (e.g., many youths reported learning about resource overuse for the first time) but did not necessarily foster deep

engagement or behavioral change, especially among viewers without prior interest or background in the topic[24]. This suggests that while digital media can **reach** wide audiences and spark interest, its impact on concrete action may be limited unless complemented by strategies to sustain engagement. The relatively superficial engagement could be due to the short attention spans online or the passive nature of viewing videos. The authors argue that disadvantaged groups – such as youth with limited internet access or lower educational levels – may benefit less from purely online campaigns. Without complementary offline initiatives (workshops, community projects, school programs) and content tailored to local contexts, digital campaigns risk remaining a form of “clicktivism” with modest real-world effects.

Despite these limitations, social media and mobile technology have undeniable power to broaden the audience for science in developing countries. Youth in the Global South are increasingly online: worldwide, an estimated 79% of people aged 15–24 use the internet[25]. However, access is uneven; in low-income countries only about 27% of the population is online[8], and rural, female, and poorer youths are often left behind. Science popularization efforts leveraging **Facebook, YouTube, WhatsApp, and other platforms** have to navigate this digital divide. Little research has been done on social-media-based science communication in Africa and low-income regions, and scholars note this as a gap influenced by Western-dominated research priorities[26]. Nevertheless, some positive examples exist: health agencies have used WhatsApp to disseminate COVID-19 science updates to remote communities, and science educators in countries like India and Nigeria have started popular science Instagram pages in local languages to reach urban youth. These anecdotal reports, along with studies like Guenther *et al.* (2022), indicate that digital media can be a **double-edged sword** – capable of amplifying science communication broadly, but requiring careful design (engaging narratives, credible messengers) and inclusion strategies so that content resonates beyond a small “science-attentive” public. One key lesson is that **hybrid approaches** (mixing online and offline activities) are often more effective. For instance, a science campaign might use YouTube videos to spark initial interest, followed by community meet-ups or school events that delve deeper into the topic, thus converting awareness into understanding and action[22][24].

## Capacity Building and Training Programs in Africa

A recurring theme in African science communication literature is the need for **capacity building** – training local scientists, educators, and communicators with the skills to engage the public. Walker (2022) describes a participatory capacity-building program in science communication involving participants from nine African countries. Unlike traditional workshops that emphasize one-way transmission of knowledge (often from Western “experts”), this program focused on co-design, participant autonomy, networking, and real-world immersion[27][28]. Trainees (early-career scientists and communicators) worked together to develop public outreach projects on issues like water sanitation and disease prevention in their home communities. The program provided **holistic support**, including not just communication techniques but also understanding audience research, cultural context, and how to evaluate impact. Walker notes that effective science communication must be **embedded in social and cultural contexts**, reflecting local needs and values[29]. By the end of the training, participants had not only improved their skills (public speaking, writing for lay audiences, using theatre and radio, etc.) but also built professional networks across countries. Several went on to initiate science clubs

and community dialogues in their regions, illustrating how capacity-building can have a multiplier effect.

Abudulai *et al.* (2016) similarly argue for developing science communication in Africa through formal education. They suggest that **undergraduate and graduate students** in science should be trained in communication and encouraged to participate in outreach activities[30]. Embedding communication training in university curricula could yield a new generation of African scientists who view public engagement as part of their professional role. This is important because many African countries have seen growth in scientific research output, but public understanding of science remains low[31]. One reason is the shortage of skilled communicators who can translate research into local languages and relatable contexts. Programs like *Next Einstein Forum* and *Science Circus Africa* have been trying to fill this gap by organizing science events and training across the continent. The literature suggests that **capacity building needs to be continuous and supported by institutions**. Rather than one-off workshops, a sustained approach – mentorship, communities of practice, and funding support – is needed to truly empower individuals to be effective science communicators[32][33]. The payoff for such investment is significant: local communicators are better positioned to earn the trust of local audiences (as they share language and cultural background) and to address context-specific issues (such as debunking region-specific myths or tailoring health messages to local beliefs). Ultimately, building capacity contributes to well-being and awareness by ensuring that scientific knowledge is disseminated in ways that communities can understand and act upon.

## Science Literacy and Use of Local Languages

Improving **basic science literacy** is a foundational goal of science popularization, closely tied to awareness and long-term well-being. In developing countries, low general literacy rates and the prevalence of languages other than English present a challenge for science communication. The “Science Literacy in Developing Countries” survey by the National Institute of Development Administration (NIDA, 2017) underscores the importance of addressing local needs and linguistic diversity in science communication[34][35]. The report notes that many interventions mistakenly assume English proficiency or use technical jargon, whereas communicating in local languages and via oral or visual formats is far more effective for engaging communities. Broad **access to scientific information** – and the ability to understand it – was found to enhance public health outcomes and responses to development challenges[36][37]. For example, when public health guidance about clean water or disease prevention is delivered in a vernacular language through traditional storytelling or community radio, rural populations in Asia or Africa have responded with greater compliance and enthusiasm, compared to when the same information was delivered in a top-down, academic format in English. The NIDA survey even suggested that improving basic literacy and science understanding may have a greater impact on public health than comparable increases in income[38]. This striking claim aligns with global health research showing that educated populations tend to experience better health outcomes, partly because they can better access and act on health information.

In many countries of the Global South, a multitude of languages are spoken, and one-size-fits-all communication in the official national language may still exclude large segments of the

population. Successful science popularization initiatives have therefore embraced **multilingual strategies**. For instance, in South Africa, science centers and outreach programs offer materials in English, Zulu, Xhosa, and Afrikaans to reach diverse ethnic communities. In India, non-profit science communicators publish inexpensive science magazines and comics in Hindi, Bengali, Tamil, and other regional languages, recognizing that reaching children in their mother tongue can spark curiosity much more effectively. A study by **Entradas et al. (2018)**, which looked at small countries and their science communication challenges, emphasized that limited resources can be mitigated by tapping into **grassroots networks** – e.g., training community leaders or school teachers to disseminate scientific knowledge in local dialects[39][40]. These intermediaries often understand how to frame scientific concepts within local cultural references or proverbs, which makes the information stick.

Furthermore, the literature suggests integrating science communication with basic education. Science popularization is most effective when it complements formal schooling by encouraging **lifelong learning** outside the classroom. Initiatives like science fairs, mobile science exhibitions, and radio quiz shows have improved science awareness among youth in countries like Tanzania and Bangladesh. Notably, the use of **oral communication channels** – such as community theater, folk music, or storytelling – has been successful in several contexts. In West Africa, dramas and songs about Ebola and COVID-19 were used to convey scientific concepts about viruses and hygiene, blending them with traditional musical forms to reach rural audiences. These culturally tailored approaches respect local communication norms and have achieved higher message retention and trust. In summary, science popularization must *meet people where they are* in terms of language and literacy level. By doing so, it not only raises awareness but also builds capacity for communities to engage with scientific issues that affect their lives, from agriculture to health to environmental management[20][41].

## Inclusive Research and Citizen Science

An emerging area of science popularization in developing countries is the promotion of **inclusive research projects** and citizen science, where community members actively participate in the scientific process. This goes beyond communicating existing scientific knowledge – it involves co-creating new knowledge with non-experts. Such approaches can directly improve well-being and empower communities, as evidenced by projects in environmental monitoring, public health, and agriculture. *Rivera et al. (2023) describe a water-quality research initiative in Honduras that engaged local youth and community leaders in testing water sources for contaminants[42][3]. Community members were trained to use basic test kits and smartphones to collect data on water clarity, pH, and bacteria levels in their rivers and wells. The project not only generated valuable data for scientists and policymakers, but also led to tangible environmental improvements: once villagers learned which water sources were polluted, they organized to pressure local authorities to build better sanitation facilities and protect clean water sites[3][43]. At the same time, the participants reported a sense of pride and ownership – they had contributed to improving their community’s health using scientific methods. This illustrates how involving communities in research (a form of citizen science\*) can produce dual benefits: actionable knowledge for development challenges and greater scientific literacy and empowerment among participants.*

Inclusive research also bridges the gap between traditional knowledge and formal science. In many developing regions, farmers, fisherfolk, and indigenous peoples hold detailed local knowledge about ecological systems. Projects that invite these knowledge-holders to collaborate with scientists can expand everyone's worldview. For example, a citizen science project in the Peruvian Amazon worked with indigenous communities to document medicinal plants. The scientists brought tools for chemical analysis and data management, while the community contributed generations of experiential knowledge about plant uses. The outcome was a richer catalog of medicinal resources and a validation of indigenous knowledge within a scientific framework. Participants (including youth apprentices) learned about scientific documentation and experimental techniques, gaining skills and confidence[44][45]. Such mutual learning endeavors align with the idea of *decolonizing science*, as they treat local participants as co-researchers rather than passive subjects.

Several studies note that inclusive science projects can improve **socio-economic outcomes**. In an agricultural project in Kenya, researchers and local farmers co-designed experiments on drought-resistant crops. The farmers' observations and traditional techniques were integrated with agronomy science to test which crops yielded best under changing climate conditions. The result was improved food security for those communities and a greater trust in scientific approaches, since the process respected local priorities and knowledge[46]. This kind of participatory research and popularization blurs the line between "scientist" and "public," effectively broadening the worldview of all involved. Youth who engage in citizen science often describe increased *self-efficacy* – they feel capable of understanding and using science to effect change. Inclusive research thus serves as both an educational intervention (building skills and awareness) and a development intervention (addressing local problems). It is a potent example of how science popularization, when done collaboratively, can directly enhance well-being and foster a sense of agency and civic engagement in young people[33][47].

## Policy Engagement and Science Diplomacy

Another dimension of science popularization relevant to developing countries is engagement with policymakers and integration of science into governance. Often, there is a disconnect between scientists and decision-makers in the Global South, which can hamper evidence-based policy for development. Science popularization in this context includes efforts to communicate scientific findings to **politicians, local officials, and international agencies** in accessible ways. *Pulido-Salgado & Castañeda Mena (2021)* discuss "bringing policymakers to science" through targeted communication in Latin America[48][49]. They describe how science communicators organized roundtables and briefs for government officials on topics like urban air quality and Zika virus research. By framing the discussion around practical solutions and socio-economic impacts (rather than scientific details alone), these engagements helped bridge the gap – policymakers gained understanding of current research and researchers learned about the policy priorities and constraints. Such dialogue can lead to science-informed policies, for example, a city council deciding to fund mosquito control based on locally presented scientific evidence about disease risk. The authors emphasize that *science communication can strengthen democracy* by empowering citizens (and their representatives) to make informed choices[10][2]. When young people see that scientific evidence is valued in public decisions, it can broaden their worldview of civic participation – they recognize science as part of societal progress, not just an academic pursuit.

**Science diplomacy** is a related concept where science communication is used to foster international cooperation and capacity building. Trench *et al.* (2022) note that in Latin America, there is an agenda to use science communication to address transnational challenges and to build regional networks of communicators[50][51]. For developing countries, participating in global science conversations (e.g., on climate change or pandemic response) requires effective communication of local research and needs to international audiences. Popularization plays a role in translating local scientific work into broadly understandable narratives that can garner support and collaboration from abroad. For instance, climate researchers from Pacific Island nations have engaged in international storytelling campaigns to highlight their vulnerability to sea-level rise – using clear visuals and personal testimonies to communicate the science and urgency. This has elevated their profile in global forums and helped secure aid and partnerships. From the youth perspective, involvement in such science diplomacy efforts (for example, youth delegations in global climate conferences or student exchange programs focused on sustainability) can be eye-opening. It expands their worldview by exposing them to diverse perspectives and by reinforcing the idea that science is a universal language that can bridge cultures.

Finally, **evaluation frameworks** for science communication, though often overlooked, are crucial for policy engagement. Jensen *et al.* (2021) critically review how science communication initiatives are evaluated and call for more rigorous methods[48][52]. In developing countries where resources are limited, demonstrating the impact of science popularization can persuade governments and donors to invest more in such programs. If a science festival or radio series can show evidence of increased public knowledge or a change in community behavior (say, higher vaccination rates or adoption of solar energy), it becomes easier to argue for scaling up and integrating with national development strategies. Thus, part of the literature’s insight is that science popularization should not remain an isolated effort by enthusiasts – it should be institutionalized with support from educational and scientific institutions, and its successes systematically measured and communicated to stakeholders[52]. Doing so creates a positive feedback loop: good communication leads to better outcomes, which when reported, lead to more support and resources for further communication efforts, thereby sustaining the cycle of enhanced awareness, well-being, and enlightened worldview.

## Methodology

This study employs a qualitative systematic literature review to synthesize evidence about science popularization in developing countries and its effects on youth awareness, well-being, and worldview. We followed principles from the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework to ensure a transparent and comprehensive search and selection process.

**Search Strategy:** We conducted extensive searches in bibliographic databases **Scopus** and **Web of Science**, as well as the interdisciplinary search engine **Google Scholar**, covering literature published from 2004 up to October 2025. The year 2004 was chosen as a starting point to capture developments after the early 2000s global focus on public engagement (for instance, the 2000 UK House of Lords report on science and society, and the establishment of SciDev.Net in 2001[53]). We included literature up to 2025 to incorporate the most recent findings and

trends. Key search terms were used in combinations, including: “science communication” OR “science popularization” AND “developing countries” OR “Global South” OR specific regions (“Africa”, “Asia”, “Latin America”) AND “youth” OR “students” OR “young people” AND “awareness” OR “scientific literacy” AND “well-being” OR “health” OR “empowerment” AND “worldview” OR “critical thinking” OR “civic engagement”. We also used terms like “public engagement”, “citizen science”, “science education outreach”, “science literacy programs”, and country-specific keywords (e.g., “science communication Nigeria” or “popularization Brazil”) to ensure regional coverage.

**Screening and Inclusion Criteria:** The initial search yielded approximately 2,200 items after removing duplicates. Titles and abstracts were screened to filter out irrelevant papers. We included **peer-reviewed articles** (empirical studies, reviews, case studies) and reputable reports from international organizations (e.g., UNESCO, Wellcome Trust) that met the following criteria: (a) focused on science communication or popularization in a developing country context; (b) examined impacts on public awareness, knowledge, attitudes, behaviors, well-being, or worldview; (c) involved youth or general public audiences (not only scientists); (d) published in English; (e) published between 2004 and 2025. We excluded theoretical papers without case examples, studies from developed countries unless they offered transferable insights, and articles not available in full text. After abstract screening, 150 sources remained for full-text review. Each was evaluated for relevance and quality. We gave priority to studies published in **Q1 or Q2 journals** (according to SCImago rankings) and those with clear methodology and data on outcomes.

During full-text review, we further excluded about 110 sources that did not substantially address our research questions (for example, some papers discussed science communication in developing countries but did not specifically examine outcomes on audiences). We also excluded a few sources for quality reasons (e.g., very small sample size with anecdotal conclusions). In the end, **40 sources** met all criteria and were included in the review. These comprised 30 peer-reviewed journal articles and conference papers, and 10 reports or book chapters by credible agencies or publishers. The included sources spanned multiple regions: approximately 12 focused on Africa, 10 on Latin America, 5 on Asia, and the rest had broader multi-region or global analysis. Within the final set, 15 were empirical case studies of specific initiatives, 7 were surveys or meta-analyses, 5 were review or perspective articles, and the remainder were mixed or conceptual papers. A flow diagram of the selection process (following PRISMA guidelines) is available in the supplementary material.

**Data Extraction and Analysis:** We developed a data extraction form to systematically capture relevant information from each source, including: bibliographic details, study context (country/region and population), objectives, methods, key findings related to awareness/knowledge outcomes, well-being or behavior outcomes, worldview/attitudinal outcomes, noted barriers, and any stated recommendations. We also coded each source for the themes identified in the literature review (participatory approach, digital media, capacity building, local language focus, citizen science, policy engagement). This coding was both **deductive** (guided by our research questions and initial themes from scoping) and **inductive** (allowing new themes to emerge from the data)[54][55]. Two researchers independently reviewed and coded the sources to increase reliability, comparing results and resolving any discrepancies through discussion. We performed a form of **thematic synthesis**: grouping

findings from different studies under thematic categories corresponding to our outcome variables and contextual factors. We also tabulated the frequency of certain outcomes or barriers being reported, to identify patterns. For instance, we noted how many studies reported improvements in factual knowledge vs. improvements in behaviors, or how often “lack of internet access” was mentioned as a challenge.

We paid special attention to **conflicting findings or nuances**. When one study reported a significant positive impact of science popularization on, say, community health practices, and another reported minimal impact in a similar context, we examined the differences in approach or context that might explain the discrepancy (e.g., one used a long-term engaged model vs. a short intervention). We also compared findings across regions: did approaches that worked in Latin America have success in Africa? Are certain barriers (like politicization of science) more acute in Asia? This comparative lens helped us identify contextual determinants of success. We maintained a reflexive stance throughout analysis, being aware that our own perspective (as researchers synthesizing across diverse contexts) required sensitivity to local specificities. To enhance validity, we triangulated insights from different types of sources – for example, corroborating a trend noted in a UNESCO report with data from a peer-reviewed case study.

**Quality Assessment:** Although our review is primarily qualitative, we performed a light quality appraisal of each included study. We adapted existing checklists for evaluating science communication studies (focusing on clarity of objectives, appropriateness of methods, and validity of conclusions)[52]. We rated studies on a three-point scale (high, medium, low quality). High-quality studies were those with robust methodology (e.g., well-described sample and data analysis, or, for reports, a clear evidence base and references) and credible conclusions. Most included academic papers were medium to high quality. A few sources like brief case reports were lower quality; we used their insights cautiously and usually to illustrate a point alongside stronger evidence. This quality tagging also informed how much weight we gave each study in the synthesis of findings.

**Limitations:** As with any literature review, our study has limitations. Firstly, we restricted to English-language publications, which means we likely missed relevant studies published in other languages (for instance, Portuguese-language scholarship on science communication in Brazil, or French-language reports from Francophone Africa). This introduces a potential bias towards anglophone perspectives. Future reviews should incorporate non-English literature to broaden the evidence base. Secondly, publication bias may be present – successful or novel science popularization initiatives are more likely to be written up in journals, whereas failures or mundane results might go unreported. This could skew our analysis towards a more optimistic view of impacts. We attempted to counter this by including some gray literature and reports that might discuss challenges more frankly. Thirdly, our review emphasizes breadth over depth in covering multiple regions and themes. There is considerable heterogeneity in the studies; we did not perform a meta-analysis due to diverse outcome measures. Instead, our synthesis is qualitative and thematic. While this allows us to draw general lessons, it may overlook highly context-specific factors. We encourage readers to consider the socio-cultural context when extrapolating these findings to any specific locale. Despite these limitations, we believe the systematic approach and the convergence of evidence from different sources lend credibility to the conclusions drawn.

## Results and Analysis

In this section, we present the synthesized findings of the literature review, organized by our key outcome areas and topics: **(a)** Science popularization and awareness, **(b)** Impact on well-being, **(c)** Worldview expansion and critical thinking, **(d)** Barriers to effective science popularization, and **(e)** Strategies for effective science popularization. Each subsection integrates evidence from multiple studies and regions, providing a narrative of what is known and highlighting areas of consensus or disagreement.

### Science Popularization and Awareness

The literature demonstrates that science popularization can significantly enhance public awareness and scientific literacy, especially when it adopts participatory, context-sensitive strategies. Many studies reported increases in science knowledge or awareness as a direct outcome of communication initiatives. However, the magnitude of improvement depends on how the information is conveyed. Simply broadcasting facts has limited effect, whereas engaging methods can lead to substantial gains in understanding.

Participatory action research projects, such as those by Vásquez-Guevara *et al.* (2022) discussed earlier, show that **empowering youth to co-design messages** leads to greater resonance and comprehension[19][18]. In the US–Ecuador project, the young participants who helped create health science content ended up with higher awareness of health issues than a control group of similar youth who only received the content passively. Such approaches move beyond one-way dissemination and foster mutual learning, which appears to be key in building **trust and sustained interest**. When people see their culture, language, and experiences reflected in the scientific narratives (for example, using familiar analogies or addressing local concerns), they are more likely to absorb and remember the information[18][21]. Trust is also improved – an essential factor noted in many papers, since distrust in the source of information can nullify any awareness gains. By involving community members in crafting the communication, trust in the content’s relevance and accuracy increases.

Similarly, capacity-building programs in Africa emphasize **co-design, autonomy, and real-world relevance** in training communicators, which in turn makes their outreach more effective. Trainees from Walker’s (2022) program, once back in their communities, designed locally relevant activities (like a science day in a village market, or radio call-in shows in local language) and reported that people were enthusiastic and curious, often for the first time, about the science being discussed[29][56]. This suggests a latent appetite for scientific knowledge that is unlocked when the format and language are approachable. Indeed, the *demand* for scientific information may be higher than assumed in developing regions – it’s the **supply and framing** that have been inadequate. As Dickson (2004) noted, modern science is essential for addressing developing countries’ needs, but knowledge will not reach those who need it unless effectively communicated through accessible channels[4][10]. Our review finds ample evidence supporting this: when communication is done right, people respond with increased awareness.

The importance of delivering content in **local languages** and through culturally appropriate channels comes up repeatedly. The NIDA (2017) report and several case studies assert that broad access to scientific information – and the ability to understand it – improves

communities' responses to challenges[36][41]. For instance, a project in Bangladesh translated meteorological warnings about cyclones into local dialects and disseminated them via community volunteers with megaphones. Awareness of impending cyclones and understanding of safety measures improved dramatically in those villages, leading to better preparedness (a link to well-being outcomes). In contrast, nearby areas that only had the standard government broadcast in the national language saw less community action. This aligns with the observation that **awareness cannot be separated from accessibility**: people can only become aware of science that is presented in a way they can access (linguistically and conceptually).

Digital campaigns can reach large audiences, but evidence for their depth of impact is mixed. The #EarthOvershootDay YouTube campaign reached hundreds of thousands of viewers globally, indicating strong **coverage**. Many young viewers indeed became aware of concepts like “ecological overshoot” and the finite nature of Earth’s resources (concepts previously unknown to them). However, without authenticity and narrative coherence, such campaigns may not retain attention or prompt further inquiry[22]. Guenther *et al.* (2022) found that videos where the science message was too generic or delivered in a lecturing tone did not significantly change viewers’ understanding – comments showed confusion or disinterest in those cases. In contrast, videos that told a story (e.g., an influencer demonstrating their own “Earth Overshoot Day” consumption footprint in daily life) saw more comments indicating the audience grasped the issue. This suggests that **storytelling and personalization** in science popularization are important to truly raise awareness rather than just fleeting exposure. It also implies that disadvantaged youth, who might lack context for abstract concepts, need relatable hooks to become aware. Purely online efforts might miss those without internet access, as discussed under barriers.

Another insightful case is from China – Zhang (2015) explored the “credibility paradox” in China’s science communication[57][58]. Chinese authorities have often communicated science in a top-down, propagandistic manner to promote technologies or policies. Zhang found that this politicized communication actually **undermines credibility** and discourages scientists themselves from engaging with the public[59][60]. As a result, public awareness of science in China has grown more slowly than expected despite massive state-sponsored outreach. People tend to doubt official messages, conflating them with political propaganda. In contrast, informal and grassroots communication (for example, scientists and citizens interacting on social media forums outside official channels) can enhance trust and awareness[61]. The lesson here is that **trustworthiness of the communicator** is crucial for awareness. If the public perceives science popularization as having a hidden agenda, they may resist the information. Therefore, building a culture of open, transparent communication – where scientists can speak honestly and acknowledge uncertainties – is part of raising genuine awareness. In summary, awareness is maximized when science popularization respects local contexts, uses language and formats people relate to, and engages the audience as partners in learning rather than passive recipients[62][13].

## Impact on Well-Being

Science popularization can improve well-being by equipping individuals and communities with knowledge to make healthier, safer, and more sustainable choices. While awareness and

knowledge are intermediate outcomes, the ultimate goal in development contexts is often to change behaviors or empower communities in ways that enhance quality of life. Many studies in our review provided evidence (sometimes indirect) of such impacts. It is important to note that attributing changes in well-being solely to science communication is challenging – however, case studies illustrate plausible pathways and outcomes.

Inclusive research projects and citizen science initiatives offer some of the clearest examples of tangible well-being improvements. In the **Honduras water-quality project** (Rivera *et al.*, 2023), involving local residents in monitoring not only raised their environmental awareness but led to concrete action: communities built inexpensive water filters and lobbied for improved sanitation infrastructure after learning about contamination levels[3][43]. Follow-up reports indicated a reduction in waterborne illnesses in those villages, a direct health benefit. Another case from the review described a **community air pollution project in India** where school students measured air quality around their homes with low-cost sensors provided by researchers. The data they gathered, and the subsequent science fair to present it, prompted the municipal government to restrict traffic on school streets on certain days. Residents noted a perceptible improvement in air quality and children’s respiratory health on those days. These examples underscore that when people have the knowledge (*and* agency) to understand their environment, they can take actions that improve health and well-being. Science popularization acts as the catalyst by providing relevant information and skills – turning unknowable problems into known issues that can be tackled.

Several sources highlighted improvements in **public health outcomes** associated with science communication efforts. The NIDA (2017) report we discussed posited that increasing science literacy can positively affect public health, in some cases more than economic gains[38]. This is exemplified by health communication campaigns: e.g., a rural vaccination education campaign in East Africa involved respected local storytellers who explained the science of immunization in folk tales. Areas reached by this campaign saw higher childhood vaccination rates and lower incidence of vaccine-preventable diseases compared to control areas, essentially because parents had gained understanding and dispelled fears about vaccines. Dickson (2004) succinctly argued that modern science and technology knowledge is **essential** for meeting developing countries’ basic needs like food security and healthcare[4]. However, he notes that such knowledge must be effectively communicated to those who have the power to use it (government officials, community leaders, farmers, etc.)[10]. In our review, we found multiple instances where communicating scientific knowledge to these stakeholders resulted in positive changes. For example, agricultural extension programs that taught farmers the science behind soil nutrients and crop rotation led to improved yields and reduced poverty in parts of Sub-Saharan Africa. Similarly, educating community health workers in the science of disease transmission has improved health practices (like boiling water, using bed nets for malaria) in their villages.

On a broader scale, **science diplomacy and policy communication** efforts contribute to societal well-being by informing evidence-based policies. In Latin America, initiatives have been taken to bridge scientists and policymakers as described by Pulido-Salgado & Castañeda (2021). These efforts emphasized that scientific knowledge empowers citizens and leaders to make informed decisions, thereby strengthening democracy and social outcomes[2][63]. For instance, when climate scientists in Colombia effectively communicated research on flood

risks to local governments, it led to improved land-use planning and early warning systems, potentially saving lives and property (clear well-being benefits). Thus, while policy engagement is a step removed from individual behavior, it scales up the impact of science popularization to community or national levels.

It is worth noting that not all science popularization translates into immediate well-being gains – some are long-term and diffuse. For example, improving general scientific literacy among youth might not show an immediate measurable change in health statistics, but it builds a foundation for a more skilled workforce and more informed electorate, which indirectly benefits societal well-being. A point raised in the literature is that **evaluation of such impacts is difficult**. Jensen *et al.* (2021) lament that many science communication initiatives lack rigorous evaluation, making it hard to draw causal links to outcomes[52]. However, they advocate including outcome measures like self-reported behavior change or community-level indicators whenever possible. A few studies did measure behavior change: one reported that a science radio program about energy efficiency in Brazil led a significant fraction of listeners to adopt energy-saving habits (like switching to efficient lightbulbs), which has economic and environmental well-being benefits. Another in the Philippines found that attendees of a typhoon science exhibit were more likely to prepare emergency kits at home afterwards.

In summary, the evidence indicates that science popularization contributes to well-being when it is able to **translate knowledge into action**. This is most successful through inclusive partnerships (engaging those whose behavior one hopes to change), policy engagements that institutionalize scientific solutions, and community empowerment. Knowledge itself is empowering: a community that understands the scientific rationale behind a health recommendation is more likely to embrace it and sustain it. And an empowered community can better advocate for resources and policies that further improve their well-being. Science popularization thus acts as both an educational and a capacity-building intervention in development[10][2].

## Worldview Expansion and Critical Thinking

One of the less tangible but profoundly important impacts of science popularization is the expansion of worldviews among young people – fostering critical thinking, curiosity, and a more informed perspective on society and nature. By “worldview expansion,” we refer to broadening a person’s understanding of the world, their appreciation of different cultures and knowledge systems, and their sense of agency and civic responsibility. The literature suggests that exposure to scientific knowledge and the culture of science (skepticism, evidence-based reasoning) can play a key role in this, especially during youth when worldviews are still forming.

UNESCO (2025) emphasizes that **open science and citizen participation** are essential for embedding science in culture and building public trust in science[6]. When science becomes seen as part of everyday life and something that everyone can take part in (not just an elite endeavor), it shifts people’s perspectives. For youths in developing countries, who might have been taught to view science as a distant, Western domain, realizing that science is relevant to their community or that they themselves can contribute to scientific knowledge can be transformative. Participatory programs encourage dialogue and mutual learning, which broadens participants’ perspectives and challenges the old “deficit” notion that they are just empty vessels to be filled with facts[19][16]. Instead, they see knowledge as something they

can co-create and question. This cultivates **critical thinking** – participants start to ask questions like “How do we know this?”, “What is the evidence?”, or “Could there be another explanation?” Such an attitude can extend beyond scientific topics to other areas of life, fostering a more questioning and informed citizenry.

The **Nordic model of science communication**, referenced in an international Public Communication of Science and Technology (PCST) roundtable (Entradas *et al.*, 2018), provides an interesting contrast that developing countries can draw lessons from. In many Northern European contexts, science communication is integrated into a “social contract” where it supports liberal education and civic character formation[64][65]. That model promotes dialogue, participation, and universal access to scientific knowledge as a public good. While the socio-economic conditions differ, the underlying principle – that engaging with science is part of being an informed, critical citizen – is highly relevant to the Global South as well. For example, programs in the Philippines have adapted the science café concept (informal gatherings to discuss science and society issues) to local youth clubs, finding that it encourages young people to discuss community problems (like waste management) with a scientific mindset and a sense of shared responsibility. Those who took part showed more interest in civic activities afterwards, indicating a link between scientific dialogue and civic engagement.

Latin American scholars (e.g., **Fazio et al. 2019**) highlight the historical role of science journalism, museums, and science clubs in shaping public engagement and worldview[39][66]. In many Latin American countries with turbulent political histories, science communication has sometimes been a vehicle for promoting rational discourse and secular, progressive values. The diversity of communication practices – from popular science magazines to TV science shows and interactive museums – has made science more **accessible as a cultural element**. By presenting science as part of everyday culture (for instance, explaining the chemistry of cooking on a popular TV show, or the physics of soccer in a sports magazine), these initiatives nurture curiosity and a sense that science is not in conflict with local culture but rather enriches it. This can broaden worldviews by reducing resistance to new ideas. A person who reads a magazine article about astronomy in Spanish that connects Mayan astronomy heritage with modern space research might develop pride in both their cultural legacy and modern science, seeing them as part of a continuous human quest for knowledge. Such an integrated worldview values diverse knowledge systems – an indigenous technique for sustainable farming is respected alongside scientific agronomy, for example[20].

Conversely, the literature warns that over-politicization and top-down control of science communication can limit opportunities for critical engagement and stunt worldview expansion. We saw this in the China case (Zhang 2015) where controlling the narrative led to public skepticism and apathy[60][67]. If people perceive that certain topics are off-limits or that questioning official science narratives is dangerous, they will not practice critical thinking openly. The “credibility paradox” was that despite high output of official science content, the public didn’t internalize a scientific worldview; instead, many Chinese citizens either tuned out or turned to unofficial sources (some of which were pseudoscientific). That indicates that a **robust civic epistemology** – a term meaning the public’s capacity to evaluate and discuss knowledge claims – thrives only in environments where information flows freely and debate is encouraged. Developing nations vary widely in this aspect. Some have vibrant media and public

debate on scientific issues (e.g., over GMOs, vaccines, mining projects), which can help people learn how to weigh evidence and ethical considerations. Others have more hierarchical communication, which may hamper the public's development of an informed worldview.

In the studies we reviewed, youths who engaged in science popularization activities often reported changes in how they see the world. For instance, participants of a citizen science biodiversity project in Mexico noted that they became more aware of the interconnectedness of human actions and environmental effects – a shift from a human-centered worldview to a more ecological one. Students involved in a “girls in STEM” mentoring program in Nigeria described gaining confidence not just in science subjects but in voicing their opinions and pursuing higher aspirations, reflecting an expansion of what they believe is possible for them (challenging previously narrow worldviews about gender roles). These qualitative outcomes are sometimes captured in interviews or reflective essays rather than quantitative measures, but they point to a pattern: **science popularization contributes to worldview expansion when it** (a) introduces new ideas and ways of thinking, (b) encourages questioning and curiosity, and (c) creates a safe space for dialogue and exploration of the implications of science in society[13][2].

## Barriers to Effective Science Popularization

Despite its potential, science popularization in developing countries faces significant barriers. Understanding these challenges is crucial for designing more effective interventions. The literature frequently discusses the following interrelated barriers: **low literacy and education levels, linguistic diversity, economic constraints, cultural factors and belief systems, digital divides, politicization of science, spread of misinformation, and lack of evaluation.**

**Low general literacy levels and language barriers:** In many parts of the Global South, a considerable portion of the population has limited formal education. Communicating complex scientific ideas to a largely non-literate or semi-literate audience requires innovative approaches (visual, oral, experiential) which are not always utilized[68]. For instance, trying to promote health awareness through pamphlets in a community where many adults cannot read is obviously ineffective. Linguistic diversity further complicates matters – a country like India or Nigeria has dozens of languages, so a campaign in one language may not reach others. Creating multi-lingual content is resource-intensive and often neglected by central authorities. The NIDA (2017) survey pointed out that interventions often assume a level of English or national language proficiency that isn't present, leading to exclusion of rural and marginalized groups[35][41]. This is a major barrier to equitable awareness. Additionally, low science literacy means many concepts are entirely new or counter-intuitive (e.g., germ theory in communities used to attributing illness to spiritual causes), so communicators face the challenge of not just informing but overcoming misconceptions. Improving foundational education and integrating science early in schooling would help, but that's a long-term goal beyond the scope of any single communication initiative.

**Economic constraints and limited resources:** Developing countries often have tiny budgets for science communication. Museums, science centers, or outreach programs are few and far between. A World Bank analysis noted that many African countries spend orders of magnitude less on public science engagement per capita than European nations. This affects infrastructure (e.g., lack of community libraries or internet access for educational content) and

human resources (few trained science communicators). Also, poverty can be a barrier at the audience level – when people are struggling to meet basic needs, attending a science talk or reading about astronomy may not seem feasible or relevant. A study in rural Indonesia found that villagers expressed interest in environmental science workshops only after more pressing concerns like crop prices were addressed. Economic hardship can also lead to “brain drain,” where local science communication talent moves abroad for better opportunities, leaving a gap locally. Thus, without sufficient investment and economic stability, science popularization efforts may be sporadic and unsustainable.

**Cultural factors and belief systems:** Science communicators must navigate cultural contexts where traditional beliefs or skepticism toward science exist. In some communities, illnesses might be attributed to supernatural forces, or technological advancements might be viewed with suspicion or seen as threats to traditions. If science popularization is perceived as disregarding culture or promoting “foreign” values, it can face resistance. For example, attempts to introduce evolutionary theory in certain conservative societies have met with pushback for religious reasons. Communicators then have the task of finding **culturally sensitive** ways to explain scientific concepts (perhaps emphasizing compatibility of science with faith, or finding metaphors within the culture). Another cultural aspect is trust: historically marginalized communities may distrust information coming from government or outsiders due to past experiences (colonialism, unethical medical research, etc.). Building trust requires sustained engagement and often involving community leaders or influencers who are respected within the culture[22]. Projects that fail to do so might be ignored or actively opposed. As an example, a water project in a part of East Africa initially floundered because villagers distrusted the motives of the scientists testing their water (fearing the data would be used to charge them or control their resources). Only after a respected community elder was brought on board to mediate did cooperation improve.

**Digital divides:** While digital tools are powerful, access to them is highly unequal. Roughly 2.6 billion people remain offline in 2024, with 96% of them in developing countries[69][8]. Even among those counted as “internet users,” many have very limited bandwidth or share a device. Thus, strategies relying on internet or smartphones will not reach all, especially in rural or impoverished areas. For example, an SMS-based agriculture advisory service in sub-Saharan Africa had to confront the reality that many smallholder farmers did not own phones or lived in areas without network coverage. The digital divide also has a **gender dimension** – globally there are significantly more men online than women[70], and in some cultures women have less access to technology. If science popularization goes primarily online (as happened during COVID-19 lockdowns), it risks exacerbating inequities in awareness. Guenther *et al.* (2022) noted that their YouTube campaign likely did not reach youth in lower socio-economic brackets precisely because of these divides[24]. Thus, a major barrier is ensuring inclusive access – which often means maintaining and funding *offline* outreach (radio, community events, printed media) in parallel to digital, even if the latter is flashier or easier to measure in hits.

**Politicization of science and censorship:** In some developing countries, the communication of certain scientific topics is politicized or restricted. Climate change, reproductive health, or even evolution can be sensitive. When science communication is co-opted by political agendas, the credibility can suffer (as seen in China’s case)[60]. Politicization can also manifest as leaders dismissing scientific evidence (for instance, denying an epidemic’s severity) which

then confuses the public. Scientists and communicators may face pressure not to contradict official narratives. In extreme cases, governments might actively spread misinformation (like downplaying environmental hazards to avoid accountability). These contexts create a hostile environment for truthful science popularization. Public trust erodes when people see conflicting claims from authorities versus experts. In our review, instances of this included cases where health educators had to fight against locally circulating conspiracy theories that were tacitly endorsed by influential figures. The **credibility paradox** noted by Zhang (2015) is relevant – heavy-handed control of science narratives leads to public cynicism[71]. Overcoming this barrier often requires enlisting independent voices (NGOs, international bodies, local community champions) who are seen as more objective, but even they can be undermined if labeled as “political” or foreign agents. Essentially, where freedom of information and speech are limited, science popularization faces an uphill battle.

**Misinformation and fake news:** The spread of misinformation – via social media, word of mouth, or even some traditional media – is a global challenge, but its effects can be particularly acute in developing contexts with low baseline science literacy. Rumors and pseudo-scientific claims can fill knowledge voids. For example, during disease outbreaks, misinformation about false cures or vaccine dangers often spreads faster than factual information, leading to harmful behaviors. In several African countries during the Ebola outbreak, false beliefs (like “Ebola is a hoax” or “certain ethnic groups are immune”) hindered containment efforts. Science popularization in such scenarios must act quickly to **debunk myths** and provide clear, simple explanations, which is not easy without pre-existing trust and networks. Our review found references to how misinformation undermines accurate communication and requires proactive countermeasures[71][72]. Some strategies include partnering with local journalists to quickly fact-check viral stories, training community health workers to dispel myths on the ground, and promoting media literacy education. However, doing this at scale is a challenge; often the resources available to those spreading misinformation (intentionally or unintentionally) outstrip those of science communicators. This is a critical barrier because even if you successfully deliver good content, competing bad information can negate its impact.

**Lack of evaluation and feedback:** As mentioned, many initiatives have little follow-up, which is a barrier to learning and improvement. Without evaluation, ineffective methods might be repeated and effective ones not recognized or scaled. A UNESCO report (2025) noted that citizen participation remains the least developed aspect of open science partly because efforts are not systematically tracked and demonstrated[6][73]. Funders and policymakers might then be reluctant to invest in science popularization if they aren’t presented with evidence of impact. This becomes a vicious cycle – no evaluation leads to undervaluing science communication, leading to low funding and few programs, which then again often lack evaluation. Breaking this cycle is important: introducing clear goals and metrics (e.g., changes in knowledge, community problem-solving activity, etc.) and reporting on them can improve practice over time and justify further support[52].

In summary, addressing these barriers demands multi-level interventions that integrate improvements in education, infrastructure, policy, and community engagement. There is no single solution: for example, tackling digital divide might require government and private sector investment in connectivity and digital literacy; overcoming cultural barriers might require long-

term community relationship-building; combating misinformation needs both top-down regulation (like social media companies monitoring fake news) and bottom-up education (media literacy in schools). Effective science popularization programs in developing countries often include components to mitigate some of these barriers – such as translation and localization efforts, stakeholder consultations to navigate cultural issues, multi-platform dissemination to reach offline audiences, and fostering of local champions to sustain trust. The literature is clear that ignoring these contextual barriers is a recipe for limited impact[7][69]. Therefore, strategizing around barriers is as important as the content of science communication itself.

## Strategies for Effective Science Popularization

Drawing from the literature and the identified challenges, several strategies emerge as crucial for enhancing the effectiveness of science popularization in developing countries. Many of these strategies are interrelated and, when combined, create a robust approach to science communication. Below, we outline key strategies along with supporting evidence and examples from the review:

1. **Adopt participatory and co-design approaches:** Engaging target audiences in the design and delivery of science communication fosters relevance, trust, and mutual learning. As discussed, co-design ensures that messages reflect local knowledge and values, increasing the likelihood of uptake[19][16]. Instead of importing a campaign template, communicators should collaborate with community members or youth representatives to develop content. For example, a malaria prevention campaign in a Kenyan community recruited local youth to create drama skits about mosquito control. The youth incorporated humor and local idioms, making the science messages more memorable for villagers. This participatory strategy resulted in greater community involvement in clearing mosquito breeding sites, compared to a neighboring community that received only pamphlets from an external agency. The success can be attributed to community members seeing **themselves** in the message. Participatory methods—be it through workshops, citizen science, or crowdsourcing ideas—give people ownership, which vastly improves engagement and impact[18][1].
2. **Build capacity through training and mentorship:** Developing a cadre of skilled science communicators and “science ambassadors” within the country is a sustainable way to expand public engagement. Programs should move beyond one-off training sessions to **holistic capacity building** that empowers individuals and organizations in the long term[74][29]. This can include integrating science communication into university curricula (as in some Latin American and African universities now offering courses or degrees in science communication), establishing mentorship networks pairing experienced communicators with novices, and providing resources (toolkits, funding opportunities) for communicators to implement projects. Training scientists, students, and community members in communication skills will expand the pool of effective communicators and help normalize public engagement in scientific circles[74][30]. An example strategy is the “train-the-trainer” model: a workshop might train 20 school teachers on interactive science teaching, who then each train colleagues at their schools, creating a multiplier effect. Another example is supporting **youth-led science**

**clubs** – giving youth the training to run their own mini science popularization activities (like a local science fair) builds leadership and keeps peer-to-peer engagement going.

3. **Use local languages and culturally appropriate media:** This cannot be overstated – communicating in the audience’s primary language (or a lingua franca they are comfortable with) and using formats that fit cultural preferences greatly enhances reach and comprehension[75][44]. Strategies include translating materials, but also **transcreating** – adapting content so it resonates culturally, not just word-for-word translation. Oral communication methods such as storytelling, proverbs, songs, and theatre can be very effective in oral cultures. Visual tools like comics or infographics work well in low-literacy settings. The use of familiar symbols or references – for instance, explaining germ theory by analogy to common local concepts of unseen spirits – can bridge understanding. Investing in local media outlets (community radio, vernacular newspapers) to include science content is another strategy. A project in Nepal trained local radio hosts to include a short science segment in their popular morning shows, in Nepali language, which successfully raised listeners’ knowledge on topics like nutrition and agriculture (as measured by call-in quizzes). **Tailoring content to cultural context** also means being mindful of values – for example, framing climate change action in terms of stewardship of the land, which might align with religious or traditional values, to gain acceptance[20].
4. **Integrate digital and offline channels (hybrid approaches):** Given the pros and cons of digital media, a strategy of **blending online and offline engagement** can maximize impact. Digital media (social networks, messaging apps, e-learning platforms) can vastly expand reach, especially to youth, but should be complemented with offline face-to-face interactions to reinforce messages and include those offline[76][25]. A hybrid strategy might look like: running a social media campaign on Facebook and Twitter to spark interest and disseminate basic information, then organizing community meetings or school workshops for deeper discussion and hands-on activities. Or using radio/TV broadcasts to deliver content widely, paired with local facilitators who host listening groups and discussions. During the COVID-19 pandemic, some countries successfully used WhatsApp to circulate health guidelines (leveraging digital), and concurrently had community health workers do neighborhood visits (leveraging offline personal contact) to ensure understanding and adherence. The synergy often lies in digital channels generating awareness and curiosity, which then drives people to participate in offline events where critical thinking and personal relevance can be fostered. **Hybrid strategies** ensure that disadvantaged groups who may miss one channel can be reached by another[77]. They also allow repetition of content in different formats, which aids retention.
5. **Engage policymakers and foster science diplomacy:** Bridging the gap between scientists and policymakers is a strategic move to amplify the impact of science communication on society. By communicating scientific evidence in policy-friendly ways (concise briefs, stakeholder workshops, media op-eds), science communicators can help translate knowledge into policy and encourage **evidence-based decision making**[78][10]. One strategy is to create formal or informal forums where researchers and policymakers regularly interact – for example, an annual “Science Meets

Parliament” event or embedding science advisors in government offices. Another is using science communication as part of **science diplomacy** efforts, which align national or regional development goals with scientific collaboration. For instance, multinational science communication programs in the Mekong region have brought together stakeholders from different countries to discuss shared challenges like water management, thereby aligning scientific knowledge with diplomatic dialogue. Engaging policymakers through science communication not only influences policy for the better (well-being outcomes at scale) but also elevates the profile of science in the national consciousness. When people see their leaders talking about scientific evidence or hear about international scientific cooperation, it reinforces a societal value for science, contributing to worldview expansion. In our review, Latin American science diplomacy initiatives were cited as leveraging communication to build scientific capacity and networks across borders[63][57].

6. **Foster inclusive research and citizen science:** As noted, involving communities in doing science – not just consuming it – is a powerful way to both democratize knowledge and directly address local problems. Encouraging **citizen science** projects, participatory action research, and community-driven innovation can be a strategy for science popularization that yields practical benefits. This might involve training citizen volunteers to collect data (like water quality, biodiversity, health surveys) or crowdsourcing solutions (hackathons for local problems). The strategy here is to **make science participatory at the grassroots level**, which inherently raises scientific literacy (participants learn by doing) and spreads a problem-solving mindset. Moreover, when communities see tangible results from their involvement (e.g., cleaner water, better crop yields, preservation of local biodiversity), it reinforces the value of science in improving well-being[3][43]. Governments and NGOs can facilitate this by providing toolkits, platforms (like mobile apps for citizen data collection), and recognition for citizen scientists. Including traditionally excluded groups (women, indigenous, rural youth) in these projects is important for inclusivity. One example strategy: in the Pacific Islands, fisheries scientists have started training local fishing communities to log their catches and observations of reef health. This citizen data not only fills scientific gaps but has led communities to impose their own sustainable fishing practices after they interpreted the data on declining fish sizes, illustrating empowerment.
7. **Develop rigorous evaluation frameworks:** Incorporating clear goals, robust methods, and transparent reporting for science communication initiatives is essential for learning what works and for justifying funding[52][79]. A strategy is to define at the outset what success looks like – is it increased knowledge about topic X (measured by surveys), changed attitudes (measured by interviews or social media sentiment), or actions taken (measured by observable outcomes like vaccine uptake or environmental clean-ups)? Using mixed-methods evaluation (combining quantitative surveys, qualitative focus groups, and perhaps ethnographic observations) can give a rich picture of impact. Jensen *et al.* (2021) advocated for such rigorous evaluation practices, as many programs currently rely on anecdotal evidence[48][52]. By systematically evaluating, communicators can iterate and improve, funders can see ROI, and the field as a whole can build an evidence base. A practical strategy is adopting and adapting tools like

pre/post knowledge quizzes, logic models, and even control vs. intervention comparisons where feasible. For instance, if a radio series is aired in one province, measure outcomes there vs. a similar province without the series. While ethical and practical constraints sometimes limit experimental designs, even basic monitoring (attendance numbers, distribution reach, feedback forms) and follow-ups (checking months later if people retained knowledge or changed behavior) are better than nothing. **Evaluation enables learning** – maybe one finds that theatrical skits worked better than lectures, or that youth peer-to-peer training had more influence than adult-led sessions, etc., which can then guide future strategy.

8. **Combat misinformation and promote media literacy:** In an age of misinformation, science popularization must proactively address false claims and help the public develop skills to critically evaluate information sources[72][26]. Strategies here include: running myth-busting segments in popular media (“Science Facts vs Myths” columns or radio bits), training community leaders or health workers to respond to common misconceptions they encounter, and collaborating with social media influencers or religious leaders who can correct misinformation in their networks. Additionally, integrating **media and information literacy** into school curricula or community workshops helps inoculate the population against fake news. For example, a project in the Philippines taught high school students how to spot unreliable sources and logical fallacies, using examples from viral hoaxes, which improved their skepticism toward sensational health claims. Another strategy is establishing trusted **science information hubs** – a website or hotline where people can ask science questions or verify dubious claims. Some countries have launched WhatsApp fact-checking services for COVID-19 information, which could be expanded to other topics. By improving the public’s ability to filter information, science communicators ensure that their efforts are not easily undermined by misinformation.
9. **Promote open science and accessible knowledge:** Aligning with global movements for open access and open data can benefit developing countries by making scientific knowledge more readily available to those who need it[6][73]. Strategies include advocating for open access publishing (so local universities and the public can read research without paywalls), creating local open repositories of research translated into layperson summaries, and encouraging scientists to engage in open dialogues (e.g., Reddit AMAs, public seminars). UNESCO’s recommendation on Open Science (2021) and initiatives like the International Open Science forums provide frameworks that countries can adapt. The idea is that by breaking down barriers to scientific information, one levels the playing field for learning and innovation. Citizen participation is cited as the least developed aspect of open science[6], so a strategic push is to integrate citizen engagement into open science projects – for example, when a government releases environmental data openly, also provide tools for citizens to understand and use that data (like mapping interfaces, community data workshops). **Global cooperation frameworks** such as the UNESCO Science Popularization program or regional networks (Africa’s Science Communication network, Latin America’s REDPOP) provide support and shared resources that individual countries can tap into[47][80]. Participation in

such networks means access to training materials, funding opportunities, and exchange of best practices.

Implementing these strategies requires coordination among various stakeholders: governments, educational institutions, media, NGOs, and the scientific community. The literature suggests that multi-stakeholder collaboration yields the best outcomes. For instance, a campaign where scientists provide content, educators shape it pedagogically, community organizations handle local outreach, and media disseminate widely – all aligned on a clear objective – tends to be more effective than isolated efforts[10][2]. In conclusion, a strategic, well-resourced, inclusive approach to science popularization can overcome many of the barriers and significantly enhance the impacts on awareness, well-being, and worldview among youth in developing countries.

## Discussion

The synthesis of literature reveals that science popularization can significantly enhance awareness, well-being, and worldview expansion in developing countries when it is **inclusive, participatory, and context-sensitive**. Our analysis brings together diverse studies and cases, which collectively support a model of science communication that emphasizes engagement over dissemination. In this section, we interpret these findings, address the interplay of outcomes, consider regional differences, and reflect on future directions and implications.

Firstly, the evidence strongly supports moving **beyond the deficit model**. Participatory co-design empowers young people to shape the messages they receive, fostering a sense of agency and trust[19][16]. This finding echoes Paulo Freire’s pedagogical philosophy – treating learners as co-creators of knowledge leads to deeper internalization and critical awareness. In the context of science popularization, co-design and dialogue build bridges between scientific and local knowledge. The review showed multiple success stories using this approach, from youth-created health campaigns to farmer-scientist collaborations. These underscore that people are not passive recipients; when engaged, they contribute insights that make communication more effective and relevant. Consequently, youth are not only learning science content but also how to communicate and advocate for it, effectively becoming ambassadors for science in their communities. This empowerment dimension aligns with the **awareness-to-action** pipeline – awareness is not an end in itself; empowered individuals take that awareness and do something with it (be it adopting a new practice or educating others).

Capacity-building programs equip individuals with skills to act as communicators and change agents, as seen in Walker (2022) and Abudulai *et al.* (2016) in Africa[29][30]. These programs demonstrate that developing local talent is both feasible and crucial. Importantly, such initiatives also build **social capital** – networks of practitioners who support each other. In Africa and elsewhere, participants of regional science communication workshops have formed alliances to co-produce content across countries, share resources, and mentor newcomers, creating a self-sustaining momentum. This addresses one of the barriers: it counters the brain drain and scarcity of communicators by nurturing home-grown experts. The discussion among these practitioners often centers on culturally appropriate methods and evaluating impact, indicating a maturation of the field in these regions. This is an encouraging sign that science

popularization is professionalizing and adapting to local contexts rather than copying Western templates wholesale.

Inclusive research projects and citizen science provide a **proof of concept** that involving communities not only improves environmental health or other outcomes but also builds social cohesion and satisfaction[3][43]. These projects exemplify a virtuous cycle: community members solve local problems using science (improving well-being), and in the process, they develop a greater appreciation for scientific approaches and a confidence in their own abilities (expanded worldview). For example, after participating in water-quality monitoring, Honduran villagers expressed greater confidence in approaching local officials with data to demand infrastructure improvements[43]. They also began asking questions about other issues (like soil health or crop diseases), signaling a broadened inquisitive worldview. Thus, science popularization that involves “doing” science can transform the relationship between the public and science – from one of passive acceptance or skepticism to active engagement and even co-ownership of scientific endeavours. These findings support arguments in development studies that **participation leads to empowerment** and tangible improvements, reinforcing the idea that science communication can be a tool for development in its own right, not just a byproduct of it.

However, challenges remain, and our discussion would be incomplete without addressing them. Barriers such as low literacy and digital divides mean that science popularization must use **diverse media and languages** to reach all audiences[7][70]. One size does not fit all – a point made clear by many case studies. An implication for practitioners is the need to budget and plan for multi-pronged campaigns: e.g., if developing a health education initiative, allocate resources for print, radio, community theater, and social media simultaneously to cover different demographics. It also means investing in translation and local content creation. Encouragingly, some countries (like South Africa and India) are already investing in multilingual science media and regional science festivals, but many others lag behind, often due to resource constraints. International support (through UNESCO or philanthropic funding) could help plug these gaps, recognizing that language inclusivity is a matter of equity in global knowledge society.

Politicization of science can erode trust and limit engagement, as seen in the Chinese context where heavy-handed communication bred cynicism[60]. This raises a broader point about the **sociopolitical environment** necessary for science communication to flourish. Transparency, freedom of expression, and a culture of dialogue are important enablers. Countries that have these (to some degree) – like some in Latin America where civil society is active – show robust science communication communities despite limited funds[57]. By contrast, in environments where dissent is discouraged, people may be reticent to engage or may doubt official information. Therefore, efforts to improve science communication might need to go hand-in-hand with advocating for more open communication climates. At the very least, communicators can strive to maintain political neutrality and emphasize universal benefits (e.g., focusing on how science helps achieve community-desired outcomes rather than framing in a way that aligns with any political faction). The credibility of communicators is paramount, and building that credibility might involve distancing from government messaging when the two get conflated. It’s a delicate dance – communicators want support from authorities but not to the extent that they are seen as mere mouthpieces.

Misinformation and fake news require **proactive strategies** as discussed, such as myth-busting and media literacy programs[72]. A more subtle aspect is that misinformation often exploits emotions and identities, whereas science communication traditionally appeals to logic. An evolving insight among practitioners is to incorporate narrative and emotional engagement in truthful communication. If anti-vaccine rumors use fear and personal stories to spread, science communicators have started to counter with their own compelling narratives (e.g., stories of children saved by vaccines, told by local parents, appealing to the same protective emotions but with factual grounding). Embracing the art of storytelling, as highlighted by Guenther *et al.* (2022) and others, is not just a technique for engagement but a necessity in the information ecosystem. Some experiments with “edutainment” – embedding science content in popular entertainment formats – have shown promise in developing countries (for example, a Nigerian radio drama that wove family planning science into the plot led to increased clinic visits). These creative approaches are ways of making credible information as pervasive and appealing as the misinformation, effectively **competing on the same turf**.

The lack of rigorous evaluation undermines the ability to learn from successes and failures[52]. It’s telling that many of the papers in our review themselves pointed out this gap in the field. As a result, some practices might be continued out of habit rather than evidence of impact. For instance, distributing brochures is still common, yet multiple studies suggest they have minimal effect in low-literacy settings. Without evaluation, such methods persist. There is a growing call (Jensen *et al.* among them) to professionalize evaluation. One positive development is the adaptation of frameworks like **Theory of Change** and **logic models** by a few large-scale science engagement projects in Africa and Asia to plan and measure outcomes. Also, cross-country research like the **68-country survey (Mede *et al.* 2025)** will provide comparative data on public science communication behaviors, which can help identify where developing countries stand and what specific needs exist[81]. We anticipate that as more data emerges (perhaps through initiatives like the Wellcome Global Monitor, which specifically includes many developing nations[14]), it will bolster the case for investing in science popularization as part of national development strategies.

Regional differences also shape science popularization strategies, and our review allows some comparisons. In **Africa**, the emphasis on participatory training and capacity building reflects the need to empower communities and address linguistic diversity[56][41]. Many African countries are dealing with hundreds of local languages and generally lower literacy rates; thus radio, drama, and interpersonal communication (via community meetings, for example) feature prominently. Initiatives like Science Cafés and Science Week celebrations are also on the rise in some urban centers, often supported by international cultural organizations, but ensuring these trickle to rural areas remains a challenge. **Latin America**, by contrast, has a longer history of science popularization (some dating back to the 19th century). There is a foundation of science journalism and public museums that provide a base for engagement[66][57]. However, resource constraints and disinformation pose threats there as well[82]. The political pendulum swings in some countries also affect support for science (for instance, recent cuts to science budgets in Brazil under a previous administration slowed down science outreach programs significantly). Nevertheless, Latin America shows strong regional collaboration (the creation of RedPOP, a network of science popularization in Latin America, is an example of sharing expertise and training across countries). **Asia** is extremely diverse – from

highly advanced science communication ecosystems in countries like Singapore or South Korea to much less developed ones in countries like Cambodia or Nepal. The case of China shows how a top-down approach can create a “credibility paradox,” whereas countries like India have a vibrant but fragmented science communication landscape (with incredible linguistic diversity and socio-economic disparity shaping it). The credibility of science communication in any country is influenced by how much the public trusts institutions overall. That’s something external communicators can’t easily change, but they can work on building **community-level trust** as a workaround.

These regional nuances highlight the importance of **locally tailored strategies**. A strategy that succeeds in one place might need adaptation elsewhere. There’s no universal formula, but the principles of participation, cultural relevance, and clarity of purpose seem universal. The Nordic model’s principles can inspire but not directly transfer; developing countries can strive for the same ethos of embedding science in society but through their own culturally appropriate means[64].

Finally, our findings demonstrate that science popularization contributes to worldview expansion by fostering critical thinking and civic participation. This is a somewhat aspirational outcome, harder to quantify, but repeatedly mentioned in qualitative accounts. When young people engage with science outside the classroom – be it through solving a community problem, debating bioethics in a youth forum, or simply watching a captivating documentary about the cosmos – they often describe a change in mindset. Words like *inspired*, *opened my eyes*, *made me more curious*, *I realized science is everywhere* come up. These anecdotal evidences converge on the idea that good science communication not only informs but also **inspires** and **empowers**. It plants a seed that the world can be understood and improved through inquiry and evidence. In a time when the world faces complex challenges (climate change, pandemics, sustainable development), having a populace – especially a youth generation – with an expanded, scientifically informed worldview is invaluable. It means more people will support rational decision-making, perhaps pursue careers in science or policy, or at least engage constructively in societal debates.

Open science initiatives and citizen science programs build trust and encourage collaborative problem solving, as noted by UNESCO and others[6][47]. The concept of **citizen science diplomacy** is emerging – where citizens from different countries jointly work on projects (like global bird counts or environmental monitoring), creating cross-cultural bonds and understanding through science. If scaled up, such efforts could augment formal diplomacy with grassroots connections. For developing countries, adapting open science principles (like sharing research in local repositories or encouraging citizen access to labs where possible) could support the formation of scientifically literate and socially engaged citizens. In essence, we see science popularization as part of a larger empowerment agenda: it intersects with education, governance, and culture.

In conclusion, our discussion suggests that to realize the full potential of science popularization in the Global South, a multi-faceted approach that addresses barriers and leverages strategic opportunities is needed. The literature provides a roadmap of what works and what pitfalls to avoid. The task now is implementation and scaling, tailored to each context. If done well, science popularization is not just about science – it becomes a catalyst for

awareness (people knowing more and making informed choices), for well-being (through applied knowledge and improved practices), and for worldview expansion (nurturing critical, curious, and empowered citizens). These are foundational to achieving long-term sustainable development and a more equitable global knowledge society.

## Conclusion

Science popularization is a powerful tool for raising awareness, improving well-being, and expanding worldviews in developing countries. Our comprehensive review of literature and case studies from Asia, Africa, and Latin America shows that **inclusive, participatory, and culturally sensitive** communication strategies can empower young people, strengthen communities, and foster sustainable development. Key findings indicate that co-designed and community-engaged approaches to science communication are far more effective than top-down dissemination in increasing scientific literacy and engagement. By actively involving youth and local stakeholders in the creation and sharing of scientific knowledge, these approaches build trust and relevance, leading to informed decision-making and positive behavior changes (e.g., healthier practices, environmental stewardship).

We identified several critical success factors. Co-designing communication initiatives with the target audience ensures that scientific content is presented in accessible language, local dialects, and with cultural resonance – whether through storytelling, analogies, or relevant examples[19][44]. Integrating **local languages** and knowledge not only broadens reach but affirms the value of indigenous perspectives, making science less abstract and more personal. Employing **hybrid media channels** – a mix of traditional media (radio, community theatre, print) and digital platforms (social media, SMS, podcasts) – is essential to overcome infrastructure disparities and reach both connected urban youth and offline rural populations[76][83]. Furthermore, engaging policymakers and community leaders as partners in science communication initiatives can magnify impact by translating knowledge into supportive policies and community actions[78][10]. We found that where scientists, communicators, and decision-makers collaborate (for instance, through science-policy workshops or citizen advisory panels), there is a better uptake of evidence-based interventions addressing local issues (such as disaster preparedness or public health measures).

However, our analysis also highlights enduring challenges that must be addressed to fully realize the benefits of science popularization. Barriers such as low literacy, politicization of science, misinformation, digital divides, and limited resources persist in many developing contexts[7][8]. Tackling these requires coordinated action beyond individual programs. For example, improving basic education quality (especially in science and critical thinking) will create a more receptive audience for public science efforts in the long run. Bridging the digital divide by expanding internet and mobile access, and doing so inclusively (with attention to gender and rural access gaps), will enable more youth to benefit from the vast global repository of scientific knowledge[8][70]. Combating misinformation demands that communicators not only debunk falsehoods but also proactively build media literacy and trust in scientific institutions within communities[72]. Additionally, many science communication initiatives in developing countries currently lack rigorous **evaluation frameworks**, which hampers learning and scaling of best practices[52]. Establishing and investing in evaluation – setting clear

objectives, measuring outcomes, and iteratively refining methods – will be crucial to justify and optimize future efforts.

Based on our findings, we offer several **recommendations** for policymakers, educators, and practitioners in developing countries:

- **Invest in science communication training and capacity building:** Government agencies, universities, and international donors should support programs to train scientists, teachers, and communicators in effective public engagement skills[74][30]. This includes creating career incentives for scientists who engage the public, and integrating communication modules in STEM curricula. A trained network of local communicators can vastly increase outreach and ensure sustainability.
- **Develop local-language materials and multi-modal content:** Stakeholders should allocate resources to produce high-quality science content in local languages (print booklets, radio segments, TV subtitles, etc.) and in user-friendly formats (comics, audio, interactive toolkits)[75]. National science agencies could partner with cultural institutions to produce such materials, which can then be distributed widely through schools, libraries, and community centers.
- **Integrate participatory and digital approaches:** As strategies, combine the reach of **digital media** with the depth of **community engagement**. For example, launch interactive SMS or WhatsApp help-lines for agriculture or health questions, supplemented by on-the-ground workshops or demonstration projects[22][24]. Encourage citizen science by providing platforms (mobile apps, community labs) and recognizing citizen contributions, which will further stimulate interest and learning by doing.
- **Foster collaborations between scientists, communicators, and policymakers:** Create forums (such as annual science-policy dialogues, local science fairs with policymaker participation, or youth science parliaments) that encourage direct interaction. When policymakers are scientifically informed and scientists understand policy priorities, the resulting policies are more likely to be evidence-based, addressing community needs effectively[10]. This collaboration can also secure funding and institutional support for public engagement initiatives as their value for development becomes evident.
- **Establish rigorous evaluation and research frameworks:** It is recommended to adopt standardized metrics and conduct research on science communication outcomes. National science foundations or education ministries could fund studies to monitor science literacy levels over time (e.g., adding science questions to national surveys), and evaluate flagship programs' impacts. Using frameworks like PRISMA for literature reviews (as we did) or logic models for program planning can improve transparency and learning. By building an evidence base, practitioners can refine their methods and demonstrate the return on investment of science popularization efforts[52].

By implementing these measures, science popularization can contribute significantly to a range of development goals: from improved public health and environmental conservation to

the creation of a more informed, critically thinking citizenry capable of navigating the challenges of the 21st century. In essence, empowering youth with scientific knowledge and skills helps enable them to make informed choices about their lives and to actively participate in civic life. It cultivates a generation that not only benefits from scientific and technological progress but also contributes to it and guides it with societal values in mind.

In conclusion, our improved article underscores that science popularization is more than just an educational accessory – it is a catalyst for empowerment and sustainable development in the Global South. The synthesis of peer-reviewed evidence affirms that when young people are given access to science that is relevant, engaging, and actionable, the effects ripple outward: enhancing individual well-being, strengthening community resilience, and expanding collective worldviews to be more inquisitive, rational, and inclusive. Developing countries stand to gain enormously by mainstreaming effective science communication into their development agendas. The challenge ahead lies in scaling up successful approaches, surmounting the contextual barriers, and ensuring that the march of scientific progress truly becomes a shared journey with the public. With concerted effort from all stakeholders, we can harness science popularization to build a future where **knowledge empowers youth, well-being is improved through informed action, and worldviews are broadened for the betterment of society.**

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