Citizen Science in India: Introduction, Challenges and Way Forward

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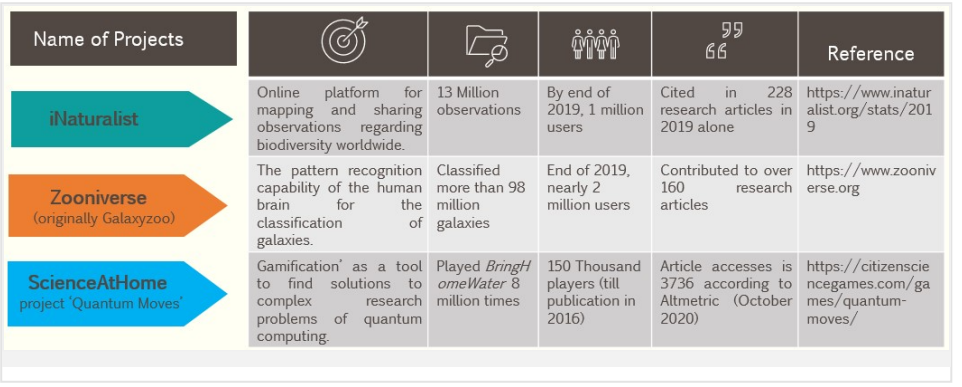
Citizen science: Introduction

According to the Oxford dictionary, the term 'citizen science' is defined as, '*scientific work undertaken by the members of the general public, often in collaboration with or under the direction of professional scientists and scientific institutions.*' Citizen science is usually described as voluntary engagements of the public, who involve themselves in the scientific projects of various disciplines, including natural history, astronomy, biodiversity, etc., out of their personal scientific interests. Even though the underlying concept of citizen science is quite old, the term *citizen science* is fairly modern - the first known modern citizen science project was accomplished and published in 1994 by Alan Irwin [Irwin, et al. 1994]. Due to the effectiveness of such projects in gathering large scale data, citizen science projects have gained enormous traction in the last two decades, with hundreds of citizen science projects currently being operational worldwide in fields as diverse as astronomy, ornithology, meteorology, oceanography, agricultural science, biodiversity and quantum computing. This article explores the advantages, challenges and requirements of citizen science projects, followed by a proposed framework for the institutionalization of citizen science in India.

Examples of Popular Citizen Science Projects

There are numerous examples of successful citizen science projects, among which iNaturalist [iNaturalist 2019], Zoonivers [Zooniverse 2020], and the flagship project *Quantum Moves* [Jens Jakob W et al. 2016] from ScienceAtHome, are described below [Table 1]. These projects have successfully utilized the advanced information and communication technologies (ICT). The use of artificial intelligence supplemented mobile and web applications for data collection have boosted the pace of the targeted outcome. It is interesting to note the strategy employed in

Quantum Moves, which is an online citizen science simulation game, where the participants move quantum atoms to complete challenges that are simulations of logical operations in a quantum computer. This is an example of gamification strategy to collect data. Mobile games are popular among masses and such gamification moves encourage wider citizen participation in highly specified fields. The strategy of 'research-enabling, game-based education' used in 'Quantum Moves' not only helped in solving some of the most daunting science problems but also reinvigorated public interest in science in the process [Ornes 2018].



Name of Projects					Reference
iNaturalist	Online platform for mapping and sharing observations regarding biodiversity worldwide.	13 Million observations	By end of 2019, 1 million users	Cited in 228 research articles in 2019 alone	https://www.inaturalist.org/stats/2019
Zooniverse (originally Galaxyzoo)	The pattern recognition capability of the human brain for the classification of galaxies.	Classified more than 98 million galaxies	End of 2019, nearly 2 million users	Contributed to over 160 research articles	https://www.zooniverse.org
ScienceAtHome project 'Quantum Moves'	Gamification' as a tool to find solutions to complex research problems of quantum computing.	Played *BringHomeWater* 8 million times	150 Thousand players (till publication in 2016)	Article accesses is 3736 according to Altmetric (October 2020)	https://citizensciencegames.com/games/quantum-moves/

Fig 1 Some successful citizen science projects.

Mechanism for Engaging the Citizens in Suitable Science Projects

Citizen science can be used as an innovative way of data collection for research which otherwise would have not been possible or would have been too expensive to carry out. There are different stages and ways in which non-experts contribute to citizen science projects. However, in the majority of cases, it is either in the form of data collection or data analysis. The methodologies employed involve the use of crowdsourcing for 'distributed observation,' 'distributed computing' and 'distributed intelligence' [Figure 1]. One major reason for the increase in the number and scope of citizen science projects is the phenomenal growth of ICT with an unprecedented number of people having access to the internet and smartphones [Dickinson, et al. 2010: 149; Bonney et al. 2014: 1436; Engels 2015].

The use of ICT based technologies provides additional benefits, such as lesser material costs, no need of physical spaces, broader outreach, and real-time information-sharing capabilities [Newman et al. 2012; Herrick et al. 2018]. Further, the development of associated mobile applications and gamification of several projects has made it even more convenient for the general public to participate in them. Hence, the continuous growth in the publication of peer-reviewed articles resulting from citizen science initiatives and their acceptability comes out as no surprise [Follett and Strezov 2015; Nature Index 2018].

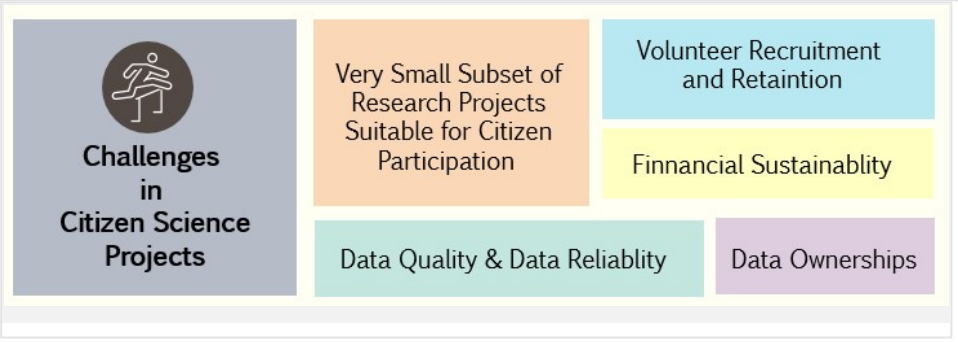


Fig 2 A representative workflow diagram for citizen science projects

Researchers get the required data of a project by distributing the workload among a larger group of volunteers [Figure 1], which drastically reduces the cost and timeline of the implementation of large and complicated projects. Some research showed that the time devoted by the volunteers is equivalent to 11-42% of the annual US National Science Foundation budget (~ $0.7-2.5 billion) [Theobald et al. 2015]. This often results in a perception that citizen science is a way to get free labour for researchers. However, the benefits to all stakeholder: the researchers, volunteers and society at large cannot be counted in mere monetary terms [Conrad and Hilchey 2011; Ryan et al. 2018].

It is established that the volunteers get the first-hand experience by associating with scientific enterprises, acquire knowledge and learn to appreciate the importance of scientific endeavours [Conrad and Hilchey 2011]. Volunteers are driven by different motivations such as a desire to learn and contribute to science, a way to formalise their leisure or recreational activities such as bird watching and stargazing and contribute to a cause like environmental protection. Whereas, by working with people having different professional and academic backgrounds, scientists often gain a new perspective on their research [Bonney et al. 2015]. Moreover, many such projects have been successful in gathering funds for sustainability. One such example is Cornell's Project FeederWatch, which raised $3,000,000 annually to track and measure range movements of 100 winter bird species [Dickinson et al. 2010].

Data Collection Tools for Citizen Science Projects

Most citizen science projects involve volunteers in collecting large sets of data. The training for data collection and the data collection itself can be accomplished in both online and offline modes. Even though the advancement of ICT technologies have changed the face of citizen science projects, in countries like India where the internet and mobile devices are not an easy commodity, offline mode of data collection holds certain importance; particularly in projects like agriculture-based citizen science projects, where the participants belong to economically

backward sections of the society. However, in India, some participants may not have access to internet-based devices.

Benefits of Citizen Science

Society at large benefits as the engagement of the general public in well-designed science projects can inculcate the scientific temperament and improve society's understanding of how science works [Bonney et al. 2015]. This is especially important in this era when misinformation campaigns often get more reach and visibility than hard facts. This has been apparent with the flooding of social media with misinformation about the COVID-19 situation. Moreover, such projects help direct research attention towards issues that affect society with better society-science conversation and strengthen society's trust in science in the process. Further, evidence-based policymaking is an essential tool for effective governance and social welfare. Here, citizen science could provide an effective way to obtain and process large data sets to support the evidence-based policymaking process [Hyder et al. 2015]. In particular, the monitoring and management of natural resources including land, air, water, minerals and forests would benefit from the increased public participation [Conrad and Hilchey 2011].

Challenges in Citizen Science Projects

Despite these advantages of citizen science, there are many issues and concerns related to different aspects of how it is conceived and practised. The following figure highlights the issues concerning citizen science projects [Figure 2].

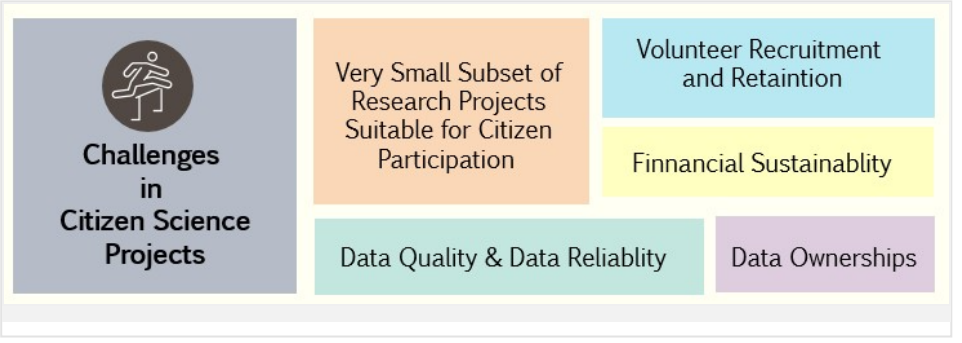


Fig 3 Possible challenges with citizen science projects at a glance

Firstly, the quality of data is often not reliable and inconsistent across various citizen science projects due to personal biases and lack of trained volunteers. This prompts a mistrust among scientists against the data collected or analysed by volunteers. However, the application of rigorous quality control measures and transparent execution of projects can help dispel such concerns [Burgess et al. 2017; Parrish et al. 2018]. Various analytical techniques have been developed

to filter the data for quality and minimise the distortions due to personal biases [Hochachka et al. 2012]. Further, strategies such as iterative project development, volunteer training and testing, replication across volunteers, expert validation, and statistical modelling of systematic errors could boost data accuracy and account for biases [Kosmala et al. 2016].

Secondly, a very small subset of research projects is suitable for public participation. Another dimension of this problem is the limited awareness among scientists about the usage of citizen science projects that could match their needs. Here, a guideline and collection of best practices would greatly help researchers ascertain the suitability of a project for public participation, and design projects specifically for public participation.

Thirdly, finding the right incentives to recruit and retain volunteers is often a daunting task. The initial motivations for volunteers are often extensions of their interests or hobbies, and a desire to learn and contribute to science [Rotman et al. 2012]. Additionally, recognition in the form certificates and co-authorship or acknowledgement in the research publication is found to be key secondary motivations to retain volunteers [Rotman et al. 2012]. Here, providing basic scientific training and feedback on their contributions can instil a sense of being invested in the projects, and contribute to long term retention [Rotman et al. 2012]. Projects should be designed to employ various incentivisation strategies to maximise volunteers' involvement with the timely interjection of relevant motivational probes. In this context, gamification is often considered an effective strategy especially for millennials [Hochachka et al. 2012; Bowser et al. 2013].

Fourthly, there are several issues relating to data ownership, usage, privacy and accessibility. Here, many approaches are discussed and debated including open access of data, and participants as 'data custodians' [Ganzevoort et al. 2017; Guerrini, et al]. Here, an automated mechanism could be introduced that tracks and periodically notify volunteers about when and how of the data contributed by them being used [Rotman et al. 2012]. Further, participants should be informed about data policy that projects follow and its implications before they start.

Lastly, the financial sustainability of these projects is often a concern, especially for community-driven projects. However, several funding agencies and governments are now waking up to the need and significance of citizen science projects and adapting mechanisms to ensure their funding [US-EPA 2018; Australia-CSA 2020.]. In this regard, the growth of citizen science follows a positive feedback mechanism as it increases scientific literacy which in turn creates a citizenry that advocates a greater allocation of funding for science projects.

Citizen Science in India

Prominent Projects so Far:

Citizen science projects have been growing rapidly in India in the last decade and a half with the associated increase in the number of publications and visibility amongst the general public [Research Stash, et al]. Many initiatives like 'Hornbill watch,' 'Roadkills India' and 'India Biodiversity Portal' have mobilised thousands and generated awareness about the scientific method and environmental protection [Sharma 2019]. In addition to the projects starting in India, many global citizen science projects such as 'eBird' and 'Seeds for Needs' now have popular India specific extensions. According to a landmark study that assessed the ecology-related citizen science projects in India, various significant outputs have been achieved including the discovery of scores of new species, a better understanding of incidences of animals being killed in road accidents, and tracking of migratory species [Sekhsaria et al. 2019].

However, the numbers of projects, publications and participants are nowhere close to the potential of a country as big, diverse and increasingly tech-savvy as India. Here, it should be noted that for the Indian context, citizen science volunteers mostly represent a small subset (generally the educated middle class) of the entire population. Considering the complex setup of our country, there remain a multitude of challenges and associated opportunities that have to be addressed to release the energy of the informed citizenry for the benefit of science and society.

India specific issues and needs:

a) Guidelines for Design and Implementation: There is a need for a collection of best practices and facilitative guidelines for the design and implementation of citizen science projects in India. These should include directions for data collection, data analysis, data quality, volunteer guidance, community engagement and result accessibility. Moreover, the issues of data ownership and data privacy must be made clear under the legal provisions. Here, the collection of guidelines and best practices developed in the US and Europe could be a good starting point to develop India specific directions [ECSA 2016; US-EPA 2019]. Such development of common standards could facilitate synergistic networking of small and local projects into large endeavours. Also, it would support the creation of a common infrastructure or 'pool' of citizen science initiatives where researchers can freely advertise for the need of volunteer services for their projects and volunteers can choose the projects based on their interest, locality and expertise [Rotman et al. 2012].

b) National Online Portal: Large scale national level consortia have been found to help facilitate inter-regional connections between citizen-science participants and to expand the spatial coverage of citizen science projects [Conrad and Hilchey 2011; Maggi et al. 2016; Requier et al.

2020]. We can achieve such large scale consortia through a national online portal, combined with a dashboard to act as a repository of all citizen science initiatives, to facilitate the connection among the stakeholders. Such a portal should facilitate online registration and access to relevant guidelines and best practices. Further, it should contain the list of titles, websites, associated institutes, names of project managers and scope of the projects. The dashboard could be used to keep track of key parameters such as number of participants, geographic and topic-wise distribution of projects, mode of public participation, number of data points collected/analysed and resultant published papers. This dashboard would be the key to monitor the execution of projects and ensuring transparency in execution.

Moreover, it would provide essential data for research on different aspects of citizen science project design and implementation strategies. In this regard, 'SciStarter' is an excellent example of a web portal that has a repository of projects, a project finder tool to locate and participate in citizen science project of one's interest, a dashboard that tracks projects and notifies on progress, a forum for discussion among all stakeholders, a collection of tools for researchers to design and implement projects, and online event organisation and registration facilities [SciStarter 2020]. Further, it regularly publishes blogs and podcasts to increase public awareness and disseminate information related to trends in citizen science. There are also many portals managed by the government agencies in different countries including the US, Scotland and Canada that perform similar functions [Canada Citizen Science Portal 2017; Scotland 2020; USA 2020].

c) Early inception of Citizen Science Concepts in Indian education System: It is important to incorporate the basics of citizen science in the school and higher education curricula. Undergraduates in STEM fields should be trained with basic methodologies and tools of citizen science and should be encouraged to come up with new ideas for citizen science projects for local communities. These projects can be further evaluated and implemented at the district and state level with the support of state-level and local higher education authorities, higher education and research institutes (HEIs) and NGOs. Moreover, Corporate Social Responsibility (CSR) funds could be utilised for community focused citizen science initiatives. In return, such projects should incorporate public education as one of their goals.

d) Role of Higher Education Institutes (HEIs): in developed countries, most citizen science initiatives originate in the HEIs. For example, many iconic projects such as ScienceAtHome and eBird started at Aarhus University, Denmark and Cornell Lab of Ornithology respectively. In contrast, the National Centre for Biological Sciences (NCBS), Bengaluru is a rare exception among the HEIs in India with a distinction of conducting multiple remarkable projects such as 'SeasonWatch' and 'Biodiversity Atlas – India.' Most other top HEIs including IITs and IISERs have failed to lead any such programmes. This is a symptom of total ignorance in India's academic circles of the potential that such projects hold despite the rapid growth in citizen science-related publications globally. For citizen science to grow in India, the HEIs have to lead the way with new innovative projects. These projects could be synergised with the public outreach programmes of the HEIs.

The national science academies, NGOs, public and private funding agencies can do much to encourage citizen science projects as these projects often face financial constraints. A separate

pipeline to evaluate design, practicability and potential impact of citizen science projects can be developed in this regard. The science academies could act as coordination and resource centres for such projects. Further, workshops, webinars and seminars could be organised by them to promote citizen science culture among researchers and STEM undergraduates.

Moreover, many countries including the US, Australia and Europe have 'Citizen Science Associations' that organise conferences, workshops and provide networking and publishing support [Australian citizen science; ECSA, 2020; US-CSA 2020]. In India, however, no such organisation exists at the moment and the science academies could help create one. Also, many universities abroad now have dedicated centres that coordinate and guide citizen science activities, while acting as bridges between society and universities. Centre for Citizen Science (CCS), Pune is the only such centre in India that is working with an impressive number of research institutes based in Pune and nearby areas [CCS-Pune 2020]. Such centres could help avoid duplication of efforts and promote collaborations in addition to acting as the regional repository of best practices. More such centres should be opened to coordinate and promote citizen science activities in and around other clusters of research institutes in India.

e) Geographical Inclusions: One major issue has been the uneven geographic and thematic spread of citizen science projects in India. South India has disproportionately large numbers of citizen science projects compared to the rest of the country [Sekhsaria et al. 2019]. This is due to the proactive leadership of HEIs and NGOs, and extensive local media coverage there. It would be great if the lessons learned during these projects are communicated for replication in the other parts of the country.

f) Diversifying across fields: Simple internet search for citizen science-related projects in India mostly provides hits for projects in the domains of biodiversity and environmental protection with a focus on volunteer involvement on data collection and monitoring aspects. Further, most of these projects are reviewed by Sekhsaria et al. 2019. To tap into the full potential of citizen science, the areas and nature of public participation have to diversify. Here, areas such as meteorology, land digitisation, genome projects, water and air quality measurements, compiling of tribal knowledge, compiling of traditional water preservation and weather prediction techniques, indexing fossil records and ancient manuscripts, and quantum computing could be ideal for the development of novel citizen science projects in India. Further, inputs from the general public can be incorporated in other stages of the projects including project design, management, data analysis and result interpretation depending on project requirements. As mentioned earlier, additional avenues for public involvement would further incentivise volunteer participation as they feel more invested in the projects.

g) Policy Interventions: Lastly, the Department of Science and Technology (DST) has released draft Scientific Social Responsibility (SSR) policy 2019, which underscores the need to develop stronger linkages between science and society [Rajput 2019]. It aims to inculcate moral responsibility amongst the scientific community to engage with the general public to enhance awareness about the scientific processes and how they benefit society. Here, citizen science can play a key role in attaining this objective. However, this draft document fails to even mention the potential that citizen science has in bridging the science-society gap. This could

be corrected in the upcoming Science, Technology and Innovation Policy (STIP 2020) with emphasis on citizen science and provisions for an institutional structure for regulating citizen science activities in the final policy document.

Proposed Framework for Citizen Science in India

All the points mentioned above directed us towards the design of a comprehensive framework to facilitate, regulate and promote citizen science in India. We propose a model to include various stakeholder engagement to build a national citizen science framework [Figure 3]. The very first understanding from literature- there is an urgent need for standardized guidelines for data collection, data analysis, data quality, volunteer guidance, community engagement and result accessibility along with the crucial issue of data ownership and data privacy. DST being the primary stakeholder in Indian STI ecosystem should take up the lead in framing the basic and standardized guidelines for citizen science projects. Here, DST has the experience of framing and implementing various science, technology and innovation-related policies in the past. However, this exercise must be a bottom-up and stakeholder-driven process.

The Science academics (IASc, NASI, INSA) may assist DST in this process. DST should also take up the task of setting up the national citizen science portal which would act as a dashboard of all citizen science project related information, guidelines, the facility for stakeholder engagements, information on funding opportunities, etc. It should be equipped with state of the art facilities in Data Science and AI. Such facilities must be built with open-source software (a very good example is NDLI) and must be accessible to all. The 'top tier HEIs' (which include institutions of national importance such as IISc, NCBS, IITs, TIFR, IISERs, CSIR labs, etc.) in India have the necessary competence to build such a portal and may partner with DST to execute the task.

It must be noted here that, in this framework, HEIs are divided into two broad categories: 'top tier HEIs,' and 'tier II and local HEIs' [Figure 3]. This division is made considering the realistic capacity, autonomy and past record of these institutions. Here, the top HEIs are best suited for large scale and technology-driven projects due to their access to better resources and high reputation among the public. Top tier institutions should take active parts in the development, design and execution of citizen science projects. The top HEIs can mentor local HEIs by providing training to researchers on methodologies and best practices by organising workshops and webinars. More international collaboration and participation of NGOs are also important in augmentation of the citizen science ecosystem. The science academies and top tier HEIs may take leads in such inceptions. Here, NGOs involved in citizen science are also clubbed with the local HEIs as the majority of them are limited in scope and function at the local level even though they are more intimately integrated with the communities compared to HEIs. Local HEIs and NGOs with their complementary strengths should work in tandem to maximise the public participation in scientific endeavours while increasing scientific literacy in the process.

The national science academies should promote ‘Citizen Science’ and encourage the HEIs in India to float more such projects. Interdisciplinary research with social scientists on the methodologies and social impact of citizen science in the Indian context should be facilitated by the academies as well.

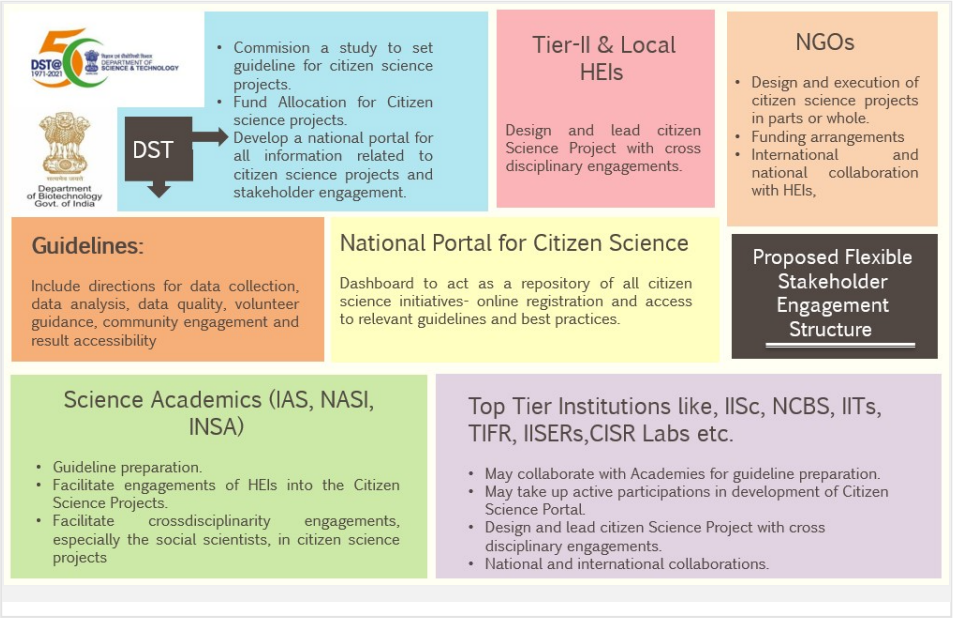


Fig 4 Possible framework and stakeholder engagements for the institutionalization of citizen science projects in India

The proposed framework should not follow any rigid structure rather take a dynamic approach for stake-holder engagements where roles are not defined for the stakeholders. The only defined parts are setting up the guidelines and national portal by a DST commissioned and approved process. This will ensure that the fundamentals of citizen science projects are built on accurate guidelines and also the legitimacy of available information.

Another important aspect that needs attention is the lack of a dedicated journal for citizen science in India unlike ‘Citizen Science: Theory and Practice’ journal published by the Citizen Science Association in the US [CSA 2020]. Here, science academies can arrange for publication of a thematic journal along with periodic reports on the trends of citizen science initiatives in India.

Conclusions

Citizen science is an important tool for larger societal participation in science and knowledge. Although in Indian context ‘citizen’ represents only a part of the society, who fits in with the required criteria of participation. Yet a reasonably large section of the society will have the

chance to be part of scientific knowledge generation. Citizen science not only helps in gathering insights for local problems but also expands scientific literacy in the process. With many scientists keeping aside their initial hesitation related to data quality and reliability, the number and scope of citizen science initiatives are likely to keep on growing. At the same time, new mechanisms are being developed to address the challenges that earlier hampered the wide-scale adoption of citizen science amongst the scientific community. Technology is expected to drive the growth of citizen science in the foreseeable future. A testimony to this is the formation of 'Citizen Science Global Partnership,' a network of citizen science associations and centres from across the globe that is supported by the UN Environment Programme and UNESCO. In future, citizen science is expected to be firmly established across disciplines in the post-colonial societies and emerging economies.

Here, India has the potential to be a leader in citizen science based on its demographics and ever-increasing penetration of technology. However, many structural issues plague the growth of citizen science in India that warrant structural changes in how it is perceived and practised in the country. The institutional framework proposed in the passages above could help resolve some of these issues. Further attention from all stakeholders could prompt at least some areas of modern science to become more inclusive, participatory, responsible and responsive to society's needs while receiving citizen support for large and complex projects. Citizen science can emerge as a new arena for South-South and North-South cooperation at the international stage due to its inherently collaborative nature and growing recognition of problems best suited for citizen science projects across the world. In this context, the next decade would be crucial and the government should come up with an evidence-based policy framework and implementation mechanism to leverage the maximum benefit of this phenomenon.

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