

Chapter 5

Discussion and Interpretations

5.1. Introduction

This chapter discusses the empirical findings of the survey of senior Indian scientists to address the aim and objectives of the current study. With no significant studies on science communication by scientists in the Indian context, the current study aimed to help scientists in India to improve their engagement in science communication with the general public. It investigates how senior Indian scientists engage in such activities, and what are their perceptions and attitudes toward different aspects of science communication. The study was intended to establish how Indian scientists perceived about: the importance of science communication, its objectives and use of different communication/media formats; science-society interactions; level of media coverage of science; moral duty, role and responsibilities of scientists; public engagement by scientists and its impact on their careers; factors affecting public engagement; willingness to engage in the future; and the possible interventions for enhancing scientists' overall public engagement in the future. The study is not focused on communication of any specific area or topic of science such as climate change, astronomy, biotechnology, nanotechnology, or environment, but provides a larger picture of scientists' personal values, views, attitudes and behaviours toward science communication in general.

The constitutional and policy provisions in the country advise scientists to take the message and benefits of science to the larger society. The new science policy initiatives in India (SSR Policy, 2019 and STI Policy, 2020) also have encouraging provisions for boosting science communication in the country. These new (draft) policies mandate science communication as a social scientific responsibility of scientists and scientific institutions. In this context and for

further guiding such policies in the country, the current study's findings would provide empirical evidence on how Indian scientists see science communication and their involvement in it. This study is the first of its kind survey exploring science communication by scientists in India. The sample of this study consisted of senior and experienced scientists from nine different broad academic disciplines and eight different types of employers, including central and state governments (universities and R&D labs), corporates and private institutions, and non-governmental organisations. Data from 204 respondents suggest that they were affiliated with about 140 different scientific, academic, and professional institutions distributed across the country. They came from different socio-cultural backgrounds, as suggested by the fact that they reported 18 different languages as their mother tongue.

The study sample consists of about 84% of scientists aged more than 55 years and about 81% of them having research experience of more than 30 years. More than 50% of the respondents held top scientific/administrative positions such as university vice-chancellors, institute/lab directors, secretaries, department heads, or group leaders. Such a sample of senior, experienced and top Indian scientists makes the findings even more important. Also, the participants of this study were scientifically highly productive scientists, with about 62% of them having more than 100 peer-reviewed publications and about 85% having at least 60 publications to their credit. The science communication views, attitudes and behaviours of such a sample of senior and experienced scientists, who are scientifically highly productive and occupied top positions in their organisations, would have a transformative effect on and serve as a trendsetter for the junior and mid-career scientists.

Further, scientists' perceptions, attitudes and behaviours about different aspects of science communication as covered in this study were found to be largely independent of the demographic variables such as age, gender, primary position, type of affiliation, research experience, and area of research. This observation is consistent with literature to some extent, where demographic variables such as gender and age had no significant impact on scientists' participation in science communication activities (Bauer & Jensen, 2011).

The discussion and interpretation of the survey results are provided objective-wise for all the four research objectives of the current study in this chapter. The findings are also compared with similar studies on scientists in different parts of the world.

5.2. Objective 1 – Science communication, its importance and roles and responsibilities of scientists

The first objective of the study, “To explore what Indian scientists think about a) the importance of science communication, in general, and b) their roles and responsibilities for science communication, in particular,” is discussed here in the following text.

The current research revealed that Indian scientists gave high importance to science communication with the general public. This is possibly the first-ever empirical evidence about Indian scientists' perceived importance of communicating science to the public. Several studies (e.g., Royal Society, 1985; Wellcome Trust, 2001; Royal Society, 2006; Nisbet & Scheufele, 2009; Agre & Leshner, 2010; Shugart & Racaniello, 2015; Dudo & Besley, 2016) have strongly suggested for greater involvement of scientists in public engagement activities. When scientists generally give more importance to ‘doing research’ than communicating it with the public, their public engagement remains low. However,

Indian scientists giving high importance to science communication indicates better prospects to enhance their engagement.

In this regard, the Indian scientists' perception also appears to show an understanding and appreciation of India's first science policy (Scientific Policy Resolution, 1958), which encourages individual initiative for the acquisition and dissemination of scientific knowledge as one of its aims. It has an implied instruction for those who have scientific knowledge to engage in its dissemination to the wider public so that the people of the country can benefit from acquiring and applying scientific knowledge in their lives. The common citizens are also expected to acquire scientific knowledge for the betterment, welfare and advancement of their own and of the nation. However, they may not be able to access the benefits of science and technology if they remain ignorant of the scientific advances. Also, low levels of scientific literacy and lack of scientific knowledge are generally blamed for misunderstanding about science among the public (Hartz & Chapell, 1997).

However, it would be difficult for ordinary people to access scientific knowledge if it is not served to them in a way and language they can understand and appreciate. Here, scientists, being producers of scientific knowledge, have an important role in disseminating scientific knowledge to the general public, directly or through the media. Inaction or lower involvement of scientists in this direction is one of the reasons for low levels of science literacy (Hartz & Chapell, 1997, Treise & Weigold, 2002, Lundy, Ruth, Telg & Irani, 2006). One way to enhance scientists' involvement in disseminating or communicating scientific knowledge to the public would be to understand how they perceive its importance or their involvement. In this context, the current study's finding that the vast majority of Indian scientists considered science communication as an important activity is really very

encouraging. It would also help fulfil the constitutional requirement for every citizen to ‘develop the scientific temper, humanism and the spirit of enquiry and reform’ as a fundamental duty (Part-IV, Article 51A(h)). New policy initiatives should focus on translating this positive attitude toward science communication into enhancing scientists’ public engagement.

The current finding also confirms several previous studies highlighting scientists’ perceptions and attitudes toward the importance of science communication. A survey of scientists in three countries showed that the majority of scientists – 78.6% American, 71.1% German, and 65.8% Taiwanese – believed communicating science with the public is a good thing to do for scientists (Lo, 2015). Comparing with the findings of Lo (2015), results from the current study showed a relatively higher percentage of Indian scientists (~97%) believing that public communication of science is important. Another large survey of US scientists conducted in 2018 revealed that about 53% of the US scientists surveyed expressed that science communication with the public was important for them (Rose, Markowitz & Brossard, 2020). However, compared to the finding of this US survey, it is found from the current study that about 44% more Indian scientists thought that science communication is an important activity.

Merino & Navarro (2019), while exploring the public engagement perceptions of Mexican scientists at the National Council of Science and Technology (Conacyt), found that about 96% of Mexican scientists considered public communication of science as an important activity. Another Mexican study also found a similar percentage of scientists believing in the importance of science communication (Guerrero, 2016). The findings (Merino & Navarro, 2019; Guerrero, 2016) are very much comparable to the current study’s findings. Another

recent study finds that most Lithuanian scientists (58%) believed that scientists should regularly communicate with the public (Valinciute, 2020). However, the percentage is relatively lower than that of Indian scientists from the current study.

The current finding is also consistent with the majority of researchers/academics in Scotland (87%) and England (85%) believing that it is important to engage and interact with public or civil communities both in principle and practice (Bond & Paterson, 2005). A qualitative study of US geneticists by Mathews, Kalfoglou & Hudson (2005) also revealed that they placed a high value on public engagement and believed that scientists should be involved more actively in such activities. McCann, Cramer & Taylor (2015) have also highlighted that research scientists at 12 US universities regarded science outreach and engagement activities as important while even facing challenges in their engagement.

A study of health researchers' attitudes revealed that most researchers believed there are potential benefits of engaging with the public (Thompson et al., 2009), indirectly highlighting the importance of science communication. Also, the majority of 155 professional astronomers from 31 different countries surveyed during the 28th International Astronomical Union General Assembly in 2012 believed that public outreach is important and that researchers should invest more time in such activities (Dang & Russo, 2015).

The majority of scientists surveyed in Great Britain during 1999-2000 think highly about the importance of science communication for the public and scientists themselves (Wellcome Trust, 2001). Another study of researchers in the UK also highlighted the importance of public engagement with research at higher education institutions (Grand, Davies, Holliman & Adams, 2015). A large study of UK scientists and engineers also highlighted the importance

of scientists' engagement with non-scientist audiences; however, not a majority of them had this opinion (Royal Society, 2006). Pitrelli, Brunelli & Murellia (2006) have reported that Italian researchers also considered science communication as important for scientists' profession.

This discussion indicates that most Indian scientists gave high importance to science communication, just like their counterparts in other countries such as America, the UK, Scotland, England, the USA, Germany, Taiwan, Italy, and Mexico. Indian scientists' perceived importance of science communication was almost independent of their demographic variables such as age, gender, research experience, primary position, and type of employer. This observation is consistent with what Besley, Oh & Nisbet (2012) found that age and gender are minor predictors in scientists' views on public engagement. Also, as the current study's respondents are senior scientists who highly regard science communication as an important activity, it is consistent with the previous study that senior scientists are more likely to engage with the public (Royal Society, 2006).

Results showed that the majority of Indian scientists (~68-87%) gave high importance to deficit objectives, including 'informing and educating the public,' 'simplifying science,' and 'inculcating scientific temper.' They also gave high importance to 'creating excitement about science' as an objective of public engagement. Interestingly, 'building public trust in science' and 'contributing to policy making' were also important objectives of science communication to Indian scientists.

About 87% of Indian scientists rated informing and educating the public as an important objective which is close to what Rose, Markowitz & Brossard (2020) found that about 95%

of US scientists also agreed that better informing the public about science is an objective of science communication. Their findings that 88.6% of US scientists agreed with exciting people about science and 88.3% with increasing public trust in science as objectives of science communication are comparable to what the current study suggests that 84.5% of Indian scientists wanted to create excitement about science and 85.7% to build public trust in science.

Kreimer, Levin & Jensen (2011) also found that Argentine researchers believed informing the public about the importance of science and contributing to public debates about science are among the main reasons for participating in science outreach activities. Informing the public, increasing the impact of science on society, contributing to public debate, and increasing public interest and awareness about science were the main purposes for Lithuanian scientists to engage in science communication (Valinciute, 2020). Mexican scientists also believed that informing and educating citizens, generating positive social attitudes, and helping people to make informed decisions are among the main purposes of science communication (Merino & Navarro, 2019). Guerrero (2016) also presented that most scientists believed that showing the importance of science in society and helping people to make informed decisions are the main objectives for their involvement in science communication. UK scientists also indirectly recognised the importance of informing and educating the public as an objective of public engagement (Wellcome Trust, 2001).

To defend science, inform, excite, and build trust were perceived by US scientists as important objectives of science communication (Dudo & Besley, 2016). However, they gave a bit higher priority to deficit objectives than engagement and public trust objectives. The current findings on the importance of science communication objectives among Indian

scientists are consistent with the findings of Dudo & Besley (2016). However, Indian scientists gave almost equal importance to all the deficit, engagement, and public trust objectives of science communication, except the policy objective getting a bit lower importance.

Most of these studies noted that one of the main objectives of science communication is to inform and educate the public because there is a perception that the public lacks an understanding (has a deficit) of scientific knowledge. Among all other objectives, informing and educating the public about science has been traditionally, and still, the most important objective of science communication among scientists. Most scientists (97%) believe that a better understanding of science is beneficial to the non-specialist public (Wellcome Trust, 2001). Moreover, many communication scholars suggest moving beyond the deficit model; and allow two-way active engagement and dialogue between science and society, where scientists not only talk but also listen to the public's perspectives and concerns.

However, the deficit model will always be in demand, especially in countries and situations where science literacy is low. However, with increasing scientific awareness, more avenues for dialogue and engagement are needed. Therefore, keeping in view India's socio-cultural and economic diversity and literacy levels, science communication efforts by scientists in India need a mix for both the deficit and engagement models while also ensuring to build public trust in science and to contribute to policies. Thus, the current study intended to examine how Indian scientists regarded the different objectives of science communication. It is noted that the complex Indian scenario seems to be well taken care of by the senior Indian scientists when they recognise the importance of all the deficit, engagement, trust, and policy objectives of science communication. Also, it is interesting that the importance of these

objectives among Indian scientists did not show any meaningful variation based on their demographic variables.

For ensuring enhanced engagement between science and society, most Indian scientists believed that it is important to use all the different ways of communication (face-to-face interactions, TV/video, radio, print, and online). The importance given by scientists to one communication medium was significantly and positively correlated to other media. The importance given to the ways of communication was also found to be positively and significantly correlated with the respondents' perceived importance of science communication. However, Indian scientists gave the highest importance to 'face-to-face interactions,' suggesting that they not only believe in information exchange but also want to establish a direct link with the public through two-way dialogue and communication. In terms of the mediated communication, they gave relatively more importance to TV/videos, print media and online media than radio. This preference might be reflective of the fact that visual media are increasingly taking over our communication spaces.

The current study's finding that Indian scientists consider different media as important ways of science communication is consistent with the findings of (Peters, 2013). Peters (2013) found that most US and German scientists believed that visibility in the media is important, and more scientists and institutions are now using mediated communications in addition to the traditional direct and face-to-face communications. The current findings are also consistent with most Mexican scientists expressing higher interest in doing public communication of science through direct interactions, interacting with the media, using social networks, and writing blogs (Merino & Navarro, 2019). These current findings of different media types are also roughly consistent with the results of a survey of UK scientists

by Wellcome Trust (2001) where scientists believed that different media (print, TV, radio, online, etc.) are used to obtain information about science and its implications. However, the current findings contrast with what Nielsen, Kjaer & Dahlgaard (2007) found that most Danish scientists were not interested in contributing to different types of media or through direct communications.

US geneticists in a study expressed that the use of the media is perhaps the best way for approaching the problem of scientific literacy (Mathews, Kalfoglou & Hudson, 2005). They also suggested that professional science societies should facilitate and promote scientists' interactions with the public and the media. Gascoigne & Metcalfe (1997) suggested that media can be a powerful method for scientists to engage with the public and reach different stakeholders such as research funders and policy-makers. News media are also believed to have the potential of spreading science literacy/awareness on a large scale (Treise & Weigold, 2002). These studies provide a strong background for using different types of media by scientists to communicate their research with non-scientist audiences. These also support the current finding where Indian scientists gave almost equal importance to direct and mediated ways of science communication. Perhaps, they are aware that the socio-cultural and linguistic diversity coupled with variable literacy levels in India demands all the possible ways of public communication to boost science communication efforts.

Most scientists believed that the current level of science coverage in the Indian news media was below average. Their perception of science in the media is largely consistent with several studies (Weigold, 2001; Salwi, 2002a; Patairiya, 2002; Patairiya, 2003; Besley & Nisbet, 2013; Dutt & Garg, 2000; Gregory, 2003; Kumar, 2013; Peters, 2013) indicating low media coverage of science as compared to other topics such as politics, crime, sports, or cinema.

Based on content analysis of 10 leading Hindi and English newspapers in India during 2011-12, science and technology coverage in Indian newspapers was found to be about 2% (Kumar, 2013), which was way below the expected level of coverage (Patairiya, 2002). Merino & Navarro (2019) also noted that the majority of Mexican scientists did not find that popular media are providing enough science news. When scientists perceive low levels of science coverage in the news media, it indirectly indicates that there should be more science coverage, as Peters (2013) noted that most scientists he studied believed visibility in the media was important.

Scientists have also expressed concern about the quality of media coverage of science, including misrepresentation, inaccuracies, and misquoting in science reporting (*e.g.*, Gascoigne & Metcalfe, 1997; Wellcome Trust, 2001; Merino & Navarro, 2019). In such a scenario, many scientists even believe that the media are a barrier in the greater understanding of science among the general public (Wellcome Trust, 2001).

In busy modern life, the general public mainly relies on the popular news media/press to get new information about scientific advances (Nelkin, 1995; Weigold, 2001; Lundy, Ruth, Telg & Irani, 2006). So poor coverage of science in the media would potentially deprive the public of scientific information that they deserve to know and which can be used to make informed decisions affecting their lives. Here, Salvi (2002b) has noted that ‘the amount of space allotted to science in different media of a country is the index of the quality of life of its average citizen.’ Therefore, this calls for further research on why media coverage of science remains relatively low and how the same can be increased.

Results suggest that Indian scientists have positive attitudes toward science-society interactions when the majority of them (~79-95%) agreed that scientific ignorance is a hurdle in the advancement of science, scientifically ignorant public can oppose science projects, public awareness about scientific issues should be increased, and better linkages between science and society are needed. These positive attitudes toward these statements on science-society interactions are positively correlated to each other and to the importance of science communication. It is found that an awareness of the impact of science communication on the welfare of society among scientists leads to having positive attitudes toward the importance of science communication, which potentially translates into more public engagement by scientists (Dudo, 2013).

Scientific ignorance or illiteracy is a potential reason for the knowledge gap between science and society. Such ignorance can create hurdles in advancing science rather than appreciating the benefits of science and technology. Scientific ignorance is considered one of the main reasons for public opposition to science and for the controversies surrounding science (Bubela et al., 2009; Rajput, 2017). Ahteensuu (2012) has also noted that lack of scientific knowledge generally leads to the general public's opposition to or negative attitudes toward science and technology. In fact, the whole movement for the public understanding of science got much impetus from Bodmer's Report (Royal Society, 1985) based on the dominant assumption that the public is generally ignorant or illiterate about scientific knowledge. To address this deficit type thinking, scientists are called to communicate scientific facts to the general public in such a way that they can understand and value science in society (Royal Society, 1985; Ahteensuu, 2012; Besley, 2015). Lack of scientific knowledge often leads to public distrust on science. The absence of appropriate communication efforts to dispel scientific ignorance may weaken science-society relations leading to public distrust on

science (Agre & Leshner, 2010), potentially forcing them to oppose science projects. We have witnessed such opposition in several cases, such as Bt Brinjal and Kudankulam Project.

Therefore, science communication is the tool to fill the gap between science and society by spreading scientific awareness, establishing a dialogue, and helping build a sense of mutual trust. Enhanced public awareness about scientific issues can potentially garner public support for the advancement of science while preventing unnecessary opposition to science projects. This is particularly important in democracies like India having a multi-party political system where scientists need political and public support to execute their R&D projects. To achieve this, it is pertinent to place science communication and public engagement at a higher pedestal in the world of science, where scientists play an active role in establishing a greater dialogue with society. If scientists fail to communicate the importance of their research and its societal/ethical implications, they may lose funding opportunities or necessary approvals to execute their projects. Hence, scientists are required to take up the responsibility to create and share authentic and reliable communications for consumption by the larger public.

Otherwise, vested interests and lobbyists may take over the discourse (Shugart & Raceneillo, 2015) and run their own propaganda and misinformation campaigns to achieve their goals at the costs of tarnishing the image of science and scientists (Agre & Leshner, 2010). Such misinformation claims on popular media and social media can influence the larger society, and pseudoscience may become part of the mainstream narratives in society, which may further widen the gap between science and society. This can be detrimental to the advancement of science and to achieve a rational and scientifically thinking society.

It is found that the majority of Indian scientists believed that communicating science to society/taxpayers was part of their job's role and responsibilities (83.79%). About 78% of scientists agreed that they have a moral duty to inform society about what research they are doing with taxpayers' money. They also showed a general agreement that scientists are responsible for communicating their research to the public (69.11%), science communication should be an essential part of a scientist's duty/job (69.50%), and scientists should play an active role in science communication (84.17%). These findings provide evidence dispelling the general perception, especially in the media circles, that scientists are not keen to engage with the public/media.

These attitudes and perceptions of Indian scientists were least impacted by their demographic variables. In most cases, the impact of demographic variables was statistically insignificant, or if significant, then the effect size was small. These observations are consistent with previous studies. For example, Besley, Oh & Nisbet (2012) also found that demographic variables such as gender and age were relatively minor factors affecting scientists' perceptions and involvement in science communication activities.

However, the positive perceptions about science communication being part of their job and about the sense of moral duty, role and responsibility among Indian scientists for communicating science to society were significantly correlated with their positive attitudes about the importance of science communication and the stronger science-society linkages, and the number of peer-reviewed publications.

The current findings on Indian scientists' sense of moral duty or responsibility in engaging with the public are consistent with several studies conducted in different countries, including

the USA, UK, Australia, Spain, South Africa, Mexico, Switzerland, Basque Country, and other international studies (Wellcome Trust, 2001; Conradie, 2004; Royal Society, 2006; Lundy et al., 2006; Searle, 2011; Roten, 2011; AAAS, 2015; Hamlyn et al., 2015; Lloron-Leturiondo & Davies, 2018; Farahi et al., 2019; Llorente et al., 2019; Merino & Navarro, 2019).

A large survey of scientists and engineers in the UK suggested that 69% of them thought that scientists have a responsibility to engage with the public (Royal Society, 2006, p.32). Another UK study also revealed a similar but bit higher percentage (73.5%) of scientists showing agreement for their duty (Hamlyn et al., 2015, p.33). An earlier survey conducted in 2000 showed even a higher percentage of UK scientists (84%) believing they have a duty to communicate (Wellcome Trust, 2001, p.21). Llorente et al. (2019) also found that 69% of the Spanish scientists surveyed believed that research staff must communicate or disseminate science and technology to society. With 80% of the scientists surveyed in Switzerland in 2007 agreeing that they have a duty to communicate their research and its social and ethical implications to the non-specialist public (Roten, 2011), it is comparable to the current findings. A comparable percentage of Mexican scientists (84%) also believed they have a duty to communicate with the public (Merino & Navarro, 2019). A large majority of scientists in the USA (~94%) believed that explaining their work to the public was one of the important potential responsibilities of scientists (AAAS, 2015, p.18-19). About 87% of the 3748 American scientists linked with the American Association for the Advancement of Science agreed that scientists should take an active role in public discussions about science and technology (Pew Research Center, 2015). About 89% of Australian scientists surveyed in 2007 also showed a high level of agreement that scientists are responsible for communicating science to society (Searle, 2011, p.220). These findings are also consistent with Conradie's

(2004) findings that the majority of South African scientists believed that scientists have a duty to communicate their research to the general public (p.160). Lundy et al. (2006) have also reported that most US agriculture scientists associated with the Southern Association of Agricultural Scientists (SAAS) indicated that they have a responsibility to help people understand their research.

From the above discussion and comparison, it is found that Indian scientists' understanding of their moral duty and responsibility in science communication is in tune with what the majority of scientists across several countries (69% to 94%) believe that they have a moral duty or responsibility for public engagement.

Contrary to the perception that junior and early-career scientists engage more than their senior counterparts (Rose et al., 2020), the current findings provide evidence that a large majority of senior and experienced scientists from the Indian sample are more inclined to engage with the public. Rather, these findings are more consistent with the *Survey of Factors Affecting Science Communication by Scientists and Engineers* where senior scientists were more likely to participate in public engagement activities (Royal Society, 2006). The majority of the senior and experienced Indian scientists surveyed own a sense of moral duty to engage reaffirms the results of an earlier study that 'sense of duty' is a greater motivation for senior scientists to engage (Martín-Sempere et al., 2008). This sense of moral duty is also shared by scientists from other countries, as noted earlier in this discussion. However, scientists' sense of duty to inform the public is dominated mainly by the one-way top-down approach of communication (Davies, 2008; Varner, 2014). Shifting to equal participants two-way dialogue approach is desirable where future scientists should be trained to promote genuine

dialogue with the public rather than just relaying top-down messages (Davies, 2008; Varner, 2014).

The finding that science communication is perceived as a part of the job for a large majority of Indian scientists (~84%) is comparable with most of the Mexican scientists (91%) thinking that it is part of the scientific activity (Merino & Navarro, 2019). Peters (2013) has also noted that nowadays many scientists believe that talking to the media is part of their professional role. However, this finding contrasts with only 26.6% of Australian scientists surveyed in 2007 saying that communicating science is part of their job (Searle, 2011, p.202). Also, the current finding is contrary to the results of an earlier UK study where most scientists did not consider science communication as part of their job, but only 5% of them said that if it were part of their job, then it would encourage them to engage with non-scientist publics (Royal Society, 2006). An international study of astronomers and physicists about outreach activities also revealed that the majority of them (69%) expressed that outreach activities should be part of a scientist's professional responsibilities (Farahi et al., 2019).

The majority of the respondents are enthusiastic about science communication and believe that they have a moral duty or responsibility to communicate science with the public. However, only a minority of them (28%) are willing to own the main responsibility for public communication of their research. Now, this is a curious case why many Indian scientists are not ready to lead science communication efforts. It can be a potential topic for further research.

On the other hand, a higher proportion of the respondents (~40%) pitched for skilled science communicators to lead science communication efforts and act as mediators between scientists

and the media/press or the public. However, there are hardly a few R&D labs/institutes in India with science communicators on their payroll or separate science communication departments. There were demands for establishing such a system for promoting public communication at R&D institutions (Salwi, 2002) but recommendations in this regard largely remained unattended. Therefore, it is an urgent call for the government agencies and policymakers to seriously address this gap area for ensuring efficient efforts in science outreach and public engagement. Recently, there is a positive development in this regard. India's upcoming Science, Technology and Innovation (STI) Policy appears to have recognised this demand by proposing various interventions, including setting up science communication wings at every public S&T institution (Department of S&T, 2020). Also, the draft Scientific Social Responsibility Policy 2019 of India (Department of S&T, 2019) emphasises the larger social responsibility of scientists in communicating their research to the public and engaging with society. The current findings provide empirical evidence, which was earlier lacking, for such policy interventions in the Indian context. It is hoped that these findings would help guide further policy on science communication by scientists in India.

Further, only about 13% of the respondents believed that media/press should play the main role in communicating science. It is possibly reflective of the poor levels of science coverage in the popular media/press (Salwi, 2002; Patariya, 2003; Besley & Nisbet, 2013; Dutt & Garg, 2000; Gregory, 2003; Kumar, 2013), as also noted by the majority of respondents of this study. With only 19% saying that government, R&D institutions, or research funding agencies should play the main role is suggestive that government or institutional agencies have a limited role, maybe in policymaking and issuing guidelines for encouraging and supporting science communication activities. In other terms, the results from about 68% of respondents are suggestive that science communicators and scientists should team up and

share the main responsibility to communicate science through active support of the media, and government and science agencies.

Overall, it is understood that a sense of moral duty or responsibility among scientists is essential for enhancing their active involvement, establishing better linkages between science and society, and ensuring public trust in science through two-way dialogue and engagement.

Results show a new bottom-up academic mindset (Larsen et al., 2011) open for accepting responsibility for science communication that would enhance scientists' public engagement if coupled with appropriate incentives, support, and interventions (Poliakoff & Webb, 2007; Roten, 2011), especially through policy (e.g., Department of S&T, 2019; National Science Foundation, 2020). These encouraging findings from a sample of top Indian scientists, who are seen as role models and trendsetters (Echlund et al., 2012), would undoubtedly inspire young researchers and middle-career scientists to lay more emphasis on public engagement. These would also provide some valuable evidence-based insights for policymaking on science communication.

It is found that most of the respondents gave high importance to science communication and the given objectives of science communication. They also perceived that all the different media formats are important for communicating science with the public. They believed that the level of media coverage of science in India was below average. They have positive attitudes toward science-society interactions and want to enhance the linkages between science and society further. A majority also believed that public communication of science is part of their job, just like publishing in peer-reviewed journals. They also believed that they have a moral duty or responsibility to communicate their research to the taxpayers who fund

their research and salary, and they should play an active role in communicating science to the public. When the majority suggested making science communication an essential part of their job, most are not ready to own the main responsibility for communicating their research with the public. Results suggest that scientists and science communicators should team up to share the main responsibility. Also, Indian scientists' sense of moral duty or responsibility for science communication is comparable with the results from studies conducted in several other countries.

5.3. Objective 2 – Science communication by scientists and its impact on their career advancement

Under this section, the survey results are discussed to address the second objective of the study, “To understand how Indian scientists engage with the general public and the media, and its impact on their career advancement.”

An important result from the current study is that almost all the respondents (99.33%) have participated in some kind of science communication activity during their careers. Such a high percentage of senior Indian scientists taking part in public engagement is consistent with the findings of a survey in the UK where senior scientists were more likely to engage than their juniors (Royal Society, 2006, Bauer & Jensen, 2011). The finding is also comparable to 91% of life sciences faculty members at a US university having participated at least once in the last year (Sturzenegger-Varvayanis et al., 2008). Also, a study of French scientists found that the more senior a scientist is in the institutional hierarchy, the more active she/he is in public engagement (Boltanski & Maldidier, 1970 as quoted by Bauer and Jensen, 2011). It may be because scientists holding senior scientific and administrative positions in scientific establishments are more required to or more exposed to engaging with non-scientist

audiences as part of their job. However, most of the senior scientists in India surveyed (60%) have participated only occasionally or rarely, with less than 40% participating often. These results are comparable to the findings from similar surveys in the UK (Royal Society, 2006; Hamlyn et al., 2015), Denmark (Nielsen, Kjaer, & Dahlgaard, 2007), Argentina (Kreimer, Levin & Jensen, 2011), USA (AAAS, 2015), Mexico (Merino & Navarro, 2019), Philippines (Navarro & McKinnon, 2020), and Lithuania (Valinciute, 2020), where the majority of the respondents (scientists) engaged in science communication at least once in a year, but the frequency of their participation largely remained occasional.

The respondents perceived that their affiliated institutions were not very frequent in organising public engagement events. Most of them (~61%) believed that their institutions organised such events occasionally or rarely, while 36% of them said that their institutions organised such events often. Comparing the percentages, it is found that respondents' engagement appeared to be slightly better than that of their institutions. A similar finding emerges from a survey of Mexican scientists where most scientists were of the opinion that science communication by the institutions is not sufficient (Guerrero, 2016). Individual scientists may be more active in their personal capacity, but to ensure consistent efforts in public engagement at both individual and institutional levels, what matters more is how S&T institutions recognise and value the importance of science communication, as noted by several studies (e.g., Gascoigne & Metcalfe, 1997; Wellcome Trust, 2001; Gething, 2003; Andrews et al., 2005; Lunsford, Church & Zimmerman, 2006; Royal Society, 2006; Poliakoff & Webb, 2007; Peters et al., 2008; Edge et al., 2011; Searle, 2011). As believed by the respondents, anecdotal evidence also suggests that many S&T institutions in India do not pay much attention to science communication and outreach activities in general.

The above observation is echoed by a multi-institutional European study that noted most research institutions in Europe lacked a culture of public engagement where efforts for engaging with the public are appropriately recognised, evaluated, and rewarded as an important part of the institutional profile and identity (Neresini & Bucchi, 2011). Also, a study of public communication by research institutes across eight countries (Brazil, Italy, Netherlands, the USA, Germany, Portugal, UK, and Japan) found that 2030 research institutes that were surveyed reported organising about 33 public events on an average per year, suggesting that science communication is taken-for-granted by most research institutes (Entradas et al., 2020). This observation by Entradas et al. (2020) is in concurrence with what Indian scientists believed about how frequently their affiliated institutions organise public engagements events (as discussed above).

The findings of the current study, coupled with those of Neresini & Bucchi (2011) and Entradas et al. (2020), suggest that science communication largely remains a low key area at the institutional level across countries and institutions and is yet to become a fully instituted activity that is well recognised and valued. This situation calls for action at the institutional level giving due importance to science communication and creating an encouraging ecosystem where contributions in establishing a dialogue between science and society are valued and rewarded.

The Indian respondents earlier suggested that all the different ways of public communication are important. However, in reality, they mostly used face-to-face interactions with the public and talking at schools and colleges. They engaged less frequently with the public through popular media/press and were least active through online modes of communication. Here, the finding that most Indian scientists use face-to-face or direct communications/talks as the most

preferred way of science communication, with online modes as less used ways of communication, is largely congruent with previous studies in the UK (Royal Society, 2006; Hamlyn et al., 2015), Denmark (Nielsen, Kjaer, & Dahlgaard, 2007), Argentina (Kreimer, Levin & Jensen, 2011), China (Jia & Liu, 2014), the USA (AAAS, 2015), and Mexico (Merino & Navarro, 2019). Besley, Oh & Nisbet (2012) have also noted a similar trend that most scientists in the US and the UK felt that communicating science through direct (face-to-face) interactions with the non-scientist publics was relatively more important than mediated communications.

However, the majority of the respondents had face-to-face interactions with the public (79%), talked at schools and colleges (88%), gave interviews to journalists (63%), and wrote popular science (64%) at least once during the last one year. On the other hand, the majority of them never wrote about popular science online (65%) or shared videos online about their research (72%). Face-to-face interactions and talking at schools and colleges were the top two ways of public engagement used by many respondents (>20%) more than six times during the last year; comparable to 20% US-based scientists engaging more than six times in face-to-face interactions (Dudo et al., 2018). About 63% of the respondents saying that they gave interviews to journalists/reporters is comparable with the findings of Peters et al. (2008), where nearly 64% of the surveyed scientists from the United States, Japan, Germany, United Kingdom and France believed that journalists interviewed them.

On the other hand, more than one-third of the respondents never gave interviews to journalists (37%) or wrote popular science (36%) during the previous year. These observations suggest that most of the respondents who are senior (85% aged more than 55 years) and experienced (81% having more than 30 years of research experience) scientists

were more comfortable with the traditional ways of direct communication than indirect and mediated or online ways of public communication. These results are broadly consistent with the findings of Dudo et al. (2018), where US-based scientists engaged with the public more often through face-to-face interactions (59%) than online platforms (48%) and the media (42%). The current finding of Indian scientists engaging more in face-to-face communications than through the media is also largely consistent with the public engagement behaviour of US-based nanoscientists (Dudo et al., 2014).

Another important finding of the current study is that a vast majority of the respondents (77%) expressed willingness to engage in science communication activities in the future if opportunities were provided. This finding is comparable to 76.6% of Mexican scientists expressing their interest in science communication (Merino & Navarro, 2019), to 71% US life sciences professors (Sturzenegger-Varvayanis et al., 2008), and to almost all Chinese scientists interviewed expressing willingness to take part in public engagement (Zhang, 2015). This result is also consistent with the majority of the American scientists associated with seven scientific societies (Besley et al., 2018) and most of the scientists associated with the University of Manchester, UK (Poliakoff & Webb, 2007) expressing their willingness to engage. DiBella, Ferri & Padderud (1991) also found that most of the scientists they investigated were willing to engage in media interviews for informing the public.

Despite most Indian scientists being willing to engage, most of them practically engage only occasionally or rarely. It suggests that they are mostly willing to engage but are largely not very active in science communication activities. This reaffirms the ‘willing but inactive’ thesis forwarded by Zhang (2015) based on in-depth interviews of Chinese scientists. The current results are also consistent with the findings of a survey of Chinese scientists, where

the majority of the respondents (94%) agreed that science communication is their responsibility but did not contribute in action (Jia & Liu, 2014). This perplexing situation requires further investigations to understand how scientists' willingness to engage can be translated into active involvement in science communication. Such understanding is pertinent as the new Indian science policies are drifting toward mandating public engagement by scientists.

Whatever is the frequency of scientists' public engagement, a vast majority of the respondents who engaged in such activities believed that communicating science with the public had been a 'good' or 'very good' experience (74%). Here, the favourable experience of Indian scientists can be a greater motivator for their future engagements, as past behaviour (engagement) is one of the critical factors deciding scientists' intentions to engage in the future (Poliakoff & Webb, 2007). The overall good experience of senior Indian scientists in science communication is comparable to the experience of US-based senior scientists being positive or very positive (Dudo et al., 2018), and to what Singapore-based experienced scientists believed that their participation in science communication activities was enjoyable, pleasant, and gratifying (Ho, Looi & Goh, 2020). Mexican scientists also felt that their experience with the media was largely good (Guerrero, 2016).

Further, 88% of the Indian respondents believed that their engagement was neither 'very difficult' nor 'very easy'. However, the majority of them (54%) being on the difficult or neutral side, with 46% respondents finding it easy, suggests that there is still much scope for appropriate interventions for improvements to make it easier for scientists to engage with the public and enhancing the quality of their engagement, especially for those who could not rate their overall public engagement as 'good' or 'very good' (47%). However, the percentage of

Indian scientists finding science communication as ‘fairly easy’ or ‘very easy’ (46%) is lower than that of Argentine scientists (76%) who find it as ‘easy’ or ‘very easy’ (Kreimer, Levin & Jensen, 2011). However, it is higher than that of British scientists (35%) who find public engagement as ‘fairly easy’ or ‘very easy’ (Royal Society, 2006).

Another important finding of the current study is that more than three-quarters of the respondents believed that they personally enjoyed public engagement and were confident and well-equipped to communicate their research. These are vital personal attributes that can help scientists decide their willingness to engage more and perform better in science communication. Here, more Indian scientists (81%) believed that they are well-equipped to communicate science with the public than British scientists (51%) (Royal Society, 2006) and American scientists (70%) (Sturzenegger-Varvayanis et al., 2008). Also, Ho, Looi & Goh (2020) reported that enjoyment and perceived efficiency are potential factors shaping Singapore-based scientists’ willingness to engage in science communication activities. However, more senior scientists than their junior counterparts in Singapore believed they were competent for outreach activities (Ho, Looni & Goh, 2020). Many Spanish younger researchers have also reported personal satisfaction and enjoyment as a motivation for their public engagement (Martin-Sempere, Garzon-Garcia & Rey-Rocha, 2008). Searle (2011) has also reported that many Australian scientists also had positive feelings such as enjoyment, satisfaction and self-esteem associated with their public engagement. Many biomedical scientists and microbiologists in the US also reported that they enjoyed engaging in science communication activities (Dudo, 2012; Dudo et al., 2018). More Indian scientists felt confident in communicating science with the public when a lack of confidence in communication skills was seen as an obstacle to participation in such activities (Holland, 1999). Personal enjoyment was the top reason for scientists to get involved in science

dissemination activities (Holliman & Jensen, 2009). Dunwoody, Brossard & Dudo (2009) also reported that scientists enjoyed public engagement through mass media. Another study found that almost all the scientists enjoyed taking part in science outreach activities (Pearson, Pringle & Thomas, 1997). These personal attributes (enjoyment, confidence and being well-equipped) play a crucial role in making someone get engaged in any activity, including public engagement, and to ensure higher performance and effectiveness in their engagement.

To further investigate the relevance of science communication from scientists' point of view, they were asked if they believed their engagement impacted the public, science or scientists. It is found that Indian scientists have encouraging attitudes toward the possible impacts of their engagement in science communication activities. The majority believed that their engagement in such activities would popularise their research while providing scientific information to the public for its wider use. It would also help scientists to increase their own scientific knowledge while enhancing their confidence in public communication. Many but not most believed that it would increase public support for their research. These positive attitudes should serve as a motivator for scientists to engage more often. Scientists' frequent engagement helps public audiences understand complex scientific topics and make informed decisions in their lives (Shugart & Racaniello, 2015). The current finding that public engagement increases scientists' confidence in public communication is consistent with literature suggesting public participation increases scientists' communication skills (Varner, 2014, Pearson et al., 1997, Davies, 2008, Laursen et al., 2009). Also, public engagement increasing scientists' own scientific knowledge is similar to public interactions enhancing scientists own research (Salguero-Gomez et al., 2009; Pace et al., 2010).

It is generally understood that for most scientists, the primary mandate is to 'do science'. Also, certain things they do add to their career advancement while certain other things have the most negligible impact on their career advancement. In this context, if public engagement affects scientists' careers, it would be a factor of deterrent or motivation. An attempt to evaluate the impact of scientists' engagement in science communication with the general public (directly or through the media) on their careers revealed that most Indian scientists were not clear if their participation in science communication activities played any role in advancing their scientific career but were largely sure that it does not impact their careers negatively. Most Indian scientists also believed that it does not help them get more research funding or recognition from their employers. This observation that involvement in science communication does not impact scientists' career advancement is consistent with the findings of Jensen, Rouquier, Kreimer & Croissant (2008), and Poliakoff & Webb (2007). These studies also found that many of the scientists surveyed did not see their public engagement activities having any significant impact (positive or negative) on their careers. Jensen (2011) has also observed no career benefits for scientists from their public engagement. Agnella et al. (2012) have also reported that many scientists did not see any career benefit from their science communication activities. Scientists' efforts in popularising science do not add any value when their science performance is measured (Shanley & López, 2009). Even involvement in public engagement activities can be deleterious to research identities and careers, where it can spoil the reputation of scientists as serious researchers (Watermeyer, 2015). Some researchers even believe that communicating science with the public can detrimentally affect scientists' careers while also damaging their professional standing in the eyes of their peers (Porter et al., 2012).

On the contrary, it is noted that if public engagement has more value for career advancement and recognition by employers, then scientists are more likely to engage. For example, 83% of US junior scientists surveyed were more inclined to participate in public engagement activities if it helped with their careers (Royal Society, 2006). Further, researchers affiliated with NSF's National Nanotechnology Infrastructure Network (NNIN) believed that their outreach efforts had a positive impact on their career advancement and were also willing to participate in the future (Dudo et al., 2014, p.3).

A minority of the Indian respondents (39%) believed that their science communication efforts are recognised or rewarded by their employers. It is similar to an Australian study, where 47% of Australian scientists acknowledged that their employers valued their public engagement contributions (Searle, 2011, p.213). Several other studies also suggest that there is a lack of institutional recognition and incentives for such activities (e.g., Royal Society, 2006; Poliakoff and Webb, 2007; Torres-Albero et al., 2011; Agnella et al., 2012)

It is observed that if public engagement adds value to a scientist's career, they are more likely to contribute more in public engagement activities. In this direction, the Indian government appears to recognise this aspect by mandating ten days of public engagement per year by scientists while giving appropriate credit for the same in scientists' promotion and annual appraisals in the recent policy initiatives (Department of S&T, 2019, 2020). Such policy provisions and incentives are being seen in the right direction and, if implemented properly, are expected to encourage Indian scientists to engage more and improve the science communication landscape in the country (Rajput, 2019; Rajput & Sharma, 2021). However, such policy initiatives would be more effective and useful if guided by strong empirical evidence suggesting what Indian scientists think about and expect from engaging in science

communication activities. It is hoped that the current findings would be fruitful in this direction.

Another interesting finding is that most Indian scientists (67%) did not believe that scientists engaging in science communication were labelled as publicists by their peers, which was bad for a scientist's career. This finding contrasts with the literature that suggests scientists feel negative about being called a 'publicist' if they engage with the public/media. Many scientists perceive science communication with the public as an inferior activity as compared to doing research (Merino & Navarro, 2018), and it generally gets linked to the 'Sagan effect' and those scientists who do it even meet repercussions (Shugart & Racaniello, 2015; Ecklund, James & Lincoln, 2012). Many US scientists believed that scientists who engage more with the public are not regarded well by their peers (Royal Society, 2006; Rose, Markowitz & Brossard, 2020). Such negative perceptions need to be addressed to ensure a conducive environment for public engagement by scientists. If publicly active scientists are not well regarded and respected by colleagues or peers (especially the senior ones), then it is likely that scientists may not take initiatives to engage more with the public or at least may weaken their willingness to engage (Rose, Markowitz & Brossard, 2020).

In a nutshell, from the above discussion, it is found that Indian scientists have positive perceptions and attitudes toward their own involvement in science communication activities, their experiences, performance, and capabilities to do such activities. They are also largely aware of the possible impacts of their involvement in science communication. This awareness provides a firm ground suggesting Indian scientists' readiness and willingness to engage and contribute more to science communication and public dialogue. Scientists' intentions to engage in science communication activities are influenced by their past behaviour, attitudes,

perceived behavioural controls, and descriptive norms, as demonstrated by Poliakoff & Webb (2007) by using the theoretical framework of the theory of planned behaviour (Ajzen, 1991).

However, despite having favourable experience, attitudes, perceived capabilities to perform, willingness to engage in future, and awareness about the possible impacts of their public engagement, the actual frequency of participation in science communication activities by most Indian scientists (60%) remains to be occasional or rare. Despite such encouraging contexts, it remains unclear why the overall frequency of most respondents is low. Identifying the possible and specific hindrances and barriers in the way of science communication by Indian scientists would be favourable in enhancing their public engagement (as discussed in the next Section 5.4).

Also, the current findings provide evidence from India that the calls by different stakeholders for more engagement by scientists (*e.g.*, Royal Society, 1985; Wellcome Trust, 2001; The Royal Society, 2006; Nisbet & Scheufele, 2009; Dudo & Besley, 2016) are well placed and also provide context for the recent push by the Indian government to R&D institutions and individual scientists to be more open and engage more with the public (Press Information Bureau, 2017; Government of India, 2018; Rajput, 2018).

5.4. Objective 3 – Factors affecting scientists’ active engagement in science communication with the general public and media

Under this section, the survey results are discussed to address the third objective of the study, “To identify the factors affecting scientists’ active engagement in science communication with the general public and media.”

Human behaviours are influenced by subjective and descriptive norms, perceived behavioural controls, past behaviours, intentions, etc. (Ajzen, 1991; Poliakoff & Webb, 2007). Our actions get influenced by what our employers, colleagues, friends and family members expect from us or do themselves, and what we individuals think about our own and others' behaviours. In other words, if scientists are expected or required to communicate science by the people around them or they believe others around are doing it, then there is a greater likelihood that they would also get involved in such activities.

In the current study, less than half of the respondents (47.49%) viewed their employers or institutions as being supportive of their science communication activities, when the majority of them either remained neutral or believed their employers were not supportive. This finding is closely comparable to 49% of US scientists believing their employers were supportive (Royal Society, 2006). This finding that many scientists did not perceive their institutions as being supportive to scientists' public engagement is consistent with literature showing lack of institutional support being a potential hindrance in science communication by scientists (*e.g.*, Royal Society, 2006; Kreimer, Levin & Jensen, 2011; Shugart & Racaniello, 2015; Watermeyer, 2015; Valinciute, 2020). However, it is contrary to what most US life science university professors believed that their employer is supportive of researchers who are active in science communication (Sturzenegger-Varvayanis et al., 2008). However, an extensive study of more than 2000 institutions across several countries found that science communication with the public is mostly a taken-for-granted activity that is waiting to be fully institutionalised across R&D institutions and universities (Entradas et al., 2020). The presence of an institutional mandate giving priority to science communication with the general public would eventually lead to the allocation of more resources for science communication and more institutional support for scientists' active engagement (Entradas et

al., 2020). When scientists are not expected to communicate by their institutions, their frequency of participation or willingness to participate is expected to be relatively low. In such instances, their public involvement would be predominantly because of their personal interests or reasons. However, the availability of institutional policies, professional communicators and funding at the institutional level is expected to increase scientists' frequency of engaging in science communication activities (Entradas et al., 2020). Also, institutional level support is necessary for science outreach and engagement to flourish and boost scientists' participation (Lunsford, Church & Zimmerman, 2006).

It is found that most of the current respondents (59.85%) believed that, just like themselves, their close academic colleagues were also occasionally active in science communication. Meanwhile, they were undecided whether many of their colleagues at their institutions or departments were active public communicators of science. This finding contrasts with most respondents (64%) in a US study saying that most or some of their colleagues at their department were active in science communication (Sturzenegger-Varvayanis et al., 2008). However, many US-based microbiologists were not optimistic that their colleagues were active in participating in science communication activities regularly (Dudo et al., 2018). Similarly, in an earlier survey in the US, about 36% of scientists said that most or some of their colleagues were active (Royal Society, 2006). Many scientists, in another study, even believed that science communication was relatively less important for their colleagues (Rose, Markowitz & Brossard, 2020).

Further, most respondents of the current study perceived that their family and close friends were relatively more supportive than their academic colleagues to their participation in public engagement activities. Compared to Indian scientists (37%), more US scientists (50%)

believed that their colleagues were supportive of their public engagement (Royal Society, 2006). There is a general human tendency if people around us or the people we value are doing something or they expect us to do something, and then we are more likely to engage ourselves in such activities. It may be called a peer-pressure or whatever, but when close colleagues are actively communicating with the public, it would potentially influence others to do so.

If scientists believe that their research is too complex for the public to understand or think that the public does not have enough scientific background to understand their research, such attitudes generally allow them to keep away from science communication activities. For example, many Lithuanian scientists (~32%) believed that their research being too complex for the public or the public with no interest in their research was a potential barrier to their frequent participation in public engagement activities (Valinciute, 2020). However, the current study provides a contrary view of Indian scientists who did not see the complexity of their research as a hindrance to public understanding. The respondents showed a general disagreement that their research was too complex for the general public to understand. This result finds support from US life science professors (70%) who also believed that their research was not too specialised for the public to be not interested in knowing it at all (Sturzenegger-Varvayanis et al., 2008). Kreimer, Levin & Jensen (2011) have also found that only about 10% of Argentine researchers believed that their research being too complex was a reason for not popularising their research with the public.

After an extensive literature review, 11 potential factors preventing active participation by scientists in public engagement activities were identified for the Indian respondents to suggest whether they believed these affected their active involvement in science

communication. The majority of senior Indian scientists did not believe that the given 11 factors prevented them from being active in science communication. It is a significant finding that Indian scientists largely disagreed that Lack of time, No interest in such activities, Lack of communication skills, No incentives/rewards and recognition, Deviation from research, Difficulty in constructing messages relevant for the public, No personal benefits, Lack of institutional support/encouragement, Lack of funding, Lack of comfort in such activities, and Science communication is not part of duty were a potential factor in their active engagement. However, a considerable number of scientists still believed that lack of time, lack of funding, difficulty in constructing public messages, and deviation from research were potential factors in their active engagement.

Much of the literature on factors affecting scientists' active involvement in science communication highlights that the factors mentioned above significantly impact scientists' engagement (*e.g.*, Gascoigne & Metcalfe, 1997; Holland, 1999; Wellcome Trust, 2001; Gething, 2003; Andrews et al., 2005; Lunsford, Church & Zimmerman, 2006; Royal Society, 2006; Poliakoff & Webb, 2007; Peters et al., 2008; Sturzenegger-Varvayanis et al., 2008; Burchell, Franklin & Holden, 2009; Dunwoody, Brossard & Dudo, 2009; Shanley & Lopez, 2009; Edge et al., 2011; Kreimer, Levin & Jensen, 2011; Searle, 2011; Agnella et al., 2012; Ecklund, James & Lincoln, 2012; Dudo, 2013; Varner, 2014; Shugart & Racaniello, 2015; Joubert, 2018; Merino & Navarro, 2018; Yuan, Besley & Dudo, 2018; Ho, Looni & Goh, 2020; Navarro & McKinnon, 2020; Valinciute, 2020). However, the current findings suggest otherwise, possibly because the current sample of scientists is more senior and experienced, with many holding top positions. Dudo (2013) has also found that scientists who have a higher status (top positions) and have more autonomy to engage externally are more likely to engage in science communication activities.

The majority of Indian scientists not seeing time constraint as a potential factor preventing their active engagement is contrary to several studies where lack of time is one of the main constraints not allowing scientists to engage with the public. For example, about 87% of professors of biological sciences at a US university felt time constraints limit their public engagement, while about 70% of them want to use their time for research and teaching purposes (Sturzenegger-Varvayanis et al., 2008).

Several studies on science communication suggest that scientists are poor communicators, and they lack the necessary skills and experience to engage with the public and the media (Metcalf & Gascoigne, 1999; Gething, 2003; Poliakoff & Webb, 2007; Dudo et al., 2018; Merino & Navarro, 2018; Ho, Looni & Goh, 2020). Lack of communication skills among scientists has always been a concern for many. On the contrary, most Indian scientists disagreed that lack of communication skills and no personal benefits were major factors affecting their public engagement. This finding is supported by Lithuanian scientists, who also believed that these were not the main barriers to their science communication (Valinciute, 2020).

Further, the current study also showed that most respondents believed that they were quite skilled in using the given media formats to communicate science with the public, comparable to the findings of Yuan, Besley & Dudo (2018). However, Indian scientists felt that they were more skilled to communicate science through face-to-face interactions, print media and online media, but less skilled to communicate through electronic media (TV/videos and radio).

It is recognised that science communication with the public is a skill that needs to be learnt through training, practice and experience. Results from the current study suggest that a large majority of the respondents (85.33%) did not undergo any formal training but learnt skills in communicating science to the public/media on their own through experience. Similar to this finding but relatively less American scientists (73%) reported that they had no media, communications or public engagement training (Royal Society, 2006). This finding was also echoed by another study where the majority of US-based life science professors (75%) said that they lacked any formal training in science communication with the general public (Sturzenegger-Varvayanis et al., 2008). The majority of Filipino scientists (89%) also reported that they did not have any formal training in science communication (Navarro & McKinnon, 2020). Pearson, Pringle & Thomas (1997) found that most scientists did not have any formal training in science communication, but many were interested in improving their communication skills and confidence. The current finding is also consistent with many American microbiologists reporting that they did not have much training in public communication of science (Dudo et al., 2018). Further, the need for improving communication skills and expertise is highlighted not only on the part of scientists but for journalists also (Claassen, 2011).

When more than 50% of the respondents did not believe that they have enough training in science communication, about 68% were hopeful that attending science communication training or workshops would help improve their public engagement. Dudo (2013) has also reported many US biomedical scientists expressing their concern for lack of formal training in communication skills. This pattern is almost like the perceptions of Mexican scientists who were either not having any knowledge on this matter or were self-taught (83%) but were interested in enhancing their skills and suggested including science communication skills in

formal science education (Guerrero, 2016). US-based agriculture scientists were also willing to receive media training if this helped their public engagement (Lundy, Ruth, Telg & Irani, 2006). Merino & Navarro (2018) also noted that most scientists expressed that they required improving their skills to popularise science among the masses. Further, scientists with formal communication training and having positive attitudes about their communication skills were more likely to engage in science communication activities (Dudo, 2013). Ho, Looni & Goh (2020) have also noted that scientists with more training and experience in science communication were more likely to feel competent in outreach activities and be more active in such activities.

However, most Indian respondents were neither willing nor unwilling to attend science communication/media training. It might be because most of them occupied top scientific and administrative positions, which leave them with little scope and time for attaining such training. Also, most of them are aged more than 55 years, and many of them might have already retired.

A large majority of Indian scientists (72.98%) were willing to participate in science communication activities in the next 12 months. It is understood that willingness to do something often results in actual behaviours or actions. Therefore, scientists' willingness to engage with the public is expected to translate into actual public communication behaviours. This finding is consistent with many US-based microbiologists expressing their willingness to engage in the next 12 months (Dudo et al., 2018). About 45% of scientists surveyed by the Royal Society (2006) also expressed their willingness to spend more time for public engagement. Other researchers have also noted that European scientists also believed that opportunities for frequent interactions between scientists and the public are needed to

revitalise the science-society relationship, and so they were willing to take responsibility for such engagements (Casini & Neresini, 2012). Martin-Sempere, Garzon-Garcia & Rey-Rocha (2008) have also found that younger Spanish scientists were also willing to communicate science through presentations at schools. Similarly, many neuroscientists from the US and Germany, giving importance to media coverage of science, were willing to engage with the media for communicating science with the public (Allgaier, Dunwoody, Brossard, Lo & Peters, 2013).

Further, an attempt was made to understand if the factors mentioned above had any predictive value for scientists' willingness to engage. Regression models with these factors (as discussed above) revealed that these potential factors explained about 15% variance in scientists overall participation in public engagement. Meanwhile, it explained about 34% variation in the respondents' willingness to engage, which was more than double the variation explained for overall engagement so far. Therefore, addressing these potential factors would influence more scientists to be more willing to engage in science communication activities in the future.

Even being willing to engage in public science communication, many scientists may still face potential obstacles and barriers in their active involvement and have apprehensions about their reputation as a researcher. Therefore, appropriate interventions may be needed to ensure that scientists feel more comfortable and optimistic about their public engagement and are confident that their involvement in science communication would add more value to being a successful scientist. The possible interventions that can potentially enhance science communication by scientists, as recommended by Indian scientists, are discussed in the next section.

5.5. Objective 4 – Needed interventions for enhancing science communication by Indian scientists

Under this section, the survey results are discussed to address the fourth objective of the study, “To determine the needed interventions for enhancing science communication by Indian scientists in the near future.”

The demand for scientists’ active role in science communication with the public is ever increasing, while the actual frequency of scientists’ participation remains low. Therefore, in addition to understanding the factors affecting scientists’ active engagement, it is crucial to understand what scientists think about how their public engagement can be enhanced. Therefore, scientists were asked to recommend the possible interventions for enhancing their involvement in science communication activities.

A majority of Indian scientists recommended eight out of the given ten interventions for enhancing science communication by scientists in India:

- Training scientists in communication and media skills (72.97%).
- Ensuring institutional support/encouragement for such activities (90.74%).
- Every S&T institution should appoint science communication specialists who are experts in engaging with the public and the media (79.15%).
- Providing financial support for such activities (76.06%).
- Guidelines for scientists on how to communicate with the public (65.64%).
- Appropriate policy for science communication by scientists (64.87%).
- Integrating science communication training as a mandatory part of science education at college and university level (62.55%).

- Offering rewards/incentives to scientists (50.58%).

However, only a minority but a still significant proportion of the respondents recommended the remaining two interventions: Making it mandatory for scientists to communicate with the public (31.66%) and Considering science communication activities in the annual assessment and promotions of scientists (37.84%).

Several of the above recommendations by top Indian scientists were also recommended in several other studies. For example, Merino & Navarro (2018) have reported that Mexican scientists also recommended institutional recognition, science communication specialists at R&D institutions, and training for researchers, among other things, for improving public communication of science. Many Australian scientists have also highlighted several things such as opportunities for communication, enhancing communication and media skills, institutional support and encouragement, help from professional science communicators, more funds, and making it part of job/duty for further improving the public engagement by scientists (Searle, 2011). Filipino scientists have also suggested institutional support, formal training in science communication, and the need for professional science communicators to improve PE efforts (Navarro & McKinnon, 2020).

Scientists from Singapore have also recommended some of these interventions, such as removing institutional barriers, increasing institutional support and encouragement, institutional guidelines/policies, recognition, and training for improving the state of science communication (Ho, Looni & Goh, 2020). A large US survey of scientists also recommended that, for encouraging willing scientists to engage more with the public, there should be an effective institutional support system including significant departmental rewards, better

recognition of efforts in public engagement by individual scientists, support from science communicators, appropriate policies and career benefits for attracting younger scientists to engage more, and coordination among different government, funding and institutional agencies to create the desired impact of science communication (Royal Society, 2006). This survey also recommended appropriate measures to attract more young scientists to contribute to science communication activities (Royal Society, 2006).

All the ten interventions showed a statistically significant and positive correlation with the respondents' likelihood of engaging in science communication activities in the future. Also, results from regression models indicated that if these interventions were made available, scientists were more likely to engage in public communication of science activities in the future.

Through open-ended comments, the respondents highlighted the importance of science communication, addressing factors affecting their engagement, the need for policy and funding, and suggestions for further improvements. Some valuable recommendations that emerged from open comments are summarised below:

- Retired scientists should be pulled in to increase science communication efforts by encouraging them financially.
- Need for communicating science in the local language and enhancing scientists' ability to communicate science in simple language and in their mother tongue.
- The need for local examples to establish a better connection with the target population was also highlighted.

- Improving the quality of science education at school and college levels was recommended by several respondents.
- Funding agencies should include science communication with the public as a component of all the funded projects.
- We need to address the administrative situation at many R&D institutions in India, where scientists are not allowed to talk to the media directly but require prior permission before talking to the media. It is seen as a hindrance in promoting free dialogue between scientists and the media or public.
- Institutional support and encouragement are needed to increase public trust in science and scientists.

However, the respondents were divided in their open comments on whether public engagement should be mandatory or voluntary for scientists. They suggested that while scientists should focus on their research, science communication specialists or departments at R&D institutions should take the lead in SciCom efforts where scientists should also actively contribute.