Chapter 4

Results and Data Analysis

4.1. Introduction

As a first of its kind effort in India, this study explores the perceptions, attitudes, and behaviours of senior Indian scientists in science communication. This chapter presents the results from the self-administered online questionnaire "Science Communication by Scientists in India: A Survey" that was completed in October 2018 by senior Indian scientists who were elected fellows of three national science academies of India (INSA, NASI, and IASc) living in India. It presents empirical evidence by quantitatively analysing the survey data to address the research objectives of this study. This chapter starts with the demographic profile and description of the respondents (sample), followed by objective-wise results from the survey questionnaire. The results and analysis presented below, including tables and figures, are based on the data from a sample of 259 respondents, until and unless otherwise stated.

4.2. Demographic Description of the Study Sample

4.2.1. Summary of the Demographic Profile of the Sample

There were 12 questions (Questions 2-13) on gender, age group, mother tongue, educational qualification, affiliation, research experience, publications, learning English language, primary position, area of research, and Fellow of which academy(ies) for getting a demographic description of the sample of anonymous respondents.

Overall, the sample of the respondents is characterised by the majority of them being male (n = 226, 86.30%), aged more than 55 years (n = 219, 84.25%), having more than 30 years' experience (n = 210, 81.08%), having PhD as their highest educational qualification (n = 253, 97.68%), holding senior scientific/administrative positions such as university vice-chancellors, institute/lab directors, secretaries, department heads or group leaders (n = 132, 50.96%), affiliated with central R&D institutions and central universities (n = 176, 67.96%), and having more than 100 peer-reviewed publications (n = 160, 61.78%).

The respondents reported to be associated with different areas of research categorised into broad academic disciplines: Biological Sciences (n = 91, 35.14%), Chemical Sciences (n = 19, 7.34%), Computer and IT (n = 10, 3.86%), Earth and Planetary Sciences (n = 18, 6.95%), Engineering and Technology (n = 24, 9.27%), Humanities and Social Sciences (n = 3, 1.16%), Mathematical Sciences (n = 26, 10.04%), Medical Sciences (n = 20, 7.72%) and Physical Sciences (n = 48, 18.53%). They were affiliated with different government, non-profit and private academic/research institutions across the country: Central Universities (n = 39, 15.06%), State Universities (n = 32, 12.36%), Private Universities (n = 12, 4.63%), Central R&D Institutes/Labs (n = 137, 52.90%), State R&D Institutes/Labs (n = 2, 0.77%), Non-Government Organisations (n = 13, 5.02%), Private Companies (n = 4, 1.54%), and Others (n = 20, 7.72%).

Many of the respondents reported that they were elected fellows of more than one of the three academies, with about 57% of them were Fellows of IASc, 47% were Fellows of INSA, and 76% were Fellows of NASI.

The demographic details of the sample are presented in Table 2.

Table 2: Demographic details of the study sample (N = 259).

Demographic Variables		Frequency	Percentage (%)
Gender	Male	226	87.26
	Female	33	12.74
	Other	0	0.00
	Total	**259**	**100**
Age Group	<25 years	0	0.00
	25-35 years	1	0.39
	35-45 years	2	0.77
	45-55 years	37	14.29
	>55 years	219	84.56
	Total	**259**	**100**
Educational Qualification (Highest Degree):	Bachelor's Degree	0	0.00
	Master's Degree	6	2.32
	Doctorate Degree (PhD)	253	97.68
	Total	**259**	**100**
The institutional Affiliation: Type	Central University	39	15.06
	State University	32	12.36
	Private University	12	4.63
	Central R&D Institute/Lab	137	52.90
	State R&D Institute/Lab	2	0.77
	Non-Government Organisation (NGO)	13	5.02
	Private Company	4	1.54
	Other	20	7.72
	Total	**259**	**100**
Current (if retired, then the last) Primary Position	Director/Head of institution or above	64	24.71
	Department Head/Group Leader	68	26.25
	Scientist	31	11.97
	Professor/Lecturer	93	35.91
	Scientific/Technical Staff	1	0.39
	Other	2	0.77
	Total	**259**	**100**
Research Experience (in years)	<10	0	0.00
	10-20	6	2.32
	20-30	43	16.60
	>30	210	81.08
	Total	**259**	**100**
Peer-reviewed Research Publications	<20	2	0.77
	20-40	9	3.47
	40-60	25	9.65
	60-80	31	11.97
	80-100	32	12.36
	>100	160	61.78
	Total	**259**	**100**
You learned English as	First Language	68	26.25
	Second Language	180	69.50
	Third Language	11	4.25
	Total	**259**	**100**
Broad Disciplines for Current Area of Research	Physical Sciences	48	18.53
	Chemical Sciences	19	7.34
	Biological Sciences	91	35.14
	Mathematical Sciences	26	10.04
	Computer and IT	10	3.86
	Earth and Planetary Sciences	18	6.95
	Medical Sciences	20	7.72
	Engineering and Technology	24	9.27
	Humanities and Social Sciences	3	1.16
	Total	**259**	**100**

4.2.2. Gender Profile

Respondents were asked to choose their gender from three given options: Male, Female and Other. The survey data shows that 87.26% of the respondents are male, and 12.74% are female (Table 2).

4.2.3. Age Profile

The majority of the respondents of this study (n = 219, 84.56%) are aged over 55 years and 14.29% (n = 37) are in the age group of 45-55 years. The remaining respondents, 0.77% (n = 2) and 0.39% (n = 1), are in the age groups of 35-45 years and 25-35 years respectively, with zero respondents in the age group of <25 years (Table 2). This shows that the two age groups of >55 years and 45-55 years collectively constitute about 99% (*precisely* 98.85%) of the sample. Statistically no significant differences were found between gender and age ($\chi 2$ (3, N = 259) = 5.529, $p > .05$). However, in terms of percentages, male scientists dominated the age group of '>55 years' while females dominated in the age group '45-55 years.'

4.2.4. Educational Profile

The majority of the respondents of this study said that PhD was the highest degree in their educational qualifications (n = 253, 97.68%), with the remaining (n = 6, 2.32%) reported a Master's Degree as their highest degree (Table 2). Chi-square tests for independence suggested statistically no significant differences between educational qualification and Gender ($\chi 2$ (1, N = 259) = 0.085, $p > .05$) or Age ($\chi 2$ (3, N = 259) = 1.122, $p > .05$). However, it is observed that all the 6 Master Degree holders were in the '>55 years' age group.

4.2.5. Current Affiliation

The respondents were asked to share their current affiliation (if retired, then the last) (optional) as an open text question. About 55 respondents either left it blank or gave invalid answers. Based on the valid answers to this question, a list of the names of the institutions, universities, R&D labs, NGOs, and corporates that the respondents mentioned was prepared. The list excluded the three national science academies (INSA, NASI, and IASc). However, some respondents entered the names of their institutions in different styles, which were manually corrected for uniformity after due cross-checking of the institutional names. The respondents (n = 204) reported that they were affiliated with 139 different S&T organisations distributed across the country, including IITs, IISc, IISERs, ICAR, CSIR, MoES, ICMR, ISRO, DRDO, TIFR, ARIES, BARC, Bose Institute, CDFD, C-MET, IASRI, IACS, IIAP, IIG, ISI, IDRBT, IPR, ILBS, IMSc, ICGEB, JNCASR, NBRC, NCCS, NCRA, NII, NIN, NISER, PRL, RGCB, SERB, ACTREC, THSTI, several universities, NGOs and private institutions. The exact list of the names of affiliations is provided in Appendix-5.

4.2.6. Affiliations – Type of Institution/Employer

As shown in Table 2, most of the respondents were affiliated with or employed by central government institutions. More than half of them (n = 137, 52.90%) were affiliated with central R&D institutes/labs, with 15.06% (n = 39) affiliated with central universities. State universities employed 12.36% (n = 32) of the respondents. Thirteen of them (5.02%) were affiliated with NGOs, 12 (4.63%) with private universities, 2 (0.77%) with state R&D institutes/labs, 4 (1.54%) with private companies, and 20 (7.72%) opted ‘Other’ as their affiliation. While cross-checking responses to this question with the previous question on affiliation, it was found that some respondents chose ‘Central university,’ and some chose ‘Central R&D institute/lab’ for the same affiliation (e.g., IIT, or IISc). Therefore, for the sake of uniformity, the type of affiliation for such institutions was manually corrected as 'Central R&D institute/lab.'

Chi-square tests for independence suggested statistically no significant differences between the type of affiliation (employer) and Gender ($\chi2$ (7, N = 259) = 4.656, p > .05) or Age ($\chi2$ (21, N = 259) = 21.051, p > .05). However, statistically significant differences were found between the type of affiliation and educational qualification ($\chi2$ (7, N = 259) = 31.881, p < .001; Cramer's V = 0.351).

4.2.7. Primary Position

From the given options, 93 (35.91%) respondents identified their primary position as Professor/Lecturer, 68 (26.25%) as Department Head/Group Leader, 64 (24.71%) as Director/Head of Institution or above, 31 (11.97%) as Scientist, 1 (0.39%) as Scientific/Technical Staff and 2 (0.77%) as 'Other' (Table 2). Some 30 respondents opted for 'Other' as their primary position and gave text answers to specify the same while filling the survey. However, most of these specific answers, such as professor, scientist, director, vice chancellor, dean, etc. were eligible entries for the given options. Accordingly, the text responses were appropriately assigned to the given options. Thus the number of 'Other' responses was reduced from 30 to 2. A majority of the academy fellows (n = 132, 50.96%) were holding (or held) key scientific/administrative positions such as department head, group leader, director of an institution, vice-chancellor, chancellor, dean, secretary of government S&T departments, etc. at the time of answering the survey.

Chi-square tests for independence suggest statistically no significant differences between Primary position held by the respondents and their Education qualification ($\chi2$ (5, N = 259) = 0.596, p > .05) or Gender ($\chi2$ (5, N = 259) = 7.366, p > .05). However, it is interesting to note that from among the female gender (n = 33, 12.74%), 48.5% held senior scientific/administrative positions, almost comparable to 51.3% males holding such positions. The overall share of female scientists holding top positions as a director/head of an institution, HoD, etc. is 24%, while they make 23% of the respondents saying their primary position is 'scientist' and 11% for 'professor/lecturer.'

Also, significant differences were found between Primary position and the Type of affiliation ($\chi 2$ (35, N = 259) = 88.361, $p < .001$; Cramer's V = 0.261). A specific particularity is that majority of the directors/heads of institutions, heads of department/group leaders, professors, and scientists (ranging from 62% to 78%) were associated with central R&D institutions and central universities.

4.2.8. Research Experience

The majority of the respondents (n = 210, 81.08%) had a research experience of more than 30 years, followed by 43 (16.60%) of them having research experience in the range of 20-30 years. Only 6 (2.32%) said their research experience was in the range of 10-20 years, with no respondent in less than 10 years category of research experience (Table 2).

A significant difference between research experience and gender among Indian scientists existed where a relatively higher percentage of females belonged to the lower experience groups while a relatively higher percentage of males belonged to the highest experience (Chi-Square, $\chi 2$ (2, N = 259) = 13.723, $p = .001$; Cramer's V = 0.230). Also, a significant relationship between Research experience and Age groups was found, where about 80% of the respondents with >30 years' experience were in the age group of '>55 years' (Chi-Square, $\chi 2$ (6, N = 259) = 183.263, $p < .001$; Cramer's V = 0.595), suggesting a positive and statistically significant correlation between the two (Pearson's r = 0.762, $p < .001$).

Also, it was found that respondents with higher research experience has higher number of peer-reviewed publications (Chi-Square, $\chi2$ (10, N = 259) = 31.295, p < .001; Cramer's V = 0.246). The majority of respondents holding top scientific/administrative positions were found to have a research experience of more than 30 years (Chi-Square, $\chi2$ (10, N = 259) = 24.105, p < .01; Cramer's V = 0.216). However, no significant differences were found between research experience and the type of organisation with which the respondents were affiliated (Chi-Square, $\chi2$ (14, N = 259) = 11.659, p > .05) or with their highest educational qualification (Chi-Square, $\chi2$ (2, N = 259) = 1.433, p > .05).

4.2.9. Peer-reviewed research publications

Majority of the respondents (n = 160, 61.78%) said that they had more than 100 peer-reviewed research publications to their credit in 2018. Thirty two (12.36%) of them said they had 80-100 publications, 31 (11.97%) 60-80 publications, 25 (9.65%) 40-60 publications, 9 (3.47%) 20-40 publications and 2 (0.77%) <20 publications (Table 2).

The number of publications was found to be significantly associated with gender, where most male respondents had more than 100 publications to their credit while the majority of females had less than 100 publications to their credit (Chi-Square, $\chi2$ (5, N = 259) = 16.827, p < .01; Cramer's V = 0.255). In terms of age, the majority of scientists aged >55 years had >100 publications while the majority of those in the 45-55 years age group had <100 publications to their credit (Chi-Square, $\chi2$ (5, N = 259) = 16.827, p < .01; Cramer's V = 0.451). A relatively higher proportion of respondents in >30 years experience group had >100 publications compared to other experience groups (Chi-Square, $\chi2$ (10, N = 259) = 31.295, p < .001; Cramer's V = 0.246). Also, a relatively higher proportion of the heads of institutions/departments/group leaders had >100 publications compared to other positions ($\chi2$

(25, N = 259) = 147.130, $p < .001$: Cramer's V = 0.337). However, there was statistically no significant variation in the number of publications across the type of employers (affiliations) ($\chi 2$ (32, N = 259) = 31.696, $p > .05$). Further, the number of publications was found to have a positive and statistically significant correlation with age (Pearson's r = 0.313, $P < .001$) and research experience (Pearson's r = 0.272, $P < .001$).

4.2.10. Mother Tongue

A summary of the responses to this open-ended question is shown in Table 3. Out of 259 participants, 258 gave valid responses. It is observed that Hindi, Bengali, Tamil, Telugu, Marathi, Kannada, and Malayalam are the top seven languages selected as a mother tongue by 224 (86.82%) of the total 258 responses. There are total 18 languages that the respondents selected as their mother tongues. As this was an open text response, there were some discrepancies in the spelling of these languages, which the researcher manually corrected.

Table 3: Descriptive statistics for the Mother tongue of the respondents (N = 258).

S. No.	Mother Tongue	Frequency	Percentage (%)
1.	Hindi	61	23.64
2.	Bengali	56	21.71
3.	Tamil	38	14.73
4.	Telugu	20	7.75
5.	Marathi	19	7.36
6.	Kannada	18	6.98
7.	Malayalam	12	4.65
8.	Odia	10	3.88
9.	Punjabi	7	2.71
10.	Gujarati	4	1.55
11.	English	3	1.16
12.	Kashmiri	3	1.16
13.	Urdu	2	0.78
14.	Maithili	1	0.39
15.	Hindustani	1	0.39
16.	Sourashtra	1	0.39
17.	Konkani	1	0.39
18.	Kumaoni	1	0.39
	Total	**258**	**100**

4.2.11. How English was learned

Majority of the scientists (n = 180, 69.50%) said they learned English as a second language, and 68 (26.25%) said they learned it as their first language. Only 11 (4.25%) of them said that they learned English as third language (Table 2). Chi-Square test showed significant relationship between how the respondents learnt English and Gender, $\chi 2$ (2, N = 259) = 10.557, $p < .05$. More female respondents learned it as their first language, while more male scientists learned it as a second language.

4.2.12. Academic Discipline

The respondents were given nine categories of broad academic disciplines to choose from to identify their current area of research. The highest proportion of the respondents (n = 91, 35.14%) said they belonged to the discipline of Biological Sciences, followed by 48 (18.53%) choosing Physical Sciences as their broad discipline. The distribution of academic disciplines is given in Table 2. A significant relationship was found between current area of research and peer-reviewed publications ($\chi 2$ (40, N = 259) = 91.441, $p < .001$); type of affiliated organisation ($\chi 2$ (56, N = 259) = 98.102, $p < .001$); and primary position ($\chi 2$ (40, N = 259) = 95.847, $p < .001$).

4.2.13. Independent variables for further analysis

For the further analysis of the data for research objectives, from the above-mentioned descriptive variables, only selected demographic/independent variables (gender, age, primary position, type of affiliation, and area of research) are used. In some cases, research experience and the number of publications are also used as per requirement.

4.3. Science communication, media, and society

This section presents empirical findings from the survey of senior Indian scientists to address research objective 1(a) To explore what Indian scientists think about the importance of science communication. Data from five close-ended survey questions (Q.14-Q.18) are presented here to describe the respondents' perceptions and attitudes about the importance of communicating science to the general public, its objectives, use of different ways of public communication, media coverage of science, and science-society interactions. Data from these questions are analysed for descriptive statistics. The concepts and constructs measured in these questions as dependent variables are tested for any impact of demographic variables (gender, age group, primary position, type of affiliation, and area of research) and their associations and correlations. The presentation of results starts with the findings of the perceived importance of communicating science to the general public among Indian scientists.

4.3.1. Importance of science communication

When different voices are being raised for enhanced involvement of scientists in science communication and public engagement, it is pertinent to understand what scientists think about science communication's importance. Therefore, the respondents were asked, 'How do you think about the importance of communicating science to the general public?' (Q.14, Appendix-1) and their responses recorded on a 5-point Likert scale are visualised in Figure 1. Results reveal that the majority of respondents (n = 200, 77.22%) believed that science communication is 'very important,' followed by 50 (19.31%) saying it is 'important,' 8 (3.09%) saying 'moderately important,' 1 (0.39%) saying 'minimally important' and none saying that it was 'not at all important.'

It is found that that a vast majority of the respondents (96.53%; n = 250) give high importance to communicating science to the general public (M = 4.73, SD = 0.53, Skewness = -2.042; Kurtosis = 4.155) on a 5-point scale of importance. That is, the vast majority of Indian scientists strongly approved public communication of science as an important activity.

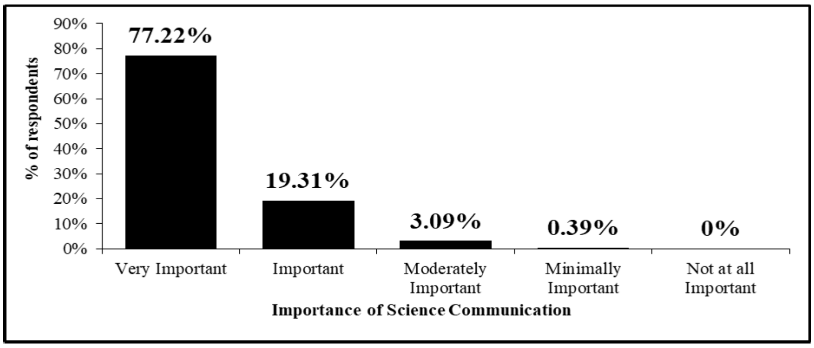

Figure 1: The perceived importance of science communication among Indian scientists.

To determine any effect of the demographic variables on the importance of science communication, group-wise means were studied, and one-way ANOVA tests were conducted for gender, age group, type of affiliated organisation (employer), primary position, research experience, and area of research (see Table 4).

ANOVA tests revealed that the perceived importance of science communication among the respondents did not show any variation based Gender ($F (1, 257) = 1.779, p > .05$); Age ($F (3, 255) = 0.213, p > .05$); Type of affiliation ($F (7, 251) = 1.200, p > .05$), and Research experience ($F (2, 256) = 0.144, p > .05$). Primary position ($F (5, 253) = 2.947, p < .05$), and Area of research ($F (8, 250) = 2.543, p < .05$) showed statistically significant impact, but their effect sizes were small (Eta-squared ($\eta 2$) = .055) and medium (Eta-squared ($\eta 2$) = .075) respectively. That is, the respondents' perception about the importance of science communication was largely unaffected by the demographic variables.

Table 4: Group-wise distribution of the importance of science communication mean scores across demographic variables and one-way ANOVA tests.

	Variables	N	Mean	SD	ANOVA
Gender	Male	226	4.72	.549	F (1, 257) = 1.779, p > .05
	Female	33	4.85	.364	
	Total	259	4.73	.531	
Age Groups	25-35 years	1	5.00	.	F (3, 255) = 0.213, p > .05
	35-45 years	2	4.50	.707	
	45-55 years	37	4.73	.560	
	>55 years	219	4.74	.527	
	Total	259	4.73	.531	
Employer	Central University	39	4.79	.469	F (7, 251) = 1.200, p > .05
	State University	32	4.72	.523	
	Private University	12	4.42	.793	
	Central R&D Institute/Lab	137	4.72	.555	
	State R&D Institute/Lab	2	4.50	.707	
	Non-Government Organisation (NGO)	13	4.92	.277	
	Private Company	4	5.00	.000	
	Other	20	4.80	.410	
	Total	259	4.73	.531	
Primary Position	Director/Head of institution or above	64	4.81	.393	F (5, 253) = 2.947, p < .05 Eta-squared (η2) = .055
	Department Head/Group Leader	68	4.82	.421	
	Scientist	31	4.84	.374	
	Professor/Lecturer	93	4.57	.682	
	Scientific/Technical Staff	1	5.00	.	
	Other	2	5.00	.000	
	Total	259	4.73	.531	
Research Experience	10-20 years	6	4.67	.516	F (2, 256) = 0.144, p > .05
	20-30 years	43	4.77	.527	
	>30 years	210	4.73	.534	
	Total	259	4.73	.531	
Area of Research	Physical Sciences	48	4.79	.504	F (8, 250) = 2.543, p < .05 Eta-squared (η2) = .075
	Chemical Sciences	19	4.63	.761	
	Biological Sciences	91	4.87	.340	
	Mathematical Sciences	26	4.54	.706	
	Computer and IT	10	4.50	.527	
	Earth and Planetary Sciences	18	4.72	.575	
	Medical Sciences	20	4.80	.410	
	Engineering and Technology	24	4.46	.658	
	Humanities and Social Sciences	3	4.67	.577	
	Total	259	4.73	.531	

Chi-square tests also suggested no significant differences between the importance of science communication and scientists' Gender, χ2 (3, N = 259) = 1.937, p > .05; Age groups, χ2 (9, N = 259) = 2.635, p > .05; Type of affiliation, χ2 (21, N = 259) = 14.266, p > .05; Primary position, χ2 (15, N = 259) = 16.473, p > .05; and Research experience, χ2 (6, N = 259) = 2.289, p > .05. However, the impact of Area of research was statistically significant (χ2 (24, N = 259) = 42.735, $p < .05$) but with moderate effect size (Cramer's V = 0.235). Respondents from biological, physical, and medical sciences in comparison to other disciplines were relatively more likely to give high importance to science communication.

In a nutshell, a vast majority (97%) of the senior Indian scientists surveyed believed that communicating science with the public general public is a highly important activity. The perceived high importance of science communication among Indian scientists did not show any meaningful variations or differences across demographic variables. Also, the importance of science communication did not show any statistically significant association with the number of publications (Pearson's r = 057, $p > .05$). It suggests that science communication is seen as an important activity almost equally across the independent variables.

4.3.2. Objectives of science communication

Another way of understanding the importance of science communication among scientists is to assess how much importance they give to the objectives of science communication and how they prioritise these objectives. Therefore, based on the literature review, a list of six objectives of science communication was prepared: 1.) To inform and educate, 2.) To inculcate scientific temper, 3.) To simplify science, 4.) To contribute to public policy, 5.) To create excitement about science, and 6.) To build public trust in science. Then, the respondents were asked to rate how important they thought these objectives were to them personally while communicating science to the general public (Q.15, Appendix-1). The responses were recorded on a 5-point scale of importance where 1 = least important and 5 = very important. The scale's internal consistency was found to be reliable with Cronbach's α value of 0.888 being higher than the acceptable level of 0.70. Table 5 provides objective-wise distribution and descriptive statistics of the responses.

Table 5: Descriptive statistics for the perceived importance of the given six objectives of science communication.

Objectives		Importance									
		1	2	3	4	5	Total	Md	M	SD	Rank #
Obj-1: To inform and educate.	F	12	8	13	57	169	259	5	4.40	1.04	1
	%	4.63	3.09	5.02	22.01	65.25	100				
Obj-2: To inculcate scientific temper.	F	11	13	19	60	156	259	5	4.30	1.08	4
	%	4.25	5.02	7.34	23.17	60.23	100				
Obj-3: To simplify science.	F	16	16	37	61	129	259	4	4.05	1.20	5
	%	6.18	6.18	14.29	23.55	49.81	100				
Obj-4: To contribute to public policy.	F	13	14	56	78	98	259	4	3.90	1.12	6
	%	5.02	5.41	21.62	30.12	37.84	100				
Obj-5: To create excitement about science.	F	12	9	19	62	157	259	5	4.32	1.06	3
	%	4.63	3.47	7.34	23.94	60.62	100				
Obj-6: To build public trust in science.	F	14	7	16	61	161	259	5	4.34	1.08	2
	%	5.41	2.70	6.18	23.55	62.16	100				

** F = Frequency, % = Percentage, Md = Median, M = Mean, SD = Standard Deviation.*
 # Rank is based on mean scores.

The mean scores for all the six objectives were above the mid-point of the 5-point scale (Table 5). These results indicate that majority of the scientists believed that all the given six objectives of communicating science to the public were important (M = 3.90-4.40, SD = 1.12-1.04). Based on the mean scores, it is found that the respondents gave top priority (first rank) to objective-1 'to inform and educate' and the least priority (6th rank) to objective-4 'to contribute to public policy' from among the six objectives. In terms of percentages, about 68-87% of the scientists said that all these objectives were either important or very important (levels 4 and 5 on the 5-point scale of importance). The median values are also high (5 for four objectives and 4 for the remaining two). Also, all the six objectives showed a strong and statistically significant correlation among each other (Pearson's r = .477 - .659, p < .001).

The perceived importance of the given six objectives of science communication was largely not impacted by the demographic variables, as revealed by a series of one-way ANOVA tests.

Chi-Square tests for independence further supported that the demographic controls either did not have any effect on the perceived importance of the given objectives of science communication or their effect sizes were weak/moderate suggesting no meaningful variation.

Further, the high importance given to all the six objectives of science communication showed a positive and statistically significant correlation with the importance of science communication in general (Pearson's $r = 0.159 – 0.313$, $p < 0.05$).

4.3.3. Different ways of science communication

Science communication happens through several ways of communication, including direct face-to-face interactions, written word, and through different channels of print, electronic and digital (online) media. For convenience and simplicity, the different ways of public communication of science were grouped into five major categories: 1.) Face-to-face interactions, 2.) TV/Videos, 3.) Radio, 4.) Print Media/Press, and 5.) Online. The respondents were asked to personally evaluate the importance of these ways on a 5-point scale where 1 = Not at all Important, 2 = Minimally Important, 3 = Moderately Important, 4 = Important, and 5 = Very Important (Q.16, Appendix-1). The results shown in Table 6 indicate that the mean scores for all the five different ways of communication are above the mid-point of the 5-point scale ($M = 3.52$-4.28, $SD = 0.83$-0.92), with median values being 4 for all. These results indicated that the majority of the scientists think that all these ways of communicating science to the public are important. However, based on mean scores, 'Face-to-face interactions' gets the top priority (first rank) and 'Radio' the least priority (5th rank) as the important ways of communication among the respondents. In terms of percentages, at least three-quarters of scientists (75-85%) believed that face-to-face interactions, TV/videos, print media/press, and online media are either important or very important ways of science communication, while a relatively lower percentage of the respondents (54%) believed 'radio' as important or very important way of science communication.

Table 6: Scientists' evaluation of the importance of the ways of science communication.

Ways of science communication		Importance									
		1	**2**	**3**	**4**	**5**	**Total**	**Md**	**M**	**SD**	**Rank#**
Face-to-Face Interactions	F	3	11	25	92	128	259	4	4.28	0.89	1
	%	1.16	4.25	9.65	35.52	49.42	100				
TV/Videos	F	2	8	41	119	89	259	4	4.10	0.83	3
	%	0.77	3.09	15.83	45.95	34.36	100				
Radio	F	5	29	85	107	33	259	4	3.52	0.92	5
	%	1.93	11.20	32.82	41.31	12.74	100				
Print Media/Press	F	1	9	36	96	117	259	4	4.23	0.84	2
	%	0.39	3.47	13.90	37.07	45.17	100				
Online	F	3	11	47	107	91	259	4	4.05	0.90	4
	%	1.16	3.25	18.15	41.31	35.14	100				

** F = Frequency, % = Percentage, Md = Median, M = Mean, SD = Standard Deviation*
 # Rank is based on mean scores.

The perceived importance of the given five ways of science communication among the respondents was largely the same across different demographic variables, as revealed by a series of one-way ANOVA tests and Chi-Square tests for independence. In some case where these tests were statistically significant ($p < .05$), the effect sizes were weak suggesting no meaningful differences.

However, a statistically significant positive correlation was found between the importance given to these five ways of public communication (Face-to-face interactions, TV/videos, Radio, Print Media/Press, and Online) and the perceived importance of science communication among the respondents (Pearson's $r = 0.188 – 0.223$, $p < .01$).

From the above analysis and discussion, it is found that the majority of Indian scientists recognised the importance of using different ways of communication for ensuring enhanced engagement between science and society, which is correlated with the importance of science communication. From among the given ways of science communication, the respondents giving the highest importance to 'face-to-face' interactions suggest that senior Indian scientists 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, scientists gave relatively more importance to TV/videos, print media, and online media than radio. This might be reflective of the fact that visual media are taking over our communication spaces.

4.3.4. Current coverage of science in Indian media

When asked how they thought about the current level of science coverage in the news media in general in India, the majority of the respondents (76.83%) said that it was either average or poor (Table 7). Only 4 (1.54%) respondents said it was very good, 29 (11.20%) said it was good, 105 (40.54%) said average, 94 (36.29%) said poor, 26 (10.04%) said very poor, and 1 (0.39%) opted for no opinion. The median value is 3 (Average), the mean score is 2.59 with a standard deviation of 0.90. These results and the mean score indicate that most scientists perceived that the current level of science coverage in Indian news media was below average.

Table 7: How do you think about the current level of science coverage in news media in general in India?

Descriptor (Scale)	Frequency	Percentage (%)
Very Poor (1)	26	10.04
Poor (2)	94	36.29
Average (3)	105	40.54
Good (4)	29	11.20
Very Good (5)	4	1.54
No Opinion (6)	1	0.39
Total	**259**	**100**

A series of one-way ANOVA tests suggested that there was no impact of demographic variables on respondents' perception of science coverage in the media, as ANOVA tests were insignificant for Gender ($F(1, 257) = 0.010$, $p > .05$); Age group ($F(3, 255) = 0.969$, $p > .05$); Primary position ($F(5, 253) = 1.224$, $p > .05$); and Area of research ($F(8, 250) = 0.741$, $p > .05$). However, impact of Type of affiliation was statistically significant ($F(7, 251) = 2.303$, $p < .01$) but with medium effect size (Eta-squared ($\eta 2$) = 0.077). Further, Chi-square tests also suggested no significant differences in the media coverage of science based on the respondents' gender, age group, primary position, and area of research, except for type of affiliation ($\chi 2$ (35, N = 259) = 56.802, $p < .05$) with small effect size (Cramer's V = 0.209). Therefore, respondents' perceived level of science coverage in the news media was almost the same across the demographic variables. Also, it did not show statistically significant correlation with the importance of science communication ($r = -0.002$, $p > .05$).

4.3.5. Attitudes toward science and society interactions

When the respondents were asked to indicate their level of agreement or disagreement with the given four general statements about science and society, the responses were recorded on a 5-point scale where 1 = Strongly Disagree and 5 = Strongly Agree, as shown in Table 8. The results showed that the mean score is well above the mid-point of the 5-point scale for all four statements about science and society. These results indicated that the majority of the scientists (~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. All the attitude variables toward science-society interactions showed a positive and statistically significant correlation among each other (Pearson's r = 0.390 – 0.655, $p < .001$).

The respondents' agreement to these four statements on science-society interactions was largely independent on the demographic variables, as one-way ANOVA tests were either statistically insignificant ($p > .05$) or statistically singnificant but with small effect size.

Table 8: Scientists' agreement with the statements about science and society.

Statements		Importance									
		1	**2**	**3**	**4**	**5**	**Total**	**Md**	**M**	**SD**	**Rank#**
Scientific ignorance is a hurdle in the advancement of science.	F	8	18	27	116	90	259	4	4.01	1.00	4
	%	3.09	6.95	10.42	44.79	34.75	100				
Scientifically ignorant public can oppose science projects.	F	8	20	22	103	106	259	4	4.08	1.04	3
	%	3.09	7.72	8.49	39.77	40.93	100				
Public awareness about scientific issues should be increased.	F	4	2	4	81	168	259	5	4.57	0.71	2
	%	1.54	0.77	1.54	31.27	64.86	100				
Better linkages between science and society are needed.	F	2	2	9	75	171	259	5	4.59	0.67	1
	%	0.77	0.77	3.47	28.96	66.02	100				

** F = Frequency, % = Percentage, Md = Median, M = Mean, SD = Standard Deviation*
 # Rank is based on mean scores.

Chi-square tests for independence also confirmed no singnificant association between the respondents' agreement to these statements and demographic variables.

However, all the four attitude variables examining scientists' awareness about how science and society interact showed a statistically significant positive correlation with the respondents' perception about the importance of science communication (Table 9). This suggests that when scientists are aware that science and society are constantly interacting and transacting with each other, they give high importance to science communication. Science communication can fill the gap between science and society and help build mutual trust by spreading scientific awareness. Enhanced public awareness about scientific issues can potentially garner public support for the advancement of science while preventing unnecessary opposition to science projects. To achieve this, it is pertinent to place science communication and public engagement at a higher pedestal in science where scientists play an active role in establishing a greater dialogue with society.

Table 9: Indian scientists' attitudes about science and association with the importance of science communication.

Attitude Variables	*r*	*P-value (2-sided)*
Scientific ignorance is a hurdle in the advancement of science.	0.173	<0.01
Scientifically ignorant public can oppose science projects.	0.241	<0.001
Public awareness about scientific issues should be increased.	0.291	<0.001
Better linkages between science and society are needed.	0.320	<0.001

4.4. Role and responsibility in science communication

This section presents empirical findings from the survey of senior Indian scientists to address research objective 1(b) 'To explore what Indian scientists think about their role and responsibilities for science communication.' Data from four close-ended survey questions (Q.19-Q.22) are presented here to describe and explore scientists' views and attitudes on whether disseminating research results to society was an important part of their current job, whether communicating science is a moral duty of scientists, whether scientists should play an active role, and who should have the mains responsibility for science communication. While analysing the data from these questions for descriptive statistics, the dependent variables are also tested for any impact of demographic variables (Gender, Age Group, Primary Position, Type of Affiliation, and Area of Research). Their associations and correlations are also explored. The presentation of results starts with finding whether Indian scientists think disseminating their research results to society is part of their job.

4.4.1. Disseminating Research Results to Society as Part of Job

The respondents were asked whether they thought disseminating their research results to society was an important part of their current job's roles and responsibilities, just like publishing their research in peer-reviewed journals. The results shown in Table 10 indicate that about 61.78% of scientists said 'Yes' it is an important part of their current job, with 22.01% said 'May be,' 13.90% said 'No' and 2.32% said they 'Don't know.' The mean score (M = 3.43, SD = 0.82) and the median value (Md = 4 = Yes) also suggest that majority of the respondents believed science communication is part of their job. If the responses for 'Yes' and 'May be' are combined, 83.79% of respondents are optimistic about considering science communication as part of their job.

Table 10: Descriptive statistics for scientists' views on whether disseminating their research results to society is part of their current job's roles and responsibilities.

Question		1 (Don't Know)	2 (No)	3 (May Be)	4 (Yes)	Total	Md	Mean	SD
Like publishing in peer-reviewed journals, do you think disseminating your research results to society is an important part of your current job's roles and responsibilities?	F	6	36	57	160	259	4	3.43	0.82
	%	2.32	13.90	22.01	61.78	100			

There was no significant association between a scientist's gender and whether science communication was an important part of a scientist's job's roles and responsibilities ($F (1, 257) = 0.156$, $p > .05$). Type of affiliation (employer) also did not show any significant association ($F (7, 251) = 1.124$, $p > .05$). However, significant sources for variation were found for Age ($F (3, 255) = 5.143$, $p < .01$; Eta-squared ($\eta 2$) = .057), Primary position ($F (5, 253) = 2.947$, $p < .05$; Eta-squared ($\eta 2$) = .063), and Area of research ($F (8, 250) = 2.543$, $p < .05$; Eta-squared ($\eta 2$) = .089). However, their effect sizes were either small or medium.

Across age groups, relatively more respondents in the higher age groups than in the lower age groups believed that science communication is part of their job. However, among the higher age groups, respondents in the age group of 44-55 years (M = 3.51) were relatively more favourable than those in the top age group of >55 years (M = 3.44). Across primary positions, respondents holding higher positions such as directors/heads of an institutions (M = 3.64) or heads of department (M = 3.59) than others were more inclined to believe that science communication is part of their job.

Across the academic disciplines, it is observed scientists from Biological Sciences (M = 3.68), Medical Sciences (M = 3.65), Physical Sciences (M = 3.38), and Computer and IT (M = 3.40) were relatively more inclined to believe that communicating science to society is part of their job. Scientists from Biological Sciences (M = 3.68) were the most positive, while those from Chemical Sciences (M = 2.89) were the least positive in this regard. Post Hoc test using Tukey HSD for Area of research also suggested that the only significant mean difference in science communication being part of job was between Biological Sciences and Chemical Sciences (.787, S.E. =.199, $p < .01$).

Further, Chi-square tests for independence also suggested that there were no significant differences in scientists' attitude toward science communication being part of their job across demographic/control variables (Gender, Age, Type of Affiliation, and Primary position), except for the moderate effect of Area of Research ($\chi 2$ (24, N = 259) = 37.336, $p < .05$; Cramer's V = 0.219).

That is, an investigation involving group-wise mean scores across demographic variables and one-way ANOVA tests and Chi-square tests revealed there is not much impact of independent variables on the science communication being part of scientists' job.

However, a statistically significant positive correlation was found between science communication being a part of the job and the number of publications (Pearson's r = .123, p

< .05) and the importance of science communication (Pearson's r = .240, p < .001). Respondents with more publications and giving more importance to science communication were more positive about science communication being a part of their job's role and responsibilities.

4.4.2. Moral duty to inform the taxpayers

The respondents were asked to show their agreement to the statement, "When taxpayers fund scientists' research and salary, scientists should have a moral duty to inform society about what they are doing with taxpayers' money." The results for scientists' agreement/disagreement to this statement (on a 5-point scale where 1 = Strongly Disagree and 5 = Strongly Agree) are shown in Table 11. These results indicate that 77.99% of scientists showed agreement to this statement (responses for Agree and Strongly Agree combined), while 12.74% were neutral and only 9.27% showed disagreement (responses for Disagree and Strongly Disagree combined). The mean score (M = 3.99, SD = 1.03) and the median value (Md = 4 = Agree) also showed an overall good agreement with the statement.

Table 11: Scientists' level of agreement with the statement on the moral duty of scientists.

Question		**1**	**2**	**3**	**4**	**5**	**Total**	**Md**	**Mean**	**SD**
When taxpayers fund scientists' research and salary, scientists should have a moral duty to inform society about what they are doing with taxpayers' money.	F	11	13	33	113	89	259	4	3.99	1.03
	%	4.25	5.02	12.74	43.63	34.36	100			

The respondents' perception that they have a moral duty to inform the society or taxpayers did not show any significant variation based on Gender (F (1, 257) = 0.005, p > .05), Age Group (F (3, 255) = 1.459, p > .05), and Type of Affiliation (Employer) (F (7, 251) = 1.271, p > .05). Statistically significant impact of Primary Position on variation in the perception about moral duty was found (F (5, 253) = 2.829, p < .05), however, with small effect size

(Eta-squared (η2) = .053). Respondents at higher positions such as director/head of an institution or head of a department were relatively more positive about informing society as their moral duty than professors and scientists.

The impact of Area of Research ($F (8, 250) = 2.543$, $p < .05$) was statistically significant, with medium effect size (Eta-squared (η2) = .066). Post Hoc test using Tukey HSD for Area of Research suggested that the only significant mean difference in science communication being part of the job was between Medical Sciences and Humanities & Social Sciences (1.967, SE = .625, $p < .05$). The respondents from Medical Sciences (M = 4.30, SD = 0.865) were most positive, while those from Humanities & Social Sciences (M = 2.33, SD = 1.528) were least positive about their moral duty in communicating science.

However, Chi-square tests for independence suggested that there were no significant differences ($p > .05$) in scientists' perceived sense of moral duty to communicate science based on demographic/control variables (Gender, Age, Type of Affiliation, Primary Position and Area of Research).

That is, an investigation involving group-wise mean scores across demographic variables and ANOVA and Chi-square tests revealed that independent variables did not have much effect on variation in scientists' sense of moral duty for communicating science.

However, scientists' perceived sense of moral duty to communicate showed a statistically significant and positive correlation with the number of peer-reviewed publications (Pearson's $r = .226$, $p < .001$), science communication as part of the job (Pearson's $r = .316$, $p < .001$), and the importance of science communication (Pearson's $r = .271$, $p < .001$). These correlations suggest that respondents with more publications, giving more importance to science communication and believing it as part of their job were more inclined to believe that they also have a moral duty to communicate their research to the taxpayers.

4.4.3. Scientists and their responsibility for communication

Scientists' attitudes toward their role and responsibility were measured by seeking their agreement/disagreement (on a 5-point scale where 1 = Strongly Disagree and 5 = Strongly Agree) to the given three statements associated with scientists, their responsibility, and science communication (Table 12). The internal scale reliability was good, with Cronbach's α = 0.832 being higher than the accepted value of 0.7. These three statements also showed statistically significant and strong positive correlations among each other (Pearson's r = .560 - .669, p < .001). Results indicated that, with the mean scores being well above the mid-point of the 5-point scale, about 69-84% of scientists show good agreement with these statements. That is, the majority of the respondents agreed that 1) Scientists are responsible for communicating their research to the public (69.11%), 2) Science communication should be an essential part of a scientist's duty/job (69.50%), and 3) Scientists should play an active role in science communication (84.17%).

Table 12: Scientists' level of agreement with the given statements on scientists' role and responsibility in science communication.

Statements		**1**	**2**	**3**	**4**	**5**	**Total**	**Md**	**Mean**	**SD**
Scientists are responsible for communicating their research to the public.	F	8	21	51	126	53	259	4	3.75	0.97
	%	3.09	8.11	19.69	48.65	20.46	100			
Science communication should be an essential part of a scientist's duty/job.	F	9	22	48	133	47	259	4	3.72	0.97
	%	3.47	8.49	18.53	51.35	18.15	100			
Scientists should play an active role in science communication.	F	3	6	32	138	80	259	4	4.10	0.79
	%	1.16	2.32	12.36	53.28	30.89	100			

An investigation involving group-wise mean scores across demographic variables and one-way ANOVA tests and Chi-square tests revealed that demographic variables did not cause any significant variation in scientists' agreement/disagreement with the given three statements about their role and responsibility.

However, scientists' agreement to these three statements about their role and responsibility was found to show a statistically significant positive correlation with scientists perceived sense of moral duty to communicate (Pearson's $r = .322 - .524$, $p < .001$), science communication being part of the job (Pearson's $r = .267 - .399$, $p < .001$), and the importance of science communication (Pearson's $r = .243 - .338$, $p < .001$). That is, respondents having a sense of moral duty, giving more importance to science communication, and believing it as part of their job were more inclined to believe that they have a responsibility to communicate science and should play an active role in science communication which should be an essential part of their job.

Also, a statistically significant and positive correlation existed between Indian scientists' positive perceptions of their moral duty, role, and responsibility in communicating science and their positive attitudes toward science-society interactions, where the majority of them believed that scientific ignorance is a hurdle in the advancement of science (80%), scientifically ignorant public can oppose science projects (81%), public awareness about scientific issues should be increased (96%), and better linkages between science and society are needed (95%) (Table 13).

Table 13: Correlation of scientists' perceptions about their moral duty, role, and responsibility in science communication with their attitudes toward science-society interactions.

Variables	*Mean*	*SD*	Scientists should have moral duty to inform *r*	Scientists are responsible for SciCom *r*	SciCom should be an essential part of current job *r*	Scientists should play an active role in SciCom *r*
Attitudes about science and society						
Scientific ignorance is a hurdle in the advancement of science.	4.01	1.01	0.187 **	0.320 ***	0.265 ***	0.238 ***
Scientifically ignorant public can oppose science projects.	4.08	1.04	0.217 ***	0.465 ***	0.422 ***	0.462 ***
Public awareness about scientific issues should be increased.	4.57	0.71	0.244 ***	0.218 ***	0.182 **	0.213 ***
Better linkages between science and society are needed.	4.59	0.67	0.252 ***	0.299 ***	0.263 ***	0.355 ***

* $p < .05$, ** $p < .01$, *** $p < .001$

4.4.4. Main responsibility for communicating science

The respondents were provided with a list of seven options and were asked to select any of them that best described their opinion on who should have the main responsibility for communicating science to the general public. The results shown in Table 14 indicate that the highest proportion of the respondents (28.19%) believed scientists themselves should have the main responsibility of communicating science to the public, followed by 24.32% who said science communication specialists and 15.44% said separate communication departments at R&D institutions should have the main responsibility. About 13% said the media/press, 8.11% R&D institutions, 7.72% funding agencies for scientific research, and 3.09% said the government should have the main responsibility. If the responses for 'science communication specialists' or 'separate science communication departments at R&D institutions' are merged, then most Indian scientists (~40%) believed that the main responsibility should rest with the communication mediators. Putting it in other words, about 68% of scientists believed either scientists themselves or science communication specialists/departments at R&D institutions should share the main responsibility of communicating science to the general public.

Table 14: Scientists' perception about who should have the main responsibility for communicating science to the public.

Descriptor	Frequency	Percentage (%)
Scientists themselves	73	28.19
Funding agencies for scientific research	20	7.72
R&D Institutions	21	8.11
Government	8	3.09
Media/Press	34	13.13
Science communication specialists	63	24.32
Separate com. depts at R&D institutions	40	15.44
Total	**259**	**100**

There was no significant association of scientists' opinion on who should have the main responsibility to communicate with Age ($\chi 2$ (18, N = 259) = 22.716, $p > .05$), Type of Affiliation ($\chi 2$ (42, N = 259) = 46.928, $p > .05$), and Primary Position ($\chi 2$ (6, N = 259) = 13.072, $p < .05$). However, there were significant sources of variation, but with small effect sizes, for Gender ($\chi 2$ (24, N = 259) = 37.336, $p < .05$; Cramer's V = 0.225), and Area of Research ($\chi 2$ (48, N = 259) = 68.538, $p < .05$; Cramer's V = 0.210).

Across Gender, relatively more female scientists than their male counterparts said that science communication specialists and separate communication departments at R&D institutions should play the main role. However, relatively more male scientists, almost double the percentage of female scientists, believed scientists themselves should play the main role in communicating science to society. About 15% of male scientists, in contrast to only 3% females, said that the Media/Press should play the main role. Relatively more female scientists gave importance to government and funding agencies to play the main role.

Across the Area of Research, a higher proportion of the respondents from Physical Sciences, Engineering and Technology, Humanities & Social Sciences, and Chemical Sciences said that scientists themselves should play the main role. While a higher proportion of scientists from Biological Sciences, Computer and IT, Earth and Planetary Sciences, Mathematical Sciences, and Medical Sciences believed that science communication specialists and communication departments at R&D institutions should play the main role.

4.5. Scientists' engagement with the general public and the media

The second objective of the current study is "To understand how a) Indian scientists engage with the general public and the media and b) its impact on their career advancement." Twelve questions (Q.23-Q.34) were used to address this objective. As this objective has two components, for the convenience of execution and analysis, results for this objective are discussed under the two separate headings: a) Scientists' engagement with the general public and the media and b) Impact of public engagement on scientists' career advancement.

This section describes the respondents' perceptions about their current practices and experiences about their engagement in science communication with the general public and the media through nine close-ended questions (Q.23-Q.31), including three matrix questions. Pre-recorded answers on the Likert or Likert-type scales were used to seek respondents' responses.

4.5.1. Frequency of scientists' overall active engagement

Scientists' responses to the question 'In general, how frequently do you actively engage in science communication activities?' (Q.23, Appendix-1) are shown in Table 15. Results indicate that 49.03% of the respondents believed that they occasionally engaged in science communication activities, 39.38% said they often engaged, 10.81% rarely, and 0.77% said they never engaged in such activities. The mean score (M = 3.27, SD = 0.679) and the median value (Md = 3 = Occasionally) also suggest that the frequency of participation by Indian scientists in public engagement activities largely remains to be 'occasionally.'

Table 15: Frequency of scientists' active engagement in science communication activities in general.

Descriptor (Scale)	Frequency	Percentage (%)
Never (1)	2	0.77
Rarely (2)	28	10.81
Occasionally (3)	127	49.03
Often (4)	102	39.38
Total	**259**	**100**

Statistically, there was no significant association between scientists' gender and their frequency of participation in public engagement activities (F (1, 257) = 2.156, p > .05). However, comparing mean scores, male scientists' frequency (M = 3.30, SD = .664) was a bit higher than their female counterparts (M = 3.09, SD = .765). Also, no significant impact of scientists' age on their PE frequency was found (F (3, 255) = 0.187, p > .05). However, comparing mean scores, respondents in the top age group of '>55 years' (M = 3.28) were slightly more active than other age groups (M = 3.00 – 3.24). Scientists' frequency in PE activities was also not impacted by the Type of affiliation (employer) (F (7, 251) = 0.761, p > .05) or Area of research (F (8, 250) = 1.113, p > .05). However, Primary position had a statistically significant effect on scientists' PE frequency (F (5, 253) = 2.353, p < .05), where respondents at higher positions such as directors/heads of institutions (M = 3.34) or heads of departments (M = 3.15) were more active than others. However, Chi-square tests for independence suggested no significant differences in scientists' frequency of participation in PE activities across demographic/control variables (Gender, Age, Type of Affiliation, Primary position, and Area of Research), as the *p*-value for all the cases was > .05.

Scientists' frequency of participation in PE activities was found to be significantly and positively correlated with the number of publications (Pearson's $r = .125$, $p < .05$), importance of science communication (Pearson's $r = .244$, $p < .001$), sense of moral duty (Pearson's $r = .176$, $p < .01$), and science communication being part of the job (Pearson's $r = .355$, $p < .001$). It suggests that the respondents who had a higher number of publications, a higher sense of the importance of (and moral duty toward) science communication and science communication being part of their job were relatively more frequent in their public engagement.

4.5.2. Frequency of overall PE activities by institutions

Scientists' responses to the question 'How frequently your institution organises public engagement activities?' (Q.24, Appendix-1) are shown in Table 16. Results indicate that 47.49% of the respondents believed that their institution occasionally organised public engagement (PE) activities, while 36.29% said often, 13.90% rarely, and 2.32% said never. The mean score ($M = 3.18$, $SD = 0.756$) and the median value ($Md = 3$ = Occasionally) also suggest that the frequency with which Indian scientists' affiliated institutions organise public engagement activities largely remains to be 'occasionally.'

Table 16: Frequency of public engagement activities organised by the respondent's institution.

Descriptor (Scale)	Frequency	Percentage (%)
Never (1)	6	2.32
Rarely (2)	36	13.90
Occasionally (3)	123	47.49
Often (4)	94	36.29
Total	**259**	**100**

Statistically, there was a significant association between scientists' gender and the frequency with which the respondents' affiliated institutions organised public engagement activities ($F (1, 257) = 7.825, p < .05$), however, with small effect size (Eta-squared ($\eta 2$) = .030). Relatively more female scientists believed that their institutions organised more PE activities ($M = 3.52, SD = .566$) than their male counterparts ($M = 3.13, SD = .764$).

Scientists' age did not statistically impact their perception of the frequency with which respondents' institutions organised public engagement activities ($F (3, 255) = 0.894, p > .05$). Type of affiliation (employer) showed significant association with scientists' frequency in PE activities ($F (7, 251) = 2.812, p < .05$) with medium effect size (Eta-squared ($\eta 2$) = .073). Post Hoc test using Tukey HSD for Type of Affiliation suggested that the only significant mean difference, in this case, was between Central R&D Labs and Central Universities (.468, S.E. =.133, $p < .05$).

Scientists' Primary position had a significant impact on their perception of the frequency of their institutions organising PE activities ($F (5, 253) = 2.442, p < .05$). Across primary positions, respondents holding higher positions such as directors/heads of institutions or heads of departments were relatively more inclined to believe that their institutions organised more PE activities. However, Area of research was not significantly associated with the institutions' frequency of organising PE activities ($F (8, 250) = 1.719, p > .05$).

Further, Chi-square tests for independence suggested that there were no significant differences in the frequency of institutions organising PE activities for Gender, Age, and Primary position. However, Type of Affiliation and Area of Research showed significant association ($p < .05$), but the effect sizes were small. That is, demographic variables did not have any meaningful impact on variation in institutions' frequency of organising PE activities.

4.5.3. Frequency of scientists' public engagement activities during last year

Six scale items (Cronbach's $\alpha = .73$) were used to assess how frequently the respondents used the different ways of science communication during the last one year. The respondents were asked how often they participated in any science communication activities (grouped into six categories) during the last one year (Q.25, Appendix-1). The responses were recorded on a 4-point scale where 1 = Never, 2 = Once, 3 = 2-5 times and 4 = 6+ times. Results for this question are shown in Table 17. These results suggest that the highest proportion of scientists who gave talks at schools and colleges (M = 2.85, SD = 0.96) was for 2-5 times (41.70%), and who interacted face to face with the public (M =2.61, SD = 1.04) was also for 2-5 times (40.54%). Similarly, the highest proportion (in terms of percentages) of scientists who gave interviews to journalists (M = 2.11, SD = 1.00), who wrote popular articles/books (M = 2.12, SD = 0.98) and who wrote about science online (M = 1.61, SD = 0.91) was again for 2-5 times, and who shared research videos online (M = 1.48, SD = 0.87) was for 'once'. However, the large majority never shared research videos online (72.20%) or wrote about science online (65.25%). About 35-37% have never given media interviews or written popular science, but the remaining majority have done so at least once in the last year. The top two instances where scientists engaged more than six times were talking at schools and colleges (27%) and face-to-face interactions (21%).

Table 17: Scientists' frequency of participation in different science communication activities during the last one year.

Science communication activities		1	2	3	4	Total	Md	Mean	SD	Rank#
Face-to-face interactions with the public (open days/public talks/expos/etc.).	F	55	45	105	54	259	3	2.61	1.04	2
	%	21.24	17.37	40.54	20.85	100				
Talking at schools and colleges.	F	31	49	108	71	259	3	2.85	0.96	1
	%	11.97	18.92	41.70	27.41	100				
Giving interviews to journalists/reporters.	F	96	61	80	22	259	2	2.11	1.00	4
	%	37.07	23.55	30.89	8.49	100				
Writing popular science articles/books.	F	92	62	86	19	259	2	2.12	0.98	3
	%	35.52	23.94	33.20	7.34	100				
Writing about science online (websites, blogs, wikis, social media).	F	169	33	47	10	259	1	1.61	0.91	5
	%	65.25	12.74	18.15	3.86	100				
Sharing research videos online.	F	187	33	26	13	259	1	1.48	0.87	6
	%	72.20	12.74	10.04	5.02	100				

* Scale: 1 = Never, 2 = Once, 3 = 2-5 times, 4 = 6+ times
\# Rank is based on mean scores.

If we make it never versus all frequencies (*i.e.*, once, 2-5 times, and 6+ times), the majority of the respondents have used at least once all the traditional ways of public engagement during the last year: face-to-face interactions (78%), talking at schools and colleges (88%), giving interviews to journalists/reporters (63%), writing popular science articles/books (64%), while the majority of them have never used the online ways with 65% never wrote about (popular) science online and 72% never shared a video about their research online (Figure 2). These results show that talking at schools and colleges remains the most popular way of public engagement while sharing research videos is the least popular. It is suggested that Indian scientists were more comfortable engaging with the public through traditional and direct ways of communication than through the mediated or online forms of communication during the last year.

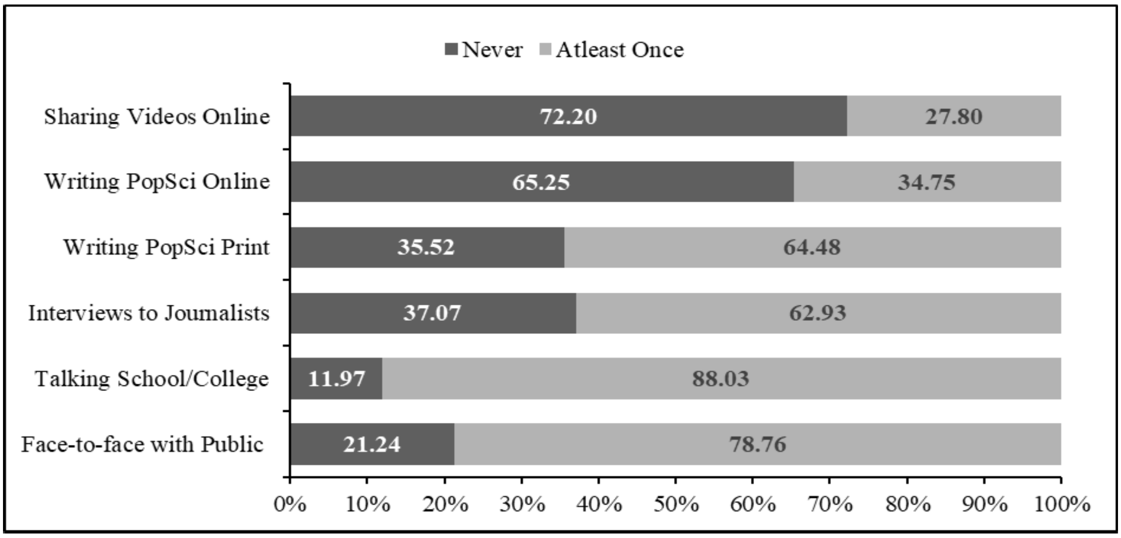

Figure 2: Frequency of scientists' participation (percentages) in different science communication activities during the last one year (N = 259).

No significant differences between these ways of public engagement and the demographic variables were found when a series of paired Chi-square tests of independence were conducted. However, the only case showing significant differences was for writing about science online with the type of affiliated organisation, $\chi2$ (21, N = 259) = 39.698, $p < .01$. However, its effect size was small (Cramer's V = 0.226). Here, a significant particularity is that a considerable number of the respondents from central R&D institutions (19%), NGOs (31%), private companies (25%), state universities (28%) and other (15%) occasionally wrote about science online when most of them across affiliations have never or rarely done so.

One-way ANOVA tests also suggest that there was no significant association between scientists' gender and their frequency of participation in all the ways of communication, except for writing popular science online (F (1, 257) = 4.206, $p < .05$) with a small effect size (Eta-squared ($\eta2$) = .016). Here, male scientists were relatively more active online (M = 1.65, SD = .941) than their male counterparts (M = 1.30, SD = .637), as also in using other ways of communication based on mean scores.

The frequency of scientists' engagement through the given six ways of communication was not statistically impacted by scientists' Age, Employer type, Primary Position, and Area of research, as *p*-values were higher (p > .05).

4.5.4. How easy is science communication?

Scientists' responses to the question 'In general, how easy/difficult do you find it to engage in science communication activities?' (Q.26, Appendix-1) are shown in Table 18. Responses were recorded on a 5-point scale (Very Difficult, Difficult, Neutral, Easy, Very Easy). Results indicate that the highest proportion of the respondents (36.29%) said that engaging in science communication activities is fairly easy, while about 28% remained neutral. The median value is 3 (Neutral) and the mean score of 3.26 (SD = 1.01) is also close to Neutral. When 'very easy' and 'fairly easy' responses are merged 'easy,' and 'very difficult' and 'fairly difficult' as 'difficult,' almost double the respondents (46%) find it easy than those who find it difficult (26%). However, only a very small percentage finds it very difficult (3%) or very easy (9%). Respondents who find it very easy are three times those who find it very difficult.

Table 18: Scientists' views on ease of engaging in science communication activities.

Descriptor (Scale)	Frequency	Percentage (%)
Very Difficult (1)	7	2.70
Fairly Difficult (2)	61	23.55
Neutral (3)	72	27.80
Fairly Easy (4)	94	36.29
Very easy (5)	24	9.27
Total	**259**	**100**

No significant variation in the ease or difficulty in engaging in science communication was found for scientists' gender (F (1, 257) = 0.004, p > .05), Age (F (3, 255) = 0.610, p > .05), Type of affiliation (F (7, 251) = 0.669, p > .05), and Area of research (F (8, 250) = 1.103, p >

.05). It was significant for Primary position ($F (5, 253) = 2.316$, $p < .05$), but with small effect size (Eta-squared ($\eta 2$) = .044). Chi-square tests for independence also suggested no significant differences in perceived level of ease/difficulty among the respondents based on their demographic variables.

However, ease of participation in science communication activities was found to be significantly and positively correlated with communication experience (Pearson's $r = 0.312$, $p < .001$) and frequency of public engagement (Pearson's $r = 0.428$, $p < .001$).

4.5.5. Overall experience in science communication activities

The respondents were asked if they were engaged in any science communication activities in the past, then how their overall experience was so far (Q.27, Appendix-1). Their responses are shown in Table 19. Results indicate that a large proportion of the respondents (40.54%) said that their overall experience in engaging in science communication activities has been 'very good.' It was followed by about 18% saying it was 'average,' with only 1.54% (n = 4) saying it was 'bad.' Interestingly, no one said that their science communication experience was 'very bad,' with 6.56% (n = 17) had 'no opinion' in this regard. The Median value is 4 (Good) and the Mean score of 4.32 (SD = 0.90) is also close to Good. In other terms, 73.74% of the respondents said their experience has been either good or very good.

Table 19: Scientists' views on their overall experience so far in science communication activities.

Descriptor (Scale)	**Frequency**	**Percentage (%)**
Very Bad (1)	0	0.00
Bad (2)	4	1.54
Average (3)	47	18.15
Good (4)	86	33.20
Very Good (5)	105	40.54
No Opinion (6)	17	6.56
Total	**259**	**100**

The overall science communication experience so far among the respondents was influenced much by their demographic variables, as suggested by one-way ANOVA tests and Chi-square tests for independence. However, it showed a statistically significant and positive correlation with respondents' perceived importance of science communication (Pearson's $r = 0.125$, $p < .05$) and frequency of public engagement (Pearson's $r = 0.211$, $p < .001$).

4.5.6. Future engagement in science communication

The respondents were asked if there is an opportunity to communicate their research to the public in the future, how likely would they get involved in science communication activities (Q.28, Appendix-1). Their responses for their likelihood were recorded on a 5-point scale (Very Unlikely, Quite Unlikely, Neutral, Quite Likely, Very Likely). Results shown in Table 20 indicate that most of the respondents (50.97%) said that they were 'quite likely' to engage in science communication activities in the future, followed by 26.25% saying they were 'very likely' to engage. If these two responses are clubbed, then 77.22% of the scientists said they were likely to engage in the future. Only 6.56% said they were unlikely (either 'quite unlikely' or 'very unlikely') to engage, with 16.22% opting to be 'neutral.' The Median value is 4 (Quite Likely) and the Mean score of 3.95 (SD = 0.87) is also very close to Quite Likely.

Table 20: Scientists' views on their likelihood to participate in science communication activities in the future, if given an opportunity.

Descriptor (Scale)	Frequency	Percentage (%)
Very Unlikely (1)	4	1.54
Quite Unlikely (2)	13	5.02
Neutral (3)	42	16.22
Quite Likely (4)	132	50.97
Very Likely (5)	68	26.25
Total	**259**	**100**

Scientists' likelihood to participate in science communication activities in future was largely independent of the demographic variables, as suggested by one-way ANOVA tests and Chi-square tests for independence.

4.5.7. The possible impacts of science communication

Six scale items (Cronbach's α = .84) were used to assess the respondents' attitudes toward the possible impact of their engagement in science communication activities (Q.29, Appendix-1). The respondents were asked if they engaged in science communication activities, then how likely did they think the six given statements would happen. Their responses were recorded on a 5-point scale (1 = Very Unlikely, 2 = Quite Unlikely, 3 = Neutral, 4 = Quite Likely, 5 = Very Likely). Results shown in Table 21 indicate that the mean scores for all the six statements are above the mid-point on the 5-point scale showing an overall positive response.

Table 21: Scientists' perception about how likely the following things will happen if they engage in science communication activities.

Statements		1	2	3	4	5	Total	Md	Mean	SD	Rank
1. It will increase scientific knowledge of the public.	F	3	8	27	164	57	259	4	4.02	0.74	2
	%	1.16	3.09	10.42	63.32	22.01	100				
2. It will increase my own scientific knowledge.	F	16	17	61	113	52	259	4	3.65	1.06	5
	%	6.18	6.56	23.55	43.63	20.08	100				
3. It will increase my confidence in public communication.	F	11	5	44	131	68	259	4	3.93	0.94	3
	%	4.25	1.93	16.99	50.58	26.25	100				
4. It will provide scientific information for wider public use.	F	7	3	25	151	73	259	4	4.08	0.81	1
	%	2.70	1.16	9.65	58.30	28.19	100				
5. It will popularise my research.	F	11	15	70	104	59	259	4	3.71	1.02	4
	%	4.25	5.79	27.03	40.15	22.78	100				
6. It will increase public support for my research.	F	21	25	99	82	32	259	3	3.31	1.07	6
	%	8.11	9.65	38.22	31.66	12.36	100				
* Scale: 1 = Very Unlikely, 2 = Quite Unlikely, 3 = Neutral, 4 = Quite Likely, 5 = Very Likely											

By merging 'quite likely' and 'very likely' responses as 'likely,' it is found that about 85% of the respondents expressed that their engagement in science communication activities would likely increase the public's scientific knowledge. Similarly, the majority of respondents said that their engagement would likely increase their own scientific knowledge (64%), increase their confidence in public communication (77%), provide scientific information for wider public use (86%), and popularise their research (63%). However, relatively lower percentage but still most of the respondents (44%) expressed that their engagement would increase public support for their research, with the highest proportion of respondents (38%) remaining neutral to this statement among all the six items. Also, a considerable number of respondents remained neutral in the case of their engagement increasing their own scientific knowledge (24%), popularising their research (27%), and increasing their confidence in public communication (17%).

The Median values (Md = 4 = Quite Likely) also suggest that the respondents believed the first five statements were likely to happen, and the Median value (Md = 3 = Neutral) for the sixth statement suggests that the respondents were neutral about their engagement increasing public support for their research. Based on the Mean scores, providing scientific information for wider public use (M = 4.08, SD = 0.81) is the most likely thing to happen, while increasing public support for research (M = 3.31, SD = 1.07) is the least likely thing to happen when scientists engaged in science communication activities.

All these six items assessing the impact of scientists' engagement were found to be significantly correlated to each other (Peasron's r = .312 – .656, $p < .001$). However, the demographic variables did not cause any meaningful variations in any of these six items assessing scientists' attitudes toward the possible impacts of their engagement, as revealed by one-way ANOVA tests and Chi-square tests for independence.

4.5.8. Personal attributes for science communication performance

Three scale items (Cronbach's α = .83) were used to assess the personal attributes (enjoyment, confidence, and being well-equipped) of the respondents associated with their performance in science communication. The respondents were given three statements about their engagement in science communication with non-specialist publics or the media and were asked to show their level of agreement/disagreement to these statements on a 5-point scale (Q.30, Appendix-1). Results shown in Table 22 indicate that the mean scores for all three statements are well above the mid-point on the 5-point scale showing an overall positive agreement.

Table 22: Scientists' level of agreement with three statements about engaging in science communication activities showing their personal attributes.

Statements		1	2	3	4	5	Total	Md	Mean	SD	Rank
I personally enjoy taking part in science communication activities.	F	4	2	47	133	73	259	4	4.04	0.79	3
	%	1.54	0.77	18.15	51.35	28.19	100				
I am confident about my ability to communicate science.	F	1	2	35	127	94	259	4	4.20	0.72	1
	%	0.39	0.77	13.51	49.03	36.29	100				
I am personally well equipped to communicate my research.	F	3	4	42	122	88	259	4	4.11	0.81	2
	%	1.16	1.54	16.22	47.10	33.98	100				

* Scale: 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree

Merging 'Strongly Agree' and 'Agree' responses, it is found that the majority of the respondents agreed that they personally enjoy taking part in science communication activities (79.54%), they are confident about their ability to communicate science (85.32%), and they are personally well-equipped to communicate their research (81.08%). Only about 1% - 3% showed disagreement, with about 14% - 18% remaining respondents were neutral to these statements. The Median value is 4 (Agree) for all three statements and the Mean scores are also above 4, suggesting a general agreement.

All three variables (personal enjoyment, confidence in abilities, being well-equipped) were found to be strongly and positively correlated to each other (Peasron's $r = .485 - .779$, $p < .001$). Further, all the variables as mentioned above were also found to be significantly and positively correlated with the frequency of public engagement activities by scientists during the last year ($r = 0.402 - 0.525$, $p < .001$) and their likelihood to engage in the future as well ($r = 0.373 - 0.531$, $p < .001$). Therefore, it is suggested that these personal attributes play a significant role in scientists' active engagement and likelihood to engage in science communication activities in the future.

Group-wise mean scores for all three personal attributes across the demographic variables did not reveal any meaningful variations. However, male scientists were relatively more positive than female scientists in that they enjoyed engaging in science communication and were confident and well-equipped in communicating science. Compared to other primary positions, directors or heads of institutions were relatively more positive in their agreement that they personally enjoyed taking part in science communication activities, were confident of their communication abilities, and were personally well-equipped for such activities.

4.5.9. Rating own engagement in science communication

The respondents were asked how they would rate their own engagement in science communication with the general public/media (Q.31, Appendix-1), and their responses were recorded on a 6-point scale (Very Poor, Poor, Average, Good, Very Good, No Opinion). Results shown in Table 23 indicate that the highest proportion of the respondents (30.89%) rated their own engagement as 'average.' However, if we combine the responses for Good and Very Good, then 52.51% of scientists rated their engagement as good/very good, while

14.29% rated it as poor/very poor, with only 2.32% expressed 'no opinion.' The Median value is 4 (Good) and the Mean score of 3.71 (SD = 1.12) is also very close to Good.

Table 23: Scientists' rating of their own engagement in science communication with the general public/media.

Descriptor (Scale)	Frequency	Percentage (%)
Very Poor (1)	5	1.93
Poor (2)	32	12.36
Average (3)	80	30.89
Good (4)	65	25.10
Very Good (5)	71	27.41
No Opinion (6)	6	2.32
Total	**259**	**100**

Scientists' own rating of engagement in science communication activities was found to have no significant variation for scientists' gender ($F(1, 257) = 0.512$, $p > .05$), Age ($F(3, 255) = 0.447$, $p > .05$), Type of affiliation ($F(7, 251) = 1.125$, $p > .05$), Primary position ($F(5, 253) = 1.833$, $p > .05$), and Area of research ($F(8, 250) = 1.178$, $p > .05$). Similarly, Chi-square tests for independence also suggested that scientists' own rating of public engagement was not significantly associated with demographic variables ($p > .05$), except for Gender, $\chi2 (5, N = 259) = 14.387$, $p < .05$. However, the effect size is small (Cramer's V = 0.236). A specific particularity is that relatively more female scientists rated their engagement as average and opted for no opinion, while relatively more male scientists rated their engagement as very good.

4.6. Impact of public engagement on scientists' career advancement

This section describes what Indian scientists thought about how their engagement in science communication activities with the public/media impacted their career advancement. Three close-ended questions, including two matrix questions, were used to record scientists' responses on 5-point Likert scales.

4.6.1. Science communication and its impact on scientists' career

To evaluate the impact of scientists' engagement in science communication with the general public (directly or through media) on their careers, they were asked to show their level of agreement/disagreement to the given four statements related to this topic on a 5-point scale (Q.32, Appendix-1). Results shown in Table 24 indicate that the mean scores for all the four statements are below the mid-point on the 5-point scale, showing an overall disagreement. A significant number of respondents chose to be neutral to all the four statements while the overall percentage of disagreement (Strongly Disagree and Disagree combined) is higher than the overall percentage of agreement (Strongly Agree and Agree combined). The highest percentage of respondents choosing to be neutral (~43%) is for the statement 'It would benefit in advancing my scientific career,' followed by 39% for the statement 'It would help me get research funding.' The highest percentage of respondents showing disagreement (75.67%) is for the statement 'It would negatively impact my scientific career.' The highest number of respondents showing agreement (27.41%) is for the statement 'My employer/institution does not give any importance to such activities for promotions, rewards, honours and recognition.'

Overall, most Indian scientists were unsure if their participation in science communication activities would help advance their scientific careers, but a large majority were sure that it did not negatively impact their careers. Most of them also believed that it does not help them get more research funding or recognition from their employers.

Table 24: Scientists' level of agreement with four statements related to their engagement in science communication and its impact on their career.

Statements		1	2	3	4	5	Total	Md	Mean	SD	Rank
It would benefit in advancing my scientific career.	F	22	60	111	51	15	259	3	2.91	1.00	1
	%	8.49	23.17	42.86	19.69	5.79	100				
It would negatively impact my scientific career.	F	81	115	58	3	2	259	2	1.96	0.81	4
	%	31.27	44.40	22.39	1.16	0.77	100				
My employer/institution does not give any importance to such activities for promotions, rewards, honours and recognition.	F	29	72	87	43	28	259	3	2.88	1.14	2
	%	11.20	27.80	33.59	16.60	10.81	100				
It would help me to get research funding.	F	39	79	101	34	6	259	3	2.57	0.97	3
	%	15.06	30.50	39.00	13.13	2.32	100				
* Scale: 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree											

The association of scientists' attitudes toward the impact of their public engagement on advancing their careers with demographic variables was either insignificant ($p > .05$) or significant with a small effect size, suggesting no meaningful differences. Chi-square tests for independence also indicated no meaningful associations with demographic variables.

4.6.2. Are scientists engaging with the public 'Publicists'?

To the question 'How do you agree/disagree with the statement that scientists who engage more in science communication are often labelled as 'Publicists' by the peers, which is not good for a scientist's career?' (Q.33, Appendix-1), their responses on a 5-point scale are shown in Table 25. The results indicate that most of the respondents (35.91%) were neutral to this statement, with slightly more respondents (n = 86, 33.20%) showed agreement as compared to 30.88% (n = 80) showing disagreement with the statement. The Median value (Md = 3) and the Mean score (M = 3, SD = 0.99) also suggest that the sample is neutral to this statement. This indicates that about 67% of the top Indian scientists do not think that scientists engaging in science communication are labelled as ‘publicists’ by their peers, which is not good for a scientist’s career.

Table 25: Indian scientists’ response to scientists who communicate being labelled as ‘Publicists’ by the peers.

Descriptor (Scale)	**Frequency**	**Percentage (%)**
Strongly Disagree (1)	17	6.56
Disagree (2)	63	24.32
Neutral (3)	93	35.91
Agree (4)	74	28.57
Strongly Agree (5)	12	4.63
Total	**259**	**100**

The demographic variables did not show any significant variation in scientists’ attitude toward scientists who communicate more being called publicists. However, in terms of percentages, relatively more female scientists (51.52%) than males (33.63%) were neutral to this statement, while relatively more male scientists than females agreed that scientists who communicate more with the public/media are called publicists and which is not good for a scientific career.

4.6.3. Is science communication important for career advancement?

Scientists were provided with three statements about science communication (Cronbach’s α = 0.809) and were asked whether these were important for scientists’ career advancement (Q.34, Appendix-1). Their responses to these statements were recorded on a 5-point scale of importance (1 = Not at all Important, 2 = Minimally important, 3 = Moderately important, 4 = Important, 5 = Very Important), and the results are shown in Table 26. The mean scores for these three statements indicate that scientists on an average believed that participating in science communication activities ($M = 3.04$, $SD = 1.09$), getting their research findings covered by news media (M = 2.99, SD = 1.22), and promoting their research findings on social media (M = 2.63, SD = 1.19) were only moderately importance as far as their career advancement is concerned (see Figure 37). Scientists' attitudes to all three statements were found to be strongly and positively correlated to each other (Pearson's r = .494 – .740, $p < .001$). There were no significant differences in these attitudes based on scientists' demographic variables.

Table 26: Scientists' perception about the importance of three given statements for their career advancement.

Statements		1	2	3	4	5	Total	Md	Mean	SD	Rank
Participation in science communication activities.	F	22	59	87	68	23	259	3	3.04	1.09	1
	%	8.49	22.78	33.59	26.25	8.88	100				
Getting your research findings covered by the news media.	F	35	61	62	73	28	259	3	2.99	1.22	2
	%	13.51	23.55	23.94	28.19	10.81	100				
Promoting your research findings on social media (such as Facebook, Twitter, LinkedIn or Youtube).	F	54	72	67	49	17	259	3	2.63	1.19	3
	%	20.85	27.80	25.87	18.92	6.56	100				
* Scale: 1 = Not at all Important, 2 = Minimally important, 3 = Moderately important, 4 = Important, 5 = Very Important											

4.7. Factors affecting scientists' active engagement in science communication

Twelve questions (Q.35-Q.46, Appendix-1) were used to address objective 3, "To identify the factors affecting scientists' active engagement in science communication with the general public and media." For the convenience of analysis, these questions were divided into two sections: 1) Factors affecting scientists' active engagement in science communication (08 questions), and 2) Training in science communication (04 questions).

Under this section, eight close-ended questions (Q.35-Q.42) were used to evaluate scientists' views to identify the factors affecting their active engagement in science communication with the general public and the media. These questions seek responses on how supportive are the institutions, academic colleagues/peers, and family and close friends to scientists engaging in science communication; how frequently their close academic colleagues participate in such activities; whether many of their institutional colleagues participate in such activities; whether their research is too complex for the public to understand; how willing they would be to participate in such activities in the next 12 months; potential factors preventing their active engagement; and how skilled they are in communicating through different media formats.

4.7.1. Do institutions encourage scientists to communicate science?

The respondents were asked how their institutions/employers supported (encouraged) scientists to communicate science with the general public and the media (Q.35, Appendix-1). Their responses were recorded on a 5-point scale (1= Not at all Supportive, 2 = Minimally Supportive, 3 = Moderately Supportive, 4 = Supportive, 5 = Very Supportive). The results shown in Table 27 indicate that the highest proportion of the respondents (37.07%) believed their institutions/employers were supportive to scientists communicating science with the general public and the media, with 6.95% (n = 18) saying Not at all Supportive, 20.46% (n = 53) Minimally Supportive, 25.10% (n = 65) Moderately Supportive, and 10.42% (n = 27) Very Supportive. The Median value of 3 and the Mean score (M = 3.24, SD = 1.10) suggest that the senior Indian scientists, on average, believed that their institutions/employers were moderately supportive to scientists who engaged in science communication. However, if responses for 'supportive' and 'very supportive' are merged, 47.49% of respondents viewed their employers as supportive.

Table 27: Scientists' perception about how supportive their institutions/employers were to scientists communicating science with the public/media.

Descriptor (Scale)	Frequency	Percentage (%)
Not at all Supportive (1)	18	6.95
Minimally Supportive (2)	53	20.46
Moderately Supportive (3)	65	25.10
Supportive (4)	96	37.07
Very Supportive (5)	27	10.42
Total	**259**	**100**

The association of scientists' views on their employers' support their was statistically insignificant found for Gender ($F (1, 257) = 0.001, p > .05$), Age ($F (3, 255) = 2.305, p > .05$), and Area of research ($F (8, 250) = 0.330, p > .05$). However, it was statistically significant for Type of affiliation ($F (7, 251) = 2.987, p < .01$), but with medium effect size (Eta-squared ($\eta 2$) = .077). Respondents from central R&D institutions and NGOs were relatively more positive ($M = 4$) and those from private companies and others were least positive ($M = 2.70$-2.75) about their employers being supportive. It was also statistically significant for Primary position ($F (5, 253) = 2.535, p < .05$) with small effect size (Eta-squared ($\eta 2$) = .048), directors of institutions and head of departments were relatively more inclined to say their employers were supportive than other positions. However, Chi-square tests for independence suggested statistically no significant differences in employers being supportive bases on demographic variables ($p > .05$).

4.7.2. Science communication by close colleagues

The respondents were asked to rate the frequency of their close academic colleagues' participation in science communication activities on a 4-point scale (1 = Often, 2 = Occasionally, 3 = Rarely, 4 = Never) (Q.36, Appendix-1), and the results are shown in Table 28. The results indicate that most of the respondents (59.85%, n = 155) believed that their close academic colleagues occasionally participated in science communication activities, with 15.83% (n = 41) saying Often, 24.32% (n = 63) Rarely, and 0.00% (n = 0) Never. The Median value of 3 (Occasionally) and the Mean score (M = 2.92, SD = 0.63) suggest that, on average, the respondents believed that their close academic colleagues occasionally participated in science communication activities.

Table 28: The frequency of participation in science communication activities by the respondents' close academic colleagues.

Descriptor (Scale)	Frequency	Percentage (%)
Never (1)	41	15.83
Rarely (2)	155	59.85
Occasionally (3)	63	24.32
Often (4)	0	0.00
Total	**259**	**100**

No significant association of scientists' views on the frequency of their close colleagues' participation in science communication activities was found for scientists' Gender ($F (1, 257) = 2.032$, $p > .05$), Age ($F (3, 255) = 0.729$, $p > .05$), Primary position ($F (5, 253) = 1.520$, $p > .05$), Type of affiliation ($F (7, 251) = 0.621$, $p > .05$) and Area of research ($F (8, 250) = 1.113$, $p > .05$). Simlarly, Chi-square tests for independence also suggested no significant differences in scientists' views on the frequency of their close colleagues' participation in science communication activities with the respondents' demographic variables ($p > .05$).

4.7.3. Are many colleagues active science communicators?

The respondents were asked if they agreed with the statement that many of their colleagues at their organisation/department took an active part in science communication activities (Q.37, Appendix-1). Their responses were recorded on a 5-point scale, and the results are shown in Table 29. The results indicate that the highest proportion of the respondents (36.29%, n = 94) chose to be neutral to this statement, with 4.25% (n = 11) strongly disagreed, 27.41% (n = 71) disagreed, 27.41% (n = 71) agreed, and 4.63% (n = 12) strongly agreed to the statement. The Median value of 3 (Neutral) and the Mean score (M = 3.01, SD = 0.95) suggest that, on average, the respondents were neutral to the statement that many of their colleagues at their organisation/department were taking an active part in science communication activities.

Table 29: The respondents' perception about their colleagues at their organisation or department taking active part in science communication activities.

Descriptor (Scale)	**Frequency**	**Percentage (%)**
Strongly Disagree (1)	11	4.25
Disagree (2)	71	27.41
Neutral (3)	94	36.29
Agree (4)	71	27.41
Strongly Agree (5)	12	4.63
Total	**259**	**100**

No significant association of scientists' views on whether their colleagues at their organisation or department were taking active part in science communication activities was found for scientists' Gender ($F (1, 257) = 0.487, p > .05$), Age ($F (3, 255) = 1.196, p > .05$), Type of affiliation ($F (7, 251) = 1.279, p > .05$) and Area of research ($F (8, 250) = 0.441, p > .05$). However, it was statistically significant for Primary position ($F (5, 253) = 2.644, p < .05$). But effect size being small (Eta-squared ($\eta 2$) = .050), there were no meaningful differences.

Chi-square tests for independence also suggest no significant differences in scientists' views on whether their colleagues at their organisation or department were taking active part in science communication activities with demographic variables ($p > .05$), except for Area of research ($\chi 2$ (32, N = 259) = 59.179, $p < .01$) with small effect size (Cramer's V = 0.239). With effect size being small, the variation was not large across different disciplines. A prominent distinction is that most respondents from Engineering and Technology (62.50%) were neutral, which constitutes the highest proportion across disciplines.

4.7.4. How supportive are colleagues, and family and close friends for science communication?

The respondents were asked about how supportive they thought their academic colleagues, and family and close friends ($r = .433$, $p < .001$) were to their participation in science communication activities (Q.38, Appendix-1). The results shown in Table 30 indicate that scientists believed that their academic colleagues were slightly above moderately supportive ($M = 3.16$, $SD = 0.95$), while their family and close friends were close to supportive ($M = 3.73$, $SD = 0.95$) for their participation in science communication activities. In terms of percentages, 37.45% of respondents said their academic colleagues were supportive/very supportive, while relatively more respondents (65.46%) said their family and close friends were supportive/very supportive. It suggests that respondents' family and close friends were more supportive than their academic colleagues to public engagement by scientists.

Table 30: Scientists' views on how supportive their academic colleagues and family/close friends are to their participation in science communication activities.

Variables		1	2	3	4	5	Total	Md	Mean	SD
Your academic colleagues/peers.	F	12	48	103	81	16	259	3	3.16	0.95
	%	4.63	18.53	39.38	31.27	6.18	100			
Your family and close friends.	F	5	23	63	115	53	259	4	3.73	0.95
	%	1.93	8.88	24.32	44.40	20.46	100			
* Scale: 1 = Not at all Supportive, 2 = Minimally Supportive, 3 = Moderately Supportive, 4 = Supportive, 5 = Very Supportive										

One-way ANOVA tests indicate that scientists' views on whether their academic colleagues and family/close friends were supportive in their public engagement activities were found to be either statistically insignificant or significant with small-medium effect sizes, suggesting no meaningful variations.

4.7.5. Is your research too complex for the public?

Scientists were asked whether they thought their research was too complex for the general public to understand (Q.38, Appendix-1), and their responses were recorded on a 5-point scale of agreement (Table 31). The results indicate that most of the respondents (44.79%, n = 116) disagreed with this statement, with 10.81% (n = 28) strongly disagreed, 20.46% (n = 53) were neutral, 18.53% (n = 48) agreed, and 5.41% (n = 14) strongly agreed with the statement. The Median value is 2 (disagree) and the Mean score is 2.63 with SD = 1.07. The lower mean score shows an overall disagreement with the statement that their research was too complex for the general public to understand. In terms of percentage, most respondents (55.60%) showed disagreement (Strongly Disagree/Disagree) with this statement.

Table 31: Scientists' views on whether they thought their research was too complex for the general public to understand.

Descriptor (Scale)	Frequency	Percentage (%)
Strongly Disagree (1)	28	10.81
Disagree (2)	116	44.79
Neutral (3)	53	20.46
Agree (4)	48	18.53
Strongly Agree (5)	14	5.41
Total	**259**	**100**

No significant association of scientists' views on whether they thought their research was too complex for the general public to understand was found for scientists' Age ($F (3, 255) = 2.186$, $p > .05$), Type of affiliation ($F (7, 251) = 0.677$, $p > .05$) and Primary position ($F (5, 253) = 1.532$, $p > .05$). However, it was statistically significant for Gender ($F (1, 257) = 6.247$, $p < .05$), but with small effect size Eta-squared ($\eta 2$) = .024). Female scientists were relatively less neutral than male scientists but showed stronger disagreement than males. Also, significant association was found for Area of research ($F(8, 250) = 7.330$, $p < .001$) with large effect size (Eta-squared ($\eta 2$) = .190), where mean score for Mathematical sciences was 3.92 (SD = 1.05) suggesting agreement, 3.00 (SD = 0.93) for Engineering and Technology suggesting neutral response, and < 3.00 for all other subjects suggesting overall disagreement.

Chi-square tests for independence also suggest no significant differences in scientists' views on whether they thought their research was too complex for the general public to understand with demographic variables ($p > .05$), except Gender ($\chi 2$ (4, N = 259) = 11.720, $p < .05$; Cramer's V = 0.213) and Area of research ($\chi 2$ (32, N = 259) = 82.010, $p < .001$; Cramer's V = 0.281).

4.7.6. Potential factors preventing active engagement

In an effort to access the potential factors preventing active participation by scientists in public engagement activities, the respondents were asked how they would like to agree/disagree with the given 11 points being potential factors (Cronbach's $\alpha = 0.833$) in this regard (Q.40, Appendix-1). These potential factors were identified based on extant literature. Responses were recorded on a 5-point scale (Strongly Disagree, Disagree, Neutral, Agree, Strongly Agree). Results shown in Table 32 indicate that the mean scores for all the 11 statements are below the mid-point on the 5-point scale showing an overall negative response. That is, the respondents showed an overall disagreement that the given 11 statements (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 my duty) were potential factors in their active engagement in science communication activities. Among these, however, mean values for lack of time and lack of funding are close to 3.00 (neutral). About 16-37% of respondents chose to be neutral to all these statements being a potential factor in their active engagement. About 41% believed that lack of time, 31% believed lack of funding, 27.42% believed difficulty in constructing messages relevant for the public, and 25.09% believed deviation from research were potential factors in their active engagement. For the remaining statements, only about 5-17% believed that these were a potential factor. Therefore, the majority of the Indian scientists did not see the given 11 statements as potential factors preventing their active participation in science communication.

Table 32: Scientists' perception about the given 11 points being a potential factor preventing their active engagement in science communication activities.

Statements		1	2	3	4	5	Total	Md	Mean	SD	Rank#
Lack of time.	F	23	76	55	91	14	259	3	2.99	1.10	1
	%	8.88	29.34	21.24	35.14	5.41	100				
No interest in such activities.	F	58	129	58	14	0	259	2	2.11	0.81	10
	%	22.39	49.81	22.39	5.41	0.00	100				
Lack of communication skills.	F	71	124	42	18	4	259	2	2.07	0.92	11
	%	27.41	47.88	16.22	6.95	1.54	100				
No incentives/rewards and recognition.	F	44	89	81	34	11	259	2	2.53	1.05	6
	%	16.99	34.36	31.27	13.13	4.25	100				
Deviation from research.	F	38	89	67	48	17	259	3	2.68	1.13	3
	%	13.67	34.36	25.87	18.53	6.56	100				
Difficulty in constructing messages relevant for the public.	F	35	92	61	65	6	259	3	2.67	1.06	4
	%	13.51	35.52	23.55	25.10	2.32	100				
No personal benefits.	F	51	98	78	24	8	259	2	2.38	1.00	8
	%	19.69	37.84	30.12	9.27	3.09	100				
Lack of institutional support/encouragement.	F	30	91	95	30	13	259	3	2.63	1.00	5
	%	11.58	35.14	36.68	11.58	5.02	100				
Lack of funding.	F	28	78	72	58	23	259	3	2.88	1.14	2
	%	10.81	30.12	27.80	22.39	8.88	100				
Lack of comfort in such activities.	F	42	100	87	26	4	259	2	2.42	0.93	7
	%	16.22	38.61	33.59	10.04	1.54	100				
Science communication is not part of my duty.	F	61	98	62	32	6	259	2	2.32	1.04	9
	%	23.55	37.84	23.94	12.36	2.32	100				

* Scale: 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree.
# Rank based on mean scores.

One-way ANOVA tests suggested the demographic variables dis not cause any meaningful variations in the respondents' attitude toward all the given factors preventing their active engagement. Chi-square tests for independence also suggested that no meaningful differences in this regard.

4.7.7. Skilfulness in communicating science through different media

The respondents' skill in communicating science was examined by using five items (Cronbach's $\alpha = 0.824$) where they were asked how skilled they thought they were in communicating science with non-specialist audiences through the given five media formats (Q.41, Appendix-1). Their responses were recorded on a 5-point scale (Very Unskilled, Quite Unskilled, Neutral, Quite Skilled, Very Skilled). Results shown in Table 33 indicate that the mean scores for all the five media formats are above the mid-point on the 5-point scale, showing an overall perception that the respondents felt they were quite skilled to use these media formats to communicate science with the public.

By combining the percentages of responses for '4' and '5' scale levels as 'Skilled,' it is found that the majority of respondents were skilled in communicating science through face-to-face interactions (~83%), print media/press (~68%), and online media formats (~53%), while many of them were skilled to communicate through TV/Videos (~43%), and radio (~40%). A significant percentage of respondents chose to be neutral about their skill in communicating through radio (39%), TV/Videos (~35%), online (~33%), and print media/press (~25%). That is, the majority of respondents expressed either they were unskilled or neutral about their skill in using electronic media (TV and Radio) for science communication. It suggests that Indian scientists are more skilled in communicating science through direct interactions, print media and online media than through electronic media. Also, the respondents' perception of being skilled in all the five media formats were found to be significantly and positively correlated to each other (Pearson's r = .398 - .794, p < .001).

Table 33: Scientists' views on how skilled they were in communicating science through media formats.

Statements		1	2	3	4	5	Total	Md	Mean	SD	Rank#
Face-to-face	F	5	7	33	161	53	259	4	3.97	0.78	1
	%	1.93	2.70	12.74	62.16	20.46	100				
Online	F	9	26	86	119	19	259	4	3.44	0.90	3
	%	3.47	10.04	33.20	45.95	7.34	100				
TV/Videos	F	12	44	92	91	20	259	3	3.24	0.98	4
	%	4.63	16.99	35.52	35.14	7.72	100				
Radio	F	12	41	101	89	16	259	3	3.22	0.94	5
	%	4.63	15.83	39.00	34.36	6.18	100				
Print Media/Press	F	5	15	64	132	43	259	4	3.75	0.87	2
	%	1.93	5.79	24.71	50.97	16.60	100				

* Scale: 1 = Very Unskilled, 2 = Quite Unskilled, 3 = Neutral, 4 = Quite Skilled, 5 = Very Skilled.
# Rank based on mean scores.

One-way ANOVA tests suggested that the respondents' attitudes toward their skill in communicating science through different media formats were largely independent of their demographic variables. Chi-square tests for independence also suggested that no meaningful differences. However, respondents holding top positions felt slightly more skilled than professors and scientists.

4.7.8. Willingness to participate in science communication activities in future

Scientists' willingness to participate in science communication activities in the next 12 months was measured on a 5-point scale of willingness (Very Unwilling, Quite Unwilling, Neutral, Quite Willing, Very Willing), and the results are shown in Table 34. The results indicate that most of the respondents (51.74%, n = 134) were quite willing to participate, with 21.24% (n = 55) very willing, 18.15% (n = 47) neutral, 8.11% (n = 21) quite unwilling, and 0.77% (n = 2) very unwilling. The Median value of 4 and the Mean score (M = 3.85, SD = 0.87) suggest an overall willingness of the respondents to participate in science communication activities in the next 12 months. In terms of percentage, 72.98% of respondents showed willingness (Quite Willing/Very Willing) to participate.

Table 34: Respondents' perception about their willingness to participate in science communication activities in the next 12 months.

Descriptor (Scale)	**Frequency**	**Percentage (%)**
Very Unwilling (1)	2	0.77
Quite Unwilling (2)	21	8.11
Neutral (3)	47	18.15
Quite Willing (4)	134	51.74
Very Willing (5)	55	21.24
Total	**259**	**100**

A series of one-way ANOVA tests for investigating any between groups variations in scientists' willingness to engage with the public in the future suggests no significant impact of demographic variables ($p > .05$). Chi-square tests for independence also showed no significant association of scientists' willingness to participate in science communication in the future with respondents' demographic variables ($p > .05$).

A regression analysis was performed to understand how much variation these factors affecting science communication by scientists explain the overall frequency of scientists' involvement in science communication activities and their willingness to engage in such activities in the next 12 months (Table 35). The regression models suggest that these factors explained about 15% variation in scientists' overall frequency of science communication activities. However, in the case of their willingness to engage in the future, these factors explained about 34% variation, which is more than double the variation (15%) explained for the overall frequency. That is, these factors have a predictive value in explaining scientists' willingness to engage in the future. Therefore, it is evident that if these factors are addressed, more scientists are willing to engage in science communication activities in the future.

Table 35: Results of regression models predicting scientists' overall frequency of science communication activities and their willingness to participate in such activities in the next 12 months.

Dependent Variables	**Frequency of scientists' overall engagement in SciCom activities** *(Mean=3.27 SD=0.68)*	**Scientists' willingness to engage in the next 12 months** *(Mean=3.85 SD=0.87)*
How Supportive is Employer	0.017	-0.064
Frequency of Close Colleagues	0.117	0.061
Many Colleagues Active in SciCom	-0.011	0.073
How Supportive are academic colleagues	-0.127	0.015
How Supportive are Family/Friends	-0.098	0.214***
My Research too complex for Public	0.038	-0.081
Lack of time	0.088	-0.111
No personal interest	-0.029	-0.140*
Lack of Com. Skills	0.087	-0.017
No incentives/recognition	-0.119	0.067
Deviation from research	0.138	-0.084
Difficulty Constructing Messages	0.035	0.049
No personal benefits	-0.138	-0.153*
Lack of inst. Support	-0.080	0.029
Lack of funding	0.128	0.074
Lack of Comfort	-0.068	0.106
SciCom not my duty	0.197**	-0.027
How Skilled: Face-to-face	-0.086	0.108
How Skilled: Online	0.085	0.076
How Skilled: TV/Videos	0.028	-0.070
How Skilled: Radio	-0.158	0.076
How Skilled: Print	-0.008	0.095
Enough training to engage	-0.016	0.138*
Training in SciCom help better PE	-0.034	-0.129*
R^2 *(%)*	**22.7**	**40.5**
Adjusted R^2 *(%)*	**14.8**	**34.4**
ANOVA	$F^{24,234}$, 2.868***	$F^{24,234}$, 6.625***

Note. *p <0.05; **p <0.01; **p < 0.001. Cell entries are standardised regression coefficients (*β*).

4.8. Training in Science Communication

Training in science communication can be a potential factor affecting scientist's active engagement with the public/media. The next four questions were used to seek respondents' views on training in science communication. These include how they were ever trained in science communication, whether they had enough training for public engagement, whether attending training/workshops on science communication/media skills would help improve their pubic engagement, and whether they were willing to attend any such training/workshops.

4.8.1. Ever trained in science communication?

The respondents were asked whether they have ever been trained in science communication with the general public/media (Q.43, Appendix-1). They were given a list of seven options to choose one that best described their position. The results shown in Table 36 indicate that most of the respondents (47.49%, n = 123) chose that they were self-taught for communicating science to the public/media, with 37.84% (n = 98) saying that they learned it by experience through their careers. Only 0.77% (n = 2) respondents chose 'My institution trained me', 1.54% (n = 4) chose 'My PhD guide trained me', and 1.16% (n = 3) chose 'Attended short term training/workshop'. No respondent said they studied a degree/diploma course in science communication, while 11.20% (n = 29) said they had no knowledge of this area. The Median value is 6 (Self-taught). The results suggest that none of the respondents has undergone any degree/diploma training in science communication, with only 3 of them having attended some short-term training/workshop and minimal involvement of their institutions or PhD guides in scientists' capacity building in this area. By combining the responses for options '3' and '6,' it is found that 85.33% of the respondents learned communicating science to the public/media on their own.

Demographic controls did not show any meaningful differences in scientists' perception about how they were trained in science communication, as revealed by series of one-way ANOVA tests and Chi-square tests for independence.

Table 36: Respondents' perception about how they were trained in science communication.

Options	Frequency	Percentage (%)
Studied a degree/diploma course (1)	0	0.00
Attended short term training/workshop (2)	3	1.16
Learned by experience through my career (3)	98	37.84
My institution trained me (4)	2	0.77
My PhD guide trained me (5)	4	1.54
Self-taught (6)	123	47.49
I have no knowledge of this area (7)	29	11.20
Total	**259**	**100**

4.8.2. Have enough training to engage with the public/media?

The respondents were asked how they agreed/disagreed with the statement that they had enough training to engage with the public/media (Q.44, Appendix-1). Their responses were recorded on a 5-point scale, and the results are shown in Table 37. The results indicate that most of the respondents (38.22%, n = 99) agreed, with 8.88% (n = 23) strongly agreed, 32.05% (n = 83) remained neutral, 15.83% (n = 41) disagreed, and 5.02% (n = 13) strongly disagreed with the statement. The overall disagreement is 20.85% and the overall agreement is 47.10%. The mean score (M = 3.30, SD = 1.00) shows a slight overall agreement with the statement that they had enough training to engage with the public/media. However, if disagreement and neutral responses are combined, the majority of respondents (52.90%) did not believe that they have enough training in science communication.

Table 37: Respondents' perception about whether they had enough training in science communication.

Descriptor (Scale)	Frequency	Percentage (%)
Strongly Disagree (1)	13	5.02
Disagree (2)	41	15.83
Neutral (3)	83	32.05
Agree (4)	99	38.22
Strongly Agree (5)	23	8.88
Total	**259**	**100**

A series of one-way ANOVA tests for investigating any between groups variations indicate no significant impact of demographic variables on whether scientists had enough training in science communication ($p > .05$). Chi-square tests for independence also showed no significant association of whether scientists had enough training in science communication with respondents' demographic variables ($p > .05$).

4.8.3. Would science communication training help in better public engagement?

The respondents were asked whether they thought attending training/workshops on science communication/media skills would further help them improve public engagement (Q.45, Appendix-1). Their responses were recorded on a 4-point scale, and the results are shown in Table 38. The results indicate that most of the respondents (44.40%, n = 115) said 'May be,' with 23.94% (n = 62) said 'Yes,' 22.01% (n = 57) said 'No,' 9.25% (n = 25) said 'Don't know.' The Median value is 3 (May be) and the mean score is 2.83 with SD = 0.90. If the responses for 'Yes' and 'May be' are combined, 68.34% of the respondents believed that attending training/workshops would help in improving their public engagement.

Table 38: Respondents' perception about whether attending science communication training/workshops would improve their public engagement.

Options	**Frequency**	**Percentage (%)**
Yes (4)	62	23.94
May be (3)	115	44.40
No (2)	57	22.01
Don't know (1)	25	9.65
Total	**259**	**100**

Gender, Type of affiliation, and Primary position did not have any statistically significant association with scientists' perception about whether science communication training/workshops would improve their PE ($p > .05$). Age group had a significant impact (F

(3, 255) = 3.062, $p < .05$), but with small effect size (Eta-squared ($\eta 2$) = .035). Area of research also had a significant association (F (8, 250) = 2.445, $p < .05$) with medium effect size (Eta-squared ($\eta 2$) = .073), where respondents from Medical Sciences were relatively more positive (M = 3.40, SD = 0.754) than all other subjects. Similarly, Chi-square tests for independence also showed no significant association of whether science communication training/workshops would improve scientists' public engagement across respondents' demographic variables ($p > .05$), except for Area of Research ($\chi 2$ (24, N = 259) = 45.822, $p < .01$; Cramer's V = 0.243), where relatively more respondents from Engineering and Technology said 'No.'

4.8.4. Willing to attend science communication/media training?

The respondents were asked how willing they were to attend science communication/media training (Q.46, Appendix-1). Their responses were recorded on a 5-point scale, and the results are shown in Table 39. The results indicate that most of the respondents (45.95%, n = 119) were neutral to attending training, with 8.88% (n = 23) very unwilling, 16.99% (n = 44) quite unwilling, 22.39% (n = 58) quite willing, and 5.79% (n = 15) very willing. The Median value is 3 (Neutral) and the mean score is 2.99 with SD = 0.99. The median and mean values suggest that the respondents were neutral, *i.e.*, neither willing nor unwilling to attend science communication/media training.

Table 39: Respondents' perception about their willingness to attend science communication/media training.

Descriptor (Scale)	Frequency	Percentage (%)
Very Unwilling (1)	23	8.88
Quite Unwilling (2)	44	16.99
Neutral (3)	119	45.95
Quite Willing (4)	58	22.39
Very Willing (5)	15	5.79
Total	**259**	**100**

Gender, Age, Type of affiliation, and Primary position did not have any statistically significant impact on scientists' willingness to attend science communication or media training ($p > .05$). Area of research also had a significant association (F (8, 250) = 3.24, $p < .01$) with medium effect size Eta-squared ($\eta 2$) = .094), where respondents from Biological Sciences, Computer and IT, and Medical Sciences were slightly more willing to attend training/workshops ($M > 3.40$) than all other subjects.

Chi-square tests for independence also suggested no significant association of scientists' willingness to attend science communication or media training across respondents' demographic variables ($p > .05$), except for Area of research ($\chi 2$ (32, N = 259) = 52.248, $p < .05$) with small effect size (Cramer's V = 0.225).

4.9. Interventions for enhancing science communication by Indian scientists

This section addresses the current study's Objective 4, "To determine the needed interventions for enhancing science communication by Indian scientists in the near future" by evaluating scientists' responses (recommendations) to the given ten possible interventions for enhancing science communication, and by seeking open-ended responses (optional) for enhancing science communication.

4.9.1. Potential interventions for enhancing scientists' engagement

The respondents were given a list of ten possible interventions (Cronbach's α = 0.868) and were asked whether they would like to recommend these for enhancing Indian scientists' engagement in science communication (SciCom) with the public/media (Q.47, Appendix-1). Their responses were recorded on a 5-point scale of recommendation (1 = Strongly

Not Recommended, 2 = Not Recommended, 3 = Neutral, 4 = Recommended, 5 = Strongly Recommended), and the results are shown in Table 40. The results indicate that the mean scores for eight interventions were above the mid-point on the 5-point scale, showing an overall recommendation for these interventions but for the two remaining interventions (making SciCom mandatory and considering SciCom activities for assessment/promotions), the mean scores were slightly below the mid-point but close to neutral. By clubbing the percentages of responses for 'recommended' and 'strongly recommended' as recommended, the vast majority of scientists recommended: 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%), and Training scientists in communication and media skills (72.97%). The majority of them also recommended: 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%), and Offering rewards/incentives to scientists (50.58%). However, only a minority but still a significant number of the respondents recommended: 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%). These results indicate that most scientists recommended the given interventions (except making it mandatory and considering it for assessment/promotions) to enhance Indian scientists' public engagement. All the recommendations were found to be significantly and positively correlated to each other (Pearson's $r = .154 - .715$, $p < .05$).

Table 40: Respondents' recommendations for interventions to enhance Indian scientists' public engagement.

Interventions		1	2	3	4	5	Total	Md	Mean	SD	Rank
Offering rewards/ incentives to scientists.	F	19	36	73	108	23	259	4	3.31	1.05	8
	%	7.34	13.90	28.19	41.70	8.88	100				
Training scientists in communication and media skills.	F	3	9	58	146	43	259	4	3.84	0.78	4
	%	1.16	3.47	22.39	56.37	16.60	100				
Ensuring institutional support/encouragement for such activities.	F	0	1	23	165	70	259	4	4.17	0.59	1
	%	0.00	0.39	8.88	63.71	27.03	100				
Providing financial support for such activities.	F	4	13	45	148	49	259	4	3.87	0.83	3
	%	1.54	5.02	17.37	57.14	18.92	100				
Every S&T institution should appoint science communication specialists who are experts in engaging with the public and the media.	F	7	10	37	128	77	259	4	4.00	0.92	2
	%	2.70	3.86	14.29	49.42	29.73	100				
Making it mandatory for scientists to communicate with the public.	F	29	59	89	59	23	259	3	2.95	1.12	10
	%	11.20	22.78	34.36	22.78	8.88	100				
Considering science communication activities in the annual assessment and promotions of scientists.	F	40	51	70	75	23	259	3	2.96	1.21	9
	%	15.44	19.69	27.03	28.96	8.88	100				
Guidelines for scientists on how to communicate with the public.	F	10	16	63	136	34	259	4	3.65	0.92	6
	%	3.86	6.18	24.32	52.51	13.13	100				
Appropriate policy for science communication by scientists.	F	7	14	70	132	36	259	4	3.68	0.88	5
	%	2.70	5.41	27.03	50.97	13.90	100				
Integrating science communication training as a mandatory part of science education at college and university level.	F	19	27	51	121	41	259	4	3.53	1.10	7
	%	7.34	10.42	19.69	46.72	15.83	100				
* Scale: 1 = Strongly Not Recommended, 2 = Not Recommended, 3 = Neutral, 4 = Recommended, 5 = Strongly Recommended											

Results of one-way ANOVA tests suggested that the given ten recommendations for enhancing scientists' involvement in science communication did not show much variations across demographic variables. However, there were some exceptions. For example, male scientists were slightly more positive (M = 3.38, SD = 1.036) than females (M = 2.82, SD =

1.074) in recommending 'Offering rewards/incentives to scientists'. In terms of primary position, respondents at top positions such as directors/heads of institutions were relatively more likely to recommend 'Every S&T institution should appoint science communication specialists who are experts in engaging with the public and the media.'

Chi-square tests for independence also suggested that scientists' recommendations for the given ten potential interventions for enhancing scientists' participation in science communication activities were largely independent on the demographic controls, as the tests were either statistically insignificant ($p > .05$) or significant with small effect suggesting no meaningful differences.

A correlation analysis suggests that five out of the given ten interventions were correlated with scientists' overall frequency of participation in science communication activities. Also, all of these were relatively more correlated with the respondents' likelihood of engaging in science communication activities in the future (Table 41). Also, results from regression analyses with the given ten interventions as independent variables suggest that the regression models explained about 13% variance in scientists' overall participation and about 20% variance in their likelihood to participate in the future, as evident from the adjusted R^2 values (Table 42). Therefore, it is indicated that if these interventions are made available, then scientists are more likely to engage in public communication of science activities.

Table 41: Correlation of the recommended interventions with scientists' frequency of participation in PE activities and their likelihood to engage in the future.

Variable	Scientists' frequency of PE activities	Scientists' likelihood to engage in PE in future
Offering incentives to scientists	0.245 ***	0.242 ***
Training scientists in SciCom	0.105	0.261 ***
Ensuring institutional support	0.076	0.219 ***
Providing financial support	0.043	0.141 *
S&T inst. appoint SciCom specialists	0.008	0.222 ***
Making PE mandatory for scientists	0.240 ***	0.404 ***
Considering SciCom in APAR/promotions	0.343 ***	0.427 ***
Guidelines for scientists on PE	0.158 *	0.321 ***
Appropriate policy for SciCom by scientists	0.172 **	0.304 ***
Mandatory SciCom education at UG/PG level	0.267 ***	0.351 ***

* $p < .05$, ** $p < .01$, *** $p < .001$

Table 42: Regression analyses for predicting the impact of the given interventions on scientists' frequency of PE activities and their likelihood to engage in PE in the future.

Variable	Scientists' frequency of PE activities	Scientists' likelihood to engage in PE in future
Offering incentives to scientists	0.179 **	0.078
Training scientists in SciCom	-0.052	0.006
Ensuring institutional support	-0.050	0.003
Providing financial support	-0.069	-0.056
S&T inst. appoint SciCom specialists	-0.050	0.110
Making PE mandatory for scientists	-0.052	0.126
Considering SciCom in APAR/promotions	0.310 ***	0.258 **
Guidelines for scientists on PE	-0.039	0.045
Appropriate policy for SciCom by scientists	0.043	0.035
Mandatory SciCom education at UG/PG level	0.127	0.015
R^2 (%)	16%	22.9%
Adjusted R^2 (%)	12.6%	19.8%
ANOVA	$F^{10, 248}$, 4.727***	$F^{10,248}$, 7.359***

Note. *p <0.05; **p <0.01; **p < 0.001. Cell entries are standardized regression coefficients (β).

4.9.2. Responses to the open-ended question

In the survey's last question (Optional), the respondents were asked if they would like to say anything else about enhancing science communication by scientists in India (Q.48, Appendix-1). In the following text, the relevant comments are presented and analysed.

In response to this optional open-ended question, a total of 117 text comments were received. Out of these, 44 comments were not about any recommendations for enhancing science communication by scientists but were general comments such 'none,' 'nothing,' 'no,' or about the survey questionnaire and its topic in general, and comments on topics that were already covered in the survey. Many of the remaining 73 comments were largely related to the interventions that are already covered in Q.47, such as making science communication mandatory, institutional encouragement, incentives and recognition to scientists for their science communication activities, training in science communication and media skills, making it integral part of research, providing more funding, framing appropriate policies, appointing science communication specialists or establishing science communication departments at each institution.

Several scientists appeared to be aware of the state of affairs in science communication in India. They highlighted the importance of science communication in their own different ways. For example, one respondent who 'strongly recommended' all the interventions covered in Q.47 said,

> Very poor efforts. There is no effort to promote science at all![1]

This observation possibly appears an exasperation that no effort is being taken to promote science at all. Maybe the respondent wanted to emphasise the need for doing more in this direction. Some other respondents said,

> It is absolutely important to enhance science communication by scientists.[2]

> We need to encourage science communication by different means.[3]

> Science communication to school children should become an essential activity.[4]

> The research carried out by scientists should be owned by all the stakeholders, including the general public.[5]

> Scientists should communicate on scientific issues of national importance.[6]

> Only to add that it [science communication] is extremely important and desired at all levels.[7]

> This [science communication] must be emphasised as a duty and means of promoting science and support for science in India.[8]

> Scientists owe a responsibility towards society. Therefore, scientists should work on 'problems relevant to the society' and not [on] subjects just to satisfy their curiosity. Therefore, regular communication by scientists is all the more important.[9]

> Science communication must be arranged at every teaching institution at all levels and at very frequent intervals. The students should also be taken around labs at all levels and at frequent intervals.[10]

> Science communications must be made mandatory.[11]

> Science communication with the public is important, everybody should realise [this].[12]

> Public outreach should become an integral part of scientific research. … Scientific communication plays an important role in taking the benefits of science to the common man.[13]

One respondent gave an interesting idea on how to further improve the situation of science communication in the country:

> Need to form small but effective scientific groups to deliberate on issues related to this important subject [science communication] and make necessary recommendations.[14]

An important recommendation that emerged was the need to communicate science in the local language and enhance scientists' ability to communicate science in simple language and in their mother tongue. This has been a perennial demand as science is largely being done and communicated in the English language and the larger population who are not comfortable with English remained left out of the discourses on science. Several scientists, recognising the importance of communicating science in local languages, expressed their views as follows:

> Unless we begin communicating in people's own language (Indian languages), no benefit is going to come out of such [efforts]. Our academies have failed miserably in communicating about science and scientific developments for encouraging common people to interact with scientists. In Japan, China, Korea, the USA, European Union countries, Russia, etc., the language used by scientists and common people is the same. The benefits are apparent in terms of the number of patents, discoveries, etc. coming out of these countries.[15]

> [The] importance of native language[s] [in communicating science to the public] cannot be underestimated.[16]

> Volunteering by experts [to communicate science] in the local language.[17]

> Science communication in local languages is vital, [but] it is not easy at all.[18]

> The medium of science communication should be Indian languages.[19]

> One should be able to communicate in regional languages when necessary.[20]

Some respondents emphasised the factors already covered in the survey, such as difficulty in framing science communication messages for the public with different levels of awareness/literacy. One scientist, associated with a hospital who agreed that there is difficulty in crafting appropriate messages for public consumption (Q.40f), said,

> There are different levels of education/awareness among [the] Indian public. There are difficulties in answering some of the questions due to this variability.[21]

A senior female scientist heading a department at a central R&D institute, who agreed that lack of time is a potential factor preventing scientists' active engagement (Q.40a), said,

> Time is a limitation for most researchers, hence, science communication lags. If institutional support and infrastructure can be improved, then a researcher can find more time to get involved in science communication [activities].[22]

A senior professor associated with an NGO said,

> The greatest barriers to science communication by scientists in India are: 1) Language, 2) Great gap in knowledge with public, and 3) Unwillingness to learn.[23]

Communicating science should require local examples to establish a better connection with the target population. This suggestion is highlighted by a senior professor working with a central R&D institute in the following way:

> Science communication must compulsorily have examples from day to day matters and must be communicated in a simple understanding way using as many common examples as possible and must avoid complicated exprssions.[24]

A relatively younger female scientist working at a central R&D institute flagged a critical issue that is always in debates on science communication by scientists:

> Most of the scientific institutions in India do not allow [scientists] speaking to [the] media or disseminating research output without prior permission. In most cases, only the head of [the] institution speaks to the media.[25]

On the contrary, a senior scientist from the field of Medical Sciences heading a research centre (NGO), who did not recommend making science communication mandatory for scientists, had a different opinion:

> Individual scientists must be discouraged from rushing to the press. This job should be left to their institutional heads.[26]

Scientists being not allowed to speak to the media or needing permission before talking to the media/press is a topic of debate and concern. Many scientists and science communication scholars would believe this as a discouragement for scientists' public communication efforts, especially if there were no professional benefits associated with such activities. In such situations, many scientists would quickly execute themselves from the hassle of getting necessary permission from competent authorities before talking to journalists. When scientists are expected to communicate science to the public directly or via the media, such policies generally prevent them from talking even about basic science. The best thing can be that directors and heads of institutions should talk to the media on policy matters, but scientists should also get an encouraging institutional environment where they can freely share their knowledge with the press/media for the benefit of the larger society or taxpayers. At least, they should be allowed to discuss the basic research and their published work.

A senior male scientist (aged >55 years) with research experience of more than 30 years, who is heading a central R&D institute, said that public trust in scientists is low, and efforts should be made to find ways to increase public trust in science and scientists.[27] Earlier in the survey, he has also given importance to 'increasing public trust in science' as an objective of science communication.

A senior scientist working at a central R&D institute remembers the earlier science popularisation efforts through TV programmes such as Surabhi, Prof. Yash Pal's Turning Point on Doordarshan, and emphasised "We must encourage such programmes on popular TV channels."[28] A senior physicist heading a central R&D lab also has a similar view for having more science content in popular media:

> TV should have regular programmes on science activities in the country and across the world. Newspapers should have a page on science once a week.[29]

A biological scientist heading a department at a central university also regrets poor coverage of science in the media and gives concession that science having a direct impact on society should be reported through the media:

> Any research that has an impact on society should at least be brought to their knowledge. Indian research rarely gets listed in our media.[30]

Maybe seeing poor coverage of science in the media and its misreporting, some respondents suggested that scientists should do the communication instead of journalists. For example, a senior professor at a central R&D institute said that instead of media, scientists should do the communication:

> Science communication should be carried out by competent scientists and not [by] journalists who do not have in-depth knowledge of subjects. Popularisation by such media persons is prone to misguide the general public.[31]

A senior physicist heading a department at a central R&D lab voices a similar concern:

> Science communication is an art. It will flourish only if outstanding scientists are brought into this area and not just average scientists who are willing to do it just for short-term gains.[32]

Several respondents believed that giving due recognition to science communication by scientists and its consideration in their career advancement coupled with institutional support and encouragement would lead to more scientists becoming active in public engagement. For example, a senior scientist from the field of earth and planetary sciences, heading a central R&D institution, said:

> Recognition at the individual level, and institutional support are important [for encouraging scientists to engage with the public].[33]

Another director of a central research lab hailing from the earth and planetary sciences further added:

> Once it [science communication] is given importance and due recognition in career development, things will start falling in place. Since most of the research in India is public-funded, the accountability, at least in the long run, should be there for the scientific community. The policy of recognising only [the] peer-reviewed papers that too only [in] the globally reputed journals and evaluating the performance of a scientist through Impact Factor alone is detrimental to the development of scientific temper.[34]

A relatively younger professor in biological sciences at a central laboratory with a research experience of more than 30 years, while suggesting for giving due incentives and recognition, said:

> Some scientists are good communicators (and teachers), others are not. So there is no point [in] having one size fits all policies. But, overall, good science communication by scientists should be incentivised and recognised, as should good teaching. Right now, we do neither.[35]

A senior Fellow from biological sciences heading a private hospital said:

> Authorities will have to encourage scientists/professors/teachers to communicate with [the] common man and also reward them accordingly.[36]

A senior professor in physical sciences at a central university recommended that retired scientists should be encouraged financially for science communication:

> The retired scientists should be encouraged through financial incentive[s] for science communication.[37]

Several respondents recommended that scientists should focus on research. As many scientists are not good at communication, so they recommended that science communication specialists or departments at R&D institutions should take care of public communication efforts.

> All institutions should have a dedicated communication cell that will act as a bridge between the professionals and the public.[38]

> Doing more science, better science is more important than communicating science to the general public. Good science, when it is published in peer-reviewed journals, will automatically receive attention from [the] knowledgeable public. This is my personal opinion.[39]

> All centrally funded Institutions must have at least a couple of faculty members in the Humanities/Management/HR Department with specialisation/PhD degree in Science Communication; [the] same should be true for all R&D Labs, PSUs, and

private industries. They must liaise with other faculty members/scientists/engineers of the organisation.[40]

More than communicating one's own research to [the] general public, we should concentrate on institutional mandates, achievements, alleviation of misgivings, misinformation about science-related public policy, etc.[41]

Politician[s] or other bureaucratic bindings are [the] main hurdle for my own science, but not the public/taxpayer. My goal is to do good science, not spending dedicated time for public outreach. Going to public, school, college to discuss about my work is also my hobby, but spending time for research work is more important than this hobby. A good work (good publication) is always propagated through [the] media and other source[s]. Spending more money and time for scientific work is better than spending for outreach/propaganda.[42]

I think many institutes are deviating from their research goals and putting too much emphasis on outreach activities. The so-called scientists engaged in outreach activities have nothing to present as they have left research long back. They work like postmasters. So the end result is that there is neither research nor a good outreach activity.[43]

More important to engage in intense research and let good communicators do the communication. Give them adequate credit for this.[44]

Science communication is not the job of a scientist. Scientists are not in general good at communications. Science communication is best left to specialists so that scientists can focus on their research. Some scientists also have excellent communication skills [who] would naturally communicate science – not necessarily *their* research – to the public. While it is important for the general public to be aware of advancements in science for a knowledge society to evolve, this is NOT the task of scientists.[45]

Just like scientists use taxpayer money, so does the military. But you don't ask the military to come and explain themselves to the public at large. So let scientists do their job in a focused manner, rather than pushing social responsibilities on their shoulders.[46]

There is a strong need for having professional science communicators who understand science and can explain it in simpler ways for [the] lay public. The tendency to 'sensationalise' and overstate must be avoided since that can have a negative impact on [the] public. Most scientists are not good at communicating their discoveries, especially in basic sciences, in simple terms to [the] general public. It is here that competent science communicators have to play an important role.[47]

As scientists are involved with [the] development and continuing scientific work, an extension department may be set [up] … to communicate the development to the public.[48]

On the other hand, several other respondents expressed that scientists should communicate more actively and even recommend a certain number of events/lectures, etc. that scientists should mandatorily do every year.

> The accomplishments of scientists must be communicated to [the] general public to muster support for basic research in India. Often science communication activities are looked at as [a] 'waste of time' by [m]any scientists, and they are uncomfortable to speak about their science to non-scientists. Such scientists should be trained and "forced" to complete at least 6 science communication activities in a year.[49]

> Organisations should encourage, but not compel [scientists to communicate with the public], since, for some, it is not their cup of tea.[50]

> Every working and retired scientist should deliver 5 lectures per year in schools/ colleges/public places on a subject of his/her expertise.[51]

> It should be voluntary activity but can be enhanced with appropriate education.[52]

> Scientists should be encouraged to communicate with [the] general public about their research. However, this should be totally their own decision. When they are at the peak of their career, they may not be able to spare time. But, when they are retired and have more time to spare, they can [spend] enough time on science communication. Scientists should be encouraged to communicate with [the] public, but it should never be mandatory.[53]

> It is a voluntary service by scientists to communicate with the masses about topics which are ailing the society, *e.g.*, disposal of plastic waste, taking care of rivers and other water bodies, etc. There is no need to present intricate problems to [the] masses who may [otherwise] lose interest soon.[54]

> [From] time to time, science camps can be organised in rural areas. Interested scientists can give at least two lectures in a year; one at a local school and another at schools in rural areas.[55]

Several scientists emphasised science communication as a skill that needs to be developed through proper science communication and media training.

> I think that institutions should create informal, informed and shared respect for good communicators as a skill of importance.[56]

> To some people, science communication skills come by birth, but to most, it could be generated by training.[57]

> Communication skill is [the] key to success.[58]

> We have to assess the communication abilities of each scientist, train those who have some ability and willingness [to engage with the public], and encourage them.[59]

> Formal training for those with aptitude.[60]

> Skill development in science writing and speech delivery during advanced/higher studies.[61]

> Communication in simple language needs training.[62]

> Science education should be of such high quality that it not only creates [a] deep interest in science but also in sharing scientific knowledge with colleagues and [the] public. Institutions should provide knowledge as well as training in communication.[63]

Some respondents stressed providing appropriate funding for science communication activities by scientists and even recommended that funded projects include science communication.

> Encouragement to young scientists through funding, etc.[64]

> Make funded project deliverables include public dissemination.[65]

> Science communication is costly. There is not much funding available for such activity in most of the Institutions.[66]

One respondent, recommending for making an appropriate policy for science communication by scientists by the government, said:

> Framing a proper need-based policy by [the] government in collaboration with universities and institutes.[67]

Some respondents highlighted a need for science communication journals in the following way:

> A periodical on Science Communication, with international coverage, may do [a] lot of good to our efforts in this direction.[68]

> There is [a] lack of reputed journals for science communication.[69]

Some scientists may be doing it because they enjoy it. For example, a senior professor at a state university said:

> Active scientists do it in [a] spirited manner without expecting any kind of recognition or so-called rewards. It is a pleasure to interact with youngsters interested in learning new and emerging topics with profound applications.[70]

Many scientists stressed improving the quality of science education at school and college levels and recommended that visits of school/college students to R&D institutions be organised more frequently.

> The science books used at [the] school level (up to Class VIII) are in English, and the so-called side books on which schools insist are in even more complicated and

awkward English. Common parents (unless they are highly educated) do not understand even a single word, though they may be knowing basic natural phenomena behind their day-to-day activities. Such science education at [the] school level creates a wide gap between common people and science.[71]

Government should arrange visits of all interested scientists to visit local schools/colleges toward popularising their sciences to the school/college students pursuing science, once in every three months.[72]

We talk too much, do very little. The trend should be reversed. There is [an] urgent need to make our science more hands-on. We must go away from the coaching class culture. This is essential to do good science, which is the first requirement for science communication. Otherwise, we will be only communicating trash science which is now widely prevalent in India. Scientific research should be promoted even at the school level.[73]

Scientific communication among young children should have special emphasis.[74]

[The] basic education system in our country should be curiosity and knowledge driven, and not marks/performance driven. Latter is the present norm, and unless this changes, science communication would not become better.[75]

One respondent recommended constituting an award for science communication:

One could think of instituting an award for the best science communicator or popularisation of science through speeches/writings.[76]

A relatively younger female professor in biological sciences at a central university said, "Publicising science is OK but should not be fake and a means of self-glorification of scientist[s]."[77] Another scientist from Engineering and Technology background and heading a central lab said:

Let science communication be handled by those scientists having a knack for public communication. Other scientists can help as and when needed, else scientists being hare-brained will foul up communication with [the] public.[78]

Finally, one senior male scientist at a central lab said,

It would certainly help the cause of science if scientists put more effort into communicating the results of their research to the lay public.[79]

Notes

1 (ID 68: Male, aged >55 years, retired, Central R&D Institute, Director/Head of Institution or above, >30 years' experience)

2 (ID 10: Female, aged >55 years, NGO, Director/Head of Institution or above, >30 years' experience)

3 (ID 25: Male, aged >55 years, Central University, Director/Head of Institution or above, >30 years' experience)

4 (ID 43: Female, aged >55 years, Other, Department Head/Group Leader, >30 years' experience)

5 (ID 79: Female, aged >55 years, Central R&D Institute, Professor/Lecturer, >30 years' experience)

6 (ID 95: Male, aged >55 years, Central University, Professor/Lecturer, >30 years' experience)

7 (ID 139: Female, aged >55 years, NGO, Director/Head of Institution or above, >30 years' experience)

8 (ID 160: Male, aged >55 years, State University, Professor/Lecturer, >30 years' experience)

9 (ID 217: Female, aged >55 years, NGO, Scientist, >30 years' experience)

10 (ID 240: Male, age 45-55 years, State University, Professor/Lecturer, experience 20-30 years)

11 (ID 50: Male, aged >55 years, Central R&D Institute, Scientist, >30 years' experience)

12 (ID 129: Male, aged >55 years Central R&D Institute, Professor/Lecturer, >30 years' experience)

13 (ID 162: Male, aged >55 years Central R&D Institute, Director/Head of Institution or above, >30 years' experience)

14 (ID 1: Male, aged >55 years, State University, Professor/Lecturer, >30 years' experience)

15 (ID 65: Male, aged >55 years, Central University, Director/Head of Institution or above, >30 years' experience)

16 (ID 93: Male, aged >55 years, Central R&D Institute, Director/Head of Institution or above, experience 20-30 years)

17 (ID 123: Male, aged >55 years, Central University, Director/Head of Institution or above, >30 years' experience)

18 (ID 146: Male, aged >55 years, NGO, Director/Head of Institution or above, >30 years' experience)

19 (ID 148: Male, aged >55 years, State University, Director/Head of Institution or above, >30 years' experience)

20 (ID 197: Male, aged >55 years, Central R&D Institute, Director/Head of Institution or above, >30 years' experience)

21 (ID 9: Male, age 45-55 years, Other, Scientist, >30 years' experience)

22 (ID 147: Female, aged >55 years, Central R&D Institute, Department Head/Group Leader, experience 10-20 years)

23 (ID 153: Male, aged >55 years, NGO, Professor/Lecturer, >30 years' experience)

24 (ID 228: Male, aged >55 years, Central R&D Institute, Professor/Lecturer, >30 years' experience)

25 (ID 37: Female, age 45-55 years, Central R&D Institute, Scientist, experience 10-20 years)

26 (ID 152: Male, aged >55 years, NGO, Director/Head of Institution or above, >30 years' experience)

27 (ID 193: Male, aged >55 years, Central R&D Institute, Director/Head of Institution or above, >30 years' experience)

28 (ID 50: Male, aged >55 years, Central R&D Institute, Scientist, >30 years' experience)

29 (ID 67: Male, aged >55 years, Central R&D Institute, Director/Head of Institution or above, >30 years' experience)

30 (ID 52: Male, aged >55 years, Central University, Department Head/Group Leader, >30 years' experience)

31 (ID 158: Male, aged >55 years, Central R&D Institute, Professor/Lecturer, >30 years' experience)

32 (ID 67: Male, aged >55 years, Central R&D Institute, Department Head/Group Leader, >30 years' experience)

33 (ID 151: Male, aged >55 years, Central R&D Institute, Director/Head of Institution or above, >30 years' experience)

34 (ID 162: Male, aged >55 years, Central R&D Institute, Director/Head of Institution or above, >30 years' experience)

35 (ID 180: Male, age 45-55 years, Central R&D Institute, Professor/Lecturer, >30 years' experience)

36 (ID 73: Male, aged >55 years, Private Company, Director/Head of Institution or above, >30 years' experience)

37 (ID 84: Male, aged >55 years, Central University, Professor/Lecturer, >30 years' experience)

38 (ID 73: Male, aged >55 years, Private Company, Director/Head of Institution or above, >30 years' experience)

39 (ID 71: Male, aged >55 years, Central University, Department Head/Group Leader, >30 years' experience)

40 (ID 81: Male, aged >55 years, Central R&D Institute/Lab, Director/Head of Institution or above, >30 years' experience)

41 (ID 118: Male, aged >55 years, Central R&D Institute/Lab, Department Head/Group Leader, >30 years' experience)

42 (ID 163: Male, age 45-55 years, Central R&D Institute/Lab, Department Head/Group Leader, experience 20-30 years)

43 (ID 164: Female, age 45-55 years, Central R&D Institute/Lab, Scientist, experience 20-30 years)

44 (ID 185: Male, aged >55 years, Private University, Professor/Lecturer, experience >30 years)

45 (ID 187: Male, aged >55 years, Other, Scientist, experience >30 years)

46 (ID 189: Male, age 45-55 years, Central R&D Institute/Lab, Professor/Lecturer, experience >30 years)

47 (ID 224: Male, aged >55 years, Central University, Professor/Lecturer, experience >30 years)

48 (ID 232: Male, aged >55 years, NGO, Director/Head of Institution or above, experience >30 years)

49 (ID 110: Male, age 45-55 years, Central R&D Institute/Lab, Scientist, experience 10-20 years)

50 (ID 129: Male, aged >55 years, Central R&D Institute/Lab, Professor/Lecturer, experience >30 years)

51 (ID 130: Male, aged >55 years, Private University, Scientist, experience >30 years)

52 (ID 220: Male, aged >55 years, Other (retired), Professor/Lecturer, experience >30 years)

53 (ID 47: Female, aged >55 years, State University, Professor/Lecturer, experience >30 years)

54 (ID 55: Female, aged >55 years, Central R&D Institute/Lab, Professor/Lecturer, experience >30 years)

55 (ID 56: Male, aged >55 years, Central University, Professor/Lecturer, experience >30 years)

56 (ID 78: Male, aged >55 years, Central R&D Institute/Lab, Scientist, experience >30 years)

57 (ID 93: Male, aged >55 years, Central R&D Institute/Lab, Director/Head of Institution or above, experience 20-30 years)

58 (ID 108: Male, aged >55 years, Private Company, Director/Head of Institution or above, >30 years)

59 (ID 146: Male, aged >55 years, NGO, Director/Head of Institution or above, experience >30 years)

60 (ID 151: Male, aged >55 years, Central R&D Institute/Lab, Director/Head of Institution or above, experience >30 years)

61 (ID 183: Male, age 45-55 years, Central R&D Institute/Lab, Department Head/Group leader, experience 20-30 years)

62 (ID 202: Female, aged >55 years, Central R&D Institute/Lab, Director/Head of Institution or above, experience >30 years)

63 (ID 63: Male, aged >55 years, Central University, Scientist, experience >30 years)

64 (ID 112: Male, aged >55 years, Central University, Professor/Lecturer, experience >30 years)

65 (ID 128: Male, aged >55 years, Central University, Professor/Lecturer, experience >30 years)

66 (ID 188: Male, aged >55 years, Central R&D Institute/Lab, Professor/Lecturer, experience >30 years)

67 (ID 177: Male, aged >55 years, State University, Professor/Lecturer, experience >30 years)

68 (ID 120: Male, aged >55 years, State University, Director/Head of Institution or above, experience >30 years)

69 (ID 242: Male, aged >55 years, State University, Professor/Lecturer, experience >30 years)

70 (ID 140: Male, aged >55 years, State University, Professor/Lecturer, experience >30 years)

71 (ID 15: Male, aged >55 years, Central R&D Institute/Lab, Professor/Lecturer, experience >30 years)

72 (ID 101: Male, aged >55 years, Central R&D Institute/Lab, Scientist, experience >30 years)

73 (ID 152: Male, aged >55 years, NGO, Director/Head of Institution or above, experience >30 years)

73 (ID 198: Male, aged >55 years, Other (retired), Professor/Lecturer, experience >30 years)

75 (ID 231: Male, age 45-55 years, Central R&D Institute/Lab, Department Head/Group leader, experience 20-30 years)

76 (ID 157: Male, aged >55 years, Central R&D Institute/Lab, Professor/Lecturer, experience >30 years)

77 (ID 132: Female, age 45-55 years, Central University, Professor/Lecturer, experience 20-30 years)

78 (ID 213: Male, aged >55 years, Central R&D Institute/Lab, Director/Head of Institution or above, experience 20-30 years)

79 (ID 124: Male, aged >55 years, Central R&D Institute/Lab, Scientist, experience 20-30 years)