Media and Communication (ISSN: 2183–2439)
2023, Volume 11, Issue 1, Pages 335–348
https://doi.org/10.17645/mac.v11i1.6077

Article

Scientific Information Literacy: Adaption of Concepts and an Investigation Into the Chinese Public

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Submitted: 31 July 2022 | Accepted: 10 February 2023 | Published: 27 March 2023

Abstract
Many studies have developed the concepts and measurements of scientific and information literacy. However, the changes in the media environment, the complexity of scientific information, and low entry barriers have brought new challenges to scientific information communication. A single scientific or information literacy concept cannot provide a clear overview of the competencies and literacy required for individuals to access scientific information in new media contexts. This study aims to adapt the existing concepts and measurement frameworks related to information literacy in science communication and to investigate scientific information literacy and the demographic differences among the Chinese public through a cross-sectional survey (N = 2,983). The results showed that compared to self-directed information acquisition, accurate information filtering, and information sharing and dissemination, the Chinese public has relatively lower levels of information credibility assessment and opinion expression. Besides, the scientific literacy levels among the Chinese public had significant differences according to gender, age, and education. This study argues that adapting current information literacy concepts into science communication can promote public understanding of scientific information. The concept of scientific information literacy should be considered as a means of understanding the impact of new media on scientific information communication. The contribution of this study is that it adapts existing concepts into a novel context, further enriching the empirical research on scientific literacy and the research perspective on science communication.

Keywords
information literacy; literacy investigation; new media; science communication; scientific literacy

Issue
This article is part of the issue "Science Communication in the Digital Age: New Actors, Environments, and Practices" edited by Julia Metag (University of Münster), Florian Wintterlin (University of Münster), and Kira Klinger (University of Münster).

1. Introduction

As Tsabari and Schejter (2019) stated, new media is a double-edged sword in its support of public engagement with science. The characteristics of new media, such as rich content, interactivity, mobility, and multimedia, provide higher affordance than traditional media while making it more difficult for non-expert audiences to access informed messages and science-related decisions.

Flew (2007) demonstrated that new media are forms of media content that integrate diverse kinds of data, text, sound, and images—and unlike previous media, it is interactive. New media provide convenience and opportunities but also bring great challenges for scientific information communication. First, new media allow users to reach information instantly and make it easier for science communicators to address audiences directly through new dissemination channels and forms (Peters et al., 2014). However, corrupting influences that could cause the de-professionalization of science might also be generated in this context (Rödder et al., 2012). Second, although new media have the advantage of massive scientific information resources, empirical evidence shows that inaccurate descriptions of scientific phenomena are present in the online world, and that new media can facilitate the rapid spread of potential misconceptions about scientific discoveries among large audiences (Liang et al., 2014). Third, new media bring great interactivity to science communication, but studies have shown that increased interactivity and engagement do not automatically improve public discourse. Uncivil social media comments left by audiences about scientific information might cause polarized views of technology-related risks (Anderson et al., 2014).

Science communication faces many challenges in an information environment with incorrect, confusing, and rapidly changing messages. Multidimensional literacies can help people deal with complicated and dynamic challenges. The literacies involved in the context of science communication and the new media environment are complex, and literacy-related terms have commonalities and differences in their concepts. For example, media literacy emphasizes the acquisition, analysis, evaluation, and dissemination of information (Potter, 2004). Scientific literacy emphasizes the understanding of the nature of science, the concepts behind key terms, and the impact of science and technology on society (Miller, 1983). Scientific information literacy highlights the ability to access and critically analyze scientific information (Welborn & Kanar, 2000). Over the past few decades, it has been recognized that there is a need to increase the proportion of citizens who are sufficiently scientifically literate to understand public policy controversies involving scientific or technical issues (Miller, 1998). Scholars have also debated and generated new insights into the definition and scope of literacy-related terms. However, from the science communication practices in the new media environment, the single concept of scientific literacy or media literacy cannot summarize the competencies and literacies required for individuals to access scientific information (Gu & Feng, 2022). Furthermore, many countries have investigated scientific literacy and information literacy, but their surveys did not measure public scientific information literacy in the new media environment. Thus, this study aims to adapt the previous concepts and measures of literacy to the context of new media science communication and further explore and examine it among the Chinese public.

The implications of the contributions of this study are conceptual, theoretical, and empirical. First, this study adapted previous concepts and measurements of scientific information literacy into the context of science communication. Traditional scientific literacy education neglects the skill of searching and understanding scientific information sources in the media, resulting in people lacking the ability to read scientific information (Majetic & Pellegrino, 2014). Previous scientific information literacy emphasizes "the ability to access and critically analyze information with a scientific nature" or "identifying misinformation related to science" (Gu & Feng, 2022). However, literacies, such as scientific information dissemination, are also significant in practical scientific communication (Abhijit, 2012). Thus, adapting the existing and relatively well-developed literacy framework to the science communication context is necessary. Second, as Miller (1998) pointed out, despite the increasing attention, there has been a marked decline in the debate and a lack of consensus on measuring scientific literacy. Moreover, the debates are primarily about the conceptual level, with little to no empirical testing of these conceptualizations. This study reviews the concepts and measurement framework of scientific information literacy, then empirically examines the updated concept of scientific information literacy through a cross-sectional survey. Third, the data in this study enriches the research perspective in scientific communication. Studies on scientific literacy and media literacy are originated and well-developed in Europe and the US (Miller, 1998), but the relevant studies in China are somewhat lacking. The findings from this study provide a diverse perspective for scientific communication research.

2. Literature Review

2.1. Literacy: Scientific, Media, Information, and Digital Competencies

The term "literacy" is usually interpreted as the ability to read and write. The expansion of the term, such as cultural, scientific, and media literacy, suggests the semantic importance of the term (Kintgen, 1988). Different literacy concepts have been developed based on the emphases in specific domains. Concepts related to scientific information communication practices, such as scientific literacy, media literacy, information literacy, and digital literacy, have driven increased attention in recent years.

Scientific literacy is widely referred to in science communication and has become an internationally recognized contemporary educational goal (Laugksch, 2000). Miller (1983) conceptualizes scientific literacy as three dimensions: (a) an understanding of scientific norms and methods (i.e., the nature of science), (b) an understanding of key scientific terms and concepts, and (c) perception and understanding of the impact of science and technology on society. In recent years, increased activities have been designed to improve scientific literacy due to growing concerns about spreading misinformation and conspiracy theories that contradict established scientific findings (Howell & Brossard, 2021). Previous scientific literacy education has often neglected the skills of finding and understanding scientific information sources in the media, leading to a lack of ability to read scientific information. Thus, scholars suggested that the combination of information and scientific literacies education can narrow the gap and increase people's ability to identify and access sources of news and information (Majetic & Pellegrino, 2014). Klucevsek (2017) pointed out that scientific literacy requires information literacy, which is a fundamental, continuous, and integral part of the scientific process. Howell and Brossard (2021) conceptualized scientific literacy into three dimensions: civil scientific literacy, digital media scientific literacy, and cognitive scientific literacy. They argued that digital media scientific literacy, as a sub-dimension of scientific literacy, has to include the ability to navigate and evaluate scientific media information, which is further required in the next stage of the lifecycle of science information. Cognitive scientific literacy refers to the process of personal thinking through information and the perception of how the thinking process shapes the conclusion (Israel et al., 2006), which can facilitate searches for scientific information and improve critical thinking and reading skills (Bannister-Tyrrell, 2017).

Media perception has become critical with the rise of digital technology (Koltay, 2011); thus, scholars have turned their attention toward literacy related to media. Bawden (2001) identified terms related to information literacy, including information literacy, media literacy, and digital literacy, which focus on a critical approach to media messages (Koltay, 2011). From the scope of the definitions, the concept of media literacy covers the narrowest scope, usually described as facilitating critical engagement with media information (Bulger & Davison, 2018). According to the basic definition, media literacy refers to active inquiry and critical thinking about the received and created information, and its connection to critical thinking is recognized (Hobbs & Jensen, 2009). The National Association for Media Literacy Education (2007) defines media literacy as the ability to access, analyze, evaluate, create, and act through various communication forms, emphasizing the ability of analysis. Information literacy is broader than media literacy, which refers to the skills required to identify sources, access information, evaluate information, and use information effectively, efficiently, and ethically. Information literacy education emphasizes the use of meta-cognitive, critical thinking, and procedural knowledge to locate information in specific domains, fields, and contexts (Koltay, 2011). Furthermore, much attention has been paid to recognizing information quality, authenticity, and credibility (Hobbs, 2006). Compared to the two literacies mentioned above, the concept of digital literacy is the broadest. Digital literacy is considered a multidisciplinary concept that includes information literacy, computer literacy, media literacy, communication literacy, and technological literacy. In addition, digital literacy emphasizes the ability to communicate through media and apply technologies to specific life contexts (Chetty et al., 2018).

2.2. Adapting Information-Literacy-Related Concepts Into Science Communication: Attempts, Limitations, and Frameworks

As Bawden (2008) stated, no single individual or group can rely on one single literacy without it being updated with new concepts and abilities in response to the changing information environment. The practice of scientific information communication faces many challenges in the new media environment, and the scientific process requires information-related literacy. Thus, the concepts and requirements of literacy have to evolve with the times. Some academic attempts have adapted concepts related to information literacy into the science communication context. In addition to including digital media scientific literacy and cognitive scientific literacy as subdimensions of scientific literacy mentioned above, some scholars have proposed the concept of scientific information literacy. Welborn and Kanar (2000) illustrated that scientific information literacy should emphasize the ability to access and critically evaluate scientific information. Gu and Feng (2022) argued that neither information nor scientific literacy captures the public perception of scientific information. They defined scientific information literacy as "the ability to think critically based on scientific evidence, sound analysis, and consensus within the scientific community to identify misinformation related to science."

The review of literacy-related concepts reveals the previous attempts to expand the concept of scientific literacy in the new media context, such as the concepts of scientific literacy and scientific information literacy, but improvements are still needed. The current definition of scientific information literacy only emphasizes the personal ability to access, identify, critically analyze, and evaluate scientific information but ignores the ability to disseminate information in the media (emphasized in digital literacy; Chetty et al., 2018) and the ability to express opinions (emphasized in new media literacy; Lin et al., 2013). The blurring of the boundaries between media consumers and producers demands attention in academic research (Koltay, 2011). Traditional media technologies did not allow users to share or negotiate their views (Berger & McDougall, 2011), but new media's interactive and participatory nature allows opinion expression. In the current practice of science communication, the public is not only the receiver but also a disseminator of scientific information and an exponent of scientific opinions. Thus, the ability of information dissemination and opinion expression proposed in the concept of media literacy should be included in scientific information communication. Besides, compared to the formulation and improvement of the concept, a framework for measurement is still lacking. This study followed the concept of scientific information literacy to show the ability and literacy required in science communication practices.

This study attempted to adapt previous concepts and measurement frameworks in the context of science communication, defining scientific information literacy as a multidimensional construct that enhances people's ability to use media to acquire, select, evaluate, and disseminate scientific information. Specifically, there are five basic dimensions of scientific information literacy framing. First, the ability to acquire scientific information, which refers to using different media skillfully and appropriately to obtain different scientific information and further meet individual needs for information. The ability to access information is fundamental for information literacy and the same for scientific information. Breivik (1987) also suggested that information literacy needs to contain the element of access to information when defining information literacy. Information access is integral to the information literacy skill level. Second, the ability to filter scientific information. The ability to recognize useful scientific information and to access information that meets personal needs from masses of information is significant in the new media environment. Besides, filtering information is in line with the concept of "understanding" in the theoretical framework of new media literacy (i.e., the ability of individuals to grasp the meaning of media content). It includes the ability of individuals to understand the ideas expressed by others on different new media platforms (Lin et al., 2013). Third, the ability to evaluate the credibility of scientific information. This indicator includes the ability to analyze and judge whether scientific information is correct, especially the ability to question, which aligns with the existing concept of scientific information literacy (Gu & Feng, 2022). This indicator also echoes the concept of critical thinking, a mental activity that emphasizes the evaluation of information (Hollis, 2019). Fourth, the ability to disseminate scientific information. This indicator refers to the ability to spread scientific information that is found. Buckingham (2009) stated that the most important development in recent years had been related to distribution rather than production technology. This indicator shares the concept of information literacy discussed by Jenkins (2006), which focuses on the ability to search, synthesize, and disseminate information. For example, people express their feelings about scientific information (e.g., like/dislike) and share media information. Lastly, the ability to express opinions. This indicator refers specifically to the ability to engage in discussion about scientific information, actively criticize and refute misinformation in science communication, and express opinions via new media. The indicator is similar to the "engagement" proposed by Lin et al. (2013), which indicates the ability to participate interactively and critically in the new media environment.

2.3. Demographic Information and Scientific Information Literacy: Importance and Relationship

In addition to the concept, empirical studies in literacy competencies are also important in literacy research. Literacy statistics, including literacy levels and demographic information, are often used as indicators of social inequality and as a basis for policies to improve rights and educational attainment (Street, 2011). Specifically, regarding the literacy competencies required in science communication, literacy gaps reflect the disadvantage and cultural oppression experienced by minority groups and people with low economic and social status (Allum et al., 2018). Also, the literacy gap might be an important indicator for evaluating groups that participate/do not-participate in science communication. In scientific literacy research, most studies focused on the temporal changes in scientific literacy and its relationship with attitudes and beliefs, but few cared about the differences in scientific literacy across groups (National Academies of Sciences, Engineering, and Medicine, 2016). Thus, the relationship between scientific information literacy and demographics is important in terms of literacy inequality and research scarcity.

Although no studies directly show an association between scientific information literacy and demographic information, some findings have suggested a relationship between literacy competencies, such as scientific literacy and information literacy, and demographic information. Bacanak and Gökdere (2009) investigated the relationship between gender and scientific literacy levels. They found that men's scientific literacy is not higher than women's, except within the life sciences field. Another study involving Nebraskan adults found that while gender and age did not significantly affect scientific literacy levels, education was positively correlated with high scientific literacy (Swendener, 2017). In terms of information literacy, a growing number of studies have shown individual differences in digital skills across different age and gender groups (Michalak et al., 2017). Therefore, gender, age, and education are important demographic indicators related to scientific and information literacy, providing a literature basis for further validation of demographic differences in scientific information literacy.

3. Study Aim and Research Question

According to the previous research on scientific literacy, media literacy, information literacy, and digital literacy, this study pointed out the limitation of current literacy-related concepts. Then, this study proposed the need to introduce information literacy into the science communication context and to develop a measurement framework and empirical studies. This study aims to adapt previous conceptual and measurement frameworks into the science communication context. In addition, this study conducted a cross-sectional survey (N = 2,983) to investigate scientific information literacy among the Chinese public. The research question addressed in this study, therefore, is:

> RQ: Are there any significant differences in the level of scientific information literacy among the Chinese public in terms of demographics, such as gender, age, and education?

4. Methods

4.1. Research Sample

This study conducted a cross-sectional survey from September to October 2021. We commissioned the professional data research company wjx to carry out the survey by distributing paid questionnaires online (around 19,334 CNY). The company wjx has a sample base of 2.6 million potential respondents reasonably distributed by gender, age, occupation, and region. The company distributed 3,000 copies nationwide by means of a convenience sample and finally collected 2,983 valid samples for this study, with a valid return rate of 99.43%. The company is responsible for the quality and validity of the data during the completion process. After distribution and data collection, the company provides the final valid data to the researcher, but the detailed recruitment process and response rate are not open to the researcher. This study adopted all valid samples offered by the company without additional censoring. The sample of this study covers all provincial administrative regions of China, and the population distribution (Figure 1 of the Supplementary File) is also basically consistent with the demographic characteristic reported by the seventh national census of China (National Bureau of Statistics, 2021; Figure 2 of the Supplementary File), which is that Southeast China has a larger population than Northwest China.

4.2. Measures

The items used for measuring variables in the questionnaire are partly original and partly adapted from previous studies (Dijkstra et al., 2012; Gu & Feng, 2022; Miller, 1998). Besides investigating the channels the public uses to access and obtain scientific information, we asked respondents how frequently they accessed scientific information through new media for descriptive analysis. The questions were: (a) What channels do you use to access and obtain scientific information (multiple choice)? (b) How often do you access scientific information through new media? The options and results are shown in Table 4. Two bilingual researchers translated the original English surveys into Chinese and then translated them back into this study.

4.2.1. Self-Directed Information Acquisition

This study used a five-point Likert scale (1 = *strongly disagree*, 5 = *strongly agree*) to measure respondents' ability to access scientific information (*M* = 3.90, *SD* = 0.67). Here are the example statements:

- Q1: I try to obtain scientific information and knowledge from different media sources to ensure that I get a comprehensive understanding.
- Q2: I compare and synthesize scientific information from different media sources to ensure reliable information.
- Q3: I go further to search for information when I am exposed to scientific information in the media that lacks evidence and support.

4.2.2. Accurate Information Filtering

This study used a five-point Likert scale (1 = *strongly disagree*, 5 = *strongly agree*) to measure respondents' ability to filter and select scientific information (*M* = 3.94, *SD* = 0.61). For example:

- Q4: I am good at using different media sources and platforms to obtain scientific information.
- Q5: I usually know which media sources to use when I want to learn about a certain topic of scientific information.
- Q6: I can use the media to gain enough useful scientific information and knowledge for life, work, and study.

4.2.3. Information Credibility Assessment

This study used a five-point Likert scale (1 = *strongly disagree*, 5 = *strongly agree*) to measure respondents' ability to assess the reliability of scientific information (*M* = 3.78, *SD* = 0.74). For example:

- Q7: I would evaluate the credibility of information by assessing the authority of the source platform.
- Q8: I would evaluate the credibility of information by assessing the identity of information providers.

4.2.4. Information Sharing and Dissemination

This study used a five-point Likert Scale (1 = *strongly disagree*, 5 = *strongly agree*) to measure the ability to share and disseminate scientific information (*M* = 3.87, *SD* = 0.70). For example:

- Q9: For scientific information from the internet, I give likes to the scientific information that attracts me.
- Q10: I like to share and spread scientific information I come across through the media to people around me.
- Q11: I retweet the scientific information that interests me on my own social media.

4.2.5. Opinion Expression

This study used a five-point Likert scale (1 = *strongly disagree*, 5 = *strongly agree*) to measure the ability to express opinions on science-related topics (*M* = 3.42, *SD* = 0.81). For example:

- Q12: I am happy to participate in discussions on topics related to scientific information.
- Q13: I will refute rumor articles about scientific information.
- Q14: I will express opinions on the scientific information that interests me through my own social media.
- Q15: I will release and disseminate the scientific information reviewed and created by myself through various media platforms.

4.2.6. Socio-Demographic Information

Socio-demographic measures include various socio-demographic information, such as gender, age, educational background, and place of residence. This questionnaire set the socio-demographic response as the following: gender (male and female), age (18–29, 30–39, 40–49, 50–59, and 60 and above), education background (0 = *below primary school or none*, 1 = *primary school*, 2 = *middle school*, 3 = *high school/technical secondary school*, 4 = *junior college*, 5 = *bachelor's degree*, 6 = *master's degree*, 7 = *PhD*).

4.3. Data Analysis

We reviewed the psychometric properties of the items adapted from previous studies before proceeding to the main analysis.

4.3.1. McDonald's ω Reliability Test

Despite the widespread use of Cronbach's alpha, some scholars have argued that it is not the best measure of reliability, nor should it be preferred as it has been for many years (Hayes & Coutts, 2020). Cronbach's alpha is not as accurate as McDonald's ω in reliability tests since Cronbach's alpha underestimates reliability and requires tau equivalence. Compared to Cronbach's alpha, McDonald's ω has performed well in previous studies, does not make as strict assumptions as Cronbach's alpha, and is conceptually easy to understand. Thus, McDonald's ω has been one of the recommended alternatives for reliability tests (McNeish, 2018). Table 1 shows the McDonald's ω coefficient for the total scale and each subscale. The McDonald's ω coefficients for both the total scale and the subscales were greater than 0.7, indicating good reliability of the science information literacy scale.

4.3.2. Validity Test (Exploratory Factor Analysis)

Table 2 shows that the KMO value is over 0.6, meeting the requirements for factor analysis. Also, the data passed Bartlett's test of sphericity ($p < 0.05$), indicating that the study data were suitable for factor analysis.

This study used varimax to rotate and explore the correspondence between the factors and the items. Table 3 presents the results of extracted factors, and five factors were extracted from the factor analysis. The percentages of explained variance of the five factors after rotation were 14.704%, 12.670%, 10.672%, 10.070%, and 7.873%, with a cumulative explained variance after rotation of 55.989%. All research items corresponded to a communality value above 0.4, implying a strong correlation between the research items and the factors, and that the factors were able to extract information effectively. Then, this study explored the correspondence between the factors and the research items (an absolute value of the factor loading greater than 0.4 indicates a correspondence between the item and the factor). Table 3 shows that Factor 1 corresponds to opinion expression; Factor 2, to information sharing and dissemination; Factor 3, to self-directed information acquisition; Factor 4, to accurate information filtering; and Factor 5, to information reliability assessment.

Table 1. McDonald's ω coefficients for scientific information literacy scale.

Scale	McDonald's ω
Total scale	0.843
Subscale—Self-directed information acquisition	0.769
Subscale—Accurate information filtering	0.754
Subscale—Information credibility assessment	0.756
Subscale—Information sharing and dissemination	0.773
Subscale—Opinion expression	0.832

Table 2. KMO and Bartlett's test.

KMO	0.884	
Bartlett's test of sphericity	Approx. chi-square	7,577.481
	df	105
	p-value	<0.05

Table 3. Factor loading (rotated).

Name	Factor loading					Communality
	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	
1			0.669			0.524
2			0.773			0.625
3			0.621			0.546
4				0.733		0.574
5				0.59		0.537
6				0.698		0.572
7					0.807	0.742
8					0.658	0.615
9		0.678				0.491
10		0.537				0.429
11		0.668				0.541
12	0.567					0.535
13	0.696					0.54
14	0.562					0.584
15	0.675					0.543

Note: Factor loadings below 0.5 are not listed in this table.

5. Findings

5.1. Scientific Information Literacy Among the Chinese Public

Table 4 shows the socio-demographic information for the 2,983 respondents. Table 2 in the Supplementary File provides details on the demographic information for evaluating biases.

Combined with skewness and kurtosis values, we used the Kolmogorov–Smirnov test to examine whether the data conformed to a normal distribution. The absolute kurtosis values were less than 10, and the absolute skewness values were less than 3 (seen in Table 1 of the Supplementary File), indicating that the data in this study were normally distributed (Kline, 2015). Then, this study tested the differences between the level of scientific information literacy and the intermediate response items through a one-sample t-test (seen in Table 5). The results indicated that the mean value of each literacy dimension level was significantly higher than the middle response option (three; $p < 0.001$).

Table 4. Socio-demographic Information of the respondents (N = 2,983).

Items	*n* (%)
Gender	
Male	1,352 (45.32)
Female	1,631 (54.68)
Age (year)	
18–29	1,679 (56.29)
30–39	992 (33.26)
40–49	240 (8.05)
50–59	58 (0.47)
60 and above	14 (0.44)
Education level	
Middle school	13 (0.44)
High school/technical secondary school	130 (4.36)
Junior college	402 (13.48)
Bachelor’s degree	2,178 (73.01)
Master’s degree	244 (8.18)
PhD	16 (0.54)

Table 4. (Cont.) Socio-demographic Information of the respondents (N = 2,983).

Items	n (%)
Exposure and access to scientific information	
New media	2,983 (100)
Books	2,219 (74.31)
Academic articles	1,386 (46.42)
Newspaper	1,254 (42)
TV	2,016 (67.52)
Radio	499 (16.71)
Interpersonal communication	1,266 (42.4)
Expert lectures	1,573 (52.68)
Science venues and facilities	1,275 (42.7)
Science activities	1,231 (41.23)
Others	5 (0.17)
Frequency of access to scientific information through new media	
Every day	1,084 (36.34)
More than three times a week	1,206 (40.43)
One to three times a week	614 (20.58)
Once a week or less	719 (2.65)

Note: Respondents with no education and primary school were zero and are not listed here.

We conducted repeated ANOVA with pairwise contrasts to compare the levels of different literacy dimensions. The Greenhouse–Geisser test showed significant differences between the dimensions of scientific information literacy ($p < 0.05$). As shown in Table 6, we also conducted pairwise comparisons. Combined with the means of the dimensions of scientific information literacy shown in Table 5, the results indicated that the level of opinion expression is the lowest sub-dimension ($M = 3.42$), and information credibility assessment is the second lowest sub-dimension ($M = 3.78$).

5.2. Differences in Socio-Demographics

The ANOVA results showed significant differences between males and females in self-directed information acquisition, accurate information filtering, and opinion expression ($p < 0.05$). Table 7 presents the results of ANOVA for gender and other variables. Men tended to report higher levels of self-directed information acquisition, accurate information filtering, and opinion expression than women.

The ANOVA results also revealed significant differences in the levels of self-directed information acquisition, accurate information filtering, information sharing and dissemination, and opinion expression among groups of different ages ($p < 0.05$). Table 8 shows the results of ANOVA for ages and other variables. The group aged 30–39 tended to report the highest levels of accurate information filtering, information credibility assessment, information sharing and dissemination, and opinion expression. The group aged 50–59 tended to report

Table 5. Results of one-sample t-test.

			Test value = 3					
	Mean	Standard deviation	t	df	p (two-tailed)	Mean difference	95% confidence interval of the difference	
							Lower	Upper
Self-directed information acquisition	3.90	0.67	74.14	2,982	$p < 0.001$	0.90	0.88	0.93
Accurate information filtering	3.94	0.61	83.95	2,982	$p < 0.001$	0.94	0.91	0.96
Information credibility assessment	3.78	0.74	57.41	2,982	$p < 0.001$	0.78	0.75	0.81
Information sharing and dissemination	3.87	0.70	67.68	2,982	$p < 0.001$	0.87	0.84	0.89
Opinion expression	3.42	0.81	28.73	2,982	$p < 0.001$	0.42	0.40	0.45

Table 6. Results of pairwise comparisons.

Dimensions (I)	Dimensions (J)	Mean Difference (I−J)	Standard error	p^1	95% confidence interval for difference	
					Lower Bound	Upper Bound
(1) Self-directed information acquisition	(2) Accurate information filtering	−0.03	0.014	0.168	−0.071	0.006
	(3) Information credibility assessment	0.12*	0.015	<0.001	0.079	0.164
	(4) Information sharing and dissemination	0.04	0.015	0.155	−0.006	0.077
	(5) Opinion expression	0.48*	0.015	<0.001	0.436	0.521
2	1	0.03	0.014	0.168	−0.006	0.071
	3	0.15*	0.015	<0.001	0.113	0.196
	4	0.07*	0.014	<0.001	0.029	0.108
	5	0.51*	0.015	<0.001	0.469	0.553
3	1	−0.12*	0.015	<0.001	−0.164	−0.079
	2	−0.15*	0.015	<0.001	−0.196	−0.113
	4	−0.09*	0.016	<0.001	−0.132	−0.04
	5	0.36*	0.017	<0.001	0.309	0.404
4	1	−0.04	0.015	0.155	−0.077	0.006
	2	−0.07*	0.014	<0.001	−0.108	−0.029
	3	0.09*	0.016	<0.001	0.04	0.132
	5	0.44*	0.013	<0.001	0.405	0.48
5	1	−0.48*	0.015	<0.001	−0.521	−0.436
	2	−0.51*	0.015	<0.001	−0.553	−0.469
	3	−0.36*	0.017	<0.001	−0.404	−0.309
	4	−0.44*	0.013	<0.001	−0.48	−0.405

Notes: Based on estimated marginal means; * the mean difference is significant at the 0.05 level; [1] adjustment for multiple comparisons—Bonferroni.

the highest levels of self-directed information acquisition, and those over 60 tended to report the lowest level of scientific information literacy (all sub-dimensions).

Results showed differences in the level of self-directed information acquisition, accurate information filtering, information credibility assessment, information sharing and dissemination, and opinion expression among people with different educational backgrounds ($p < 0.05$). Table 9 presents the results of ANOVA for education background and other variables. People with doctoral education tended to report the highest level of scientific information literacy (all sub-dimensions). People with middle school education tended to report the lowest levels of self-directed information acquisition, information credibility assessment, and information sharing and dissemination. People with high school and junior college education tended to report the lowest levels of accurate information filtering and opinion expression.

Table 7. Gender differences in levels of information literacy.

	Gender (Mean ± *SD*)			
	Female (n = 1,631)	Male (n = 1,352)	*F*	*p*
Self-directed information acquisition	3.88 ± 0.68	3.93 ± 0.65	5.13	0.024*
Accurate information filtering	3.91 ± 0.60	3.96 ± 0.61	4.437	0.035*
Information credibility assessment	3.77 ± 0.75	3.79 ± 0.74	0.624	0.43
Information sharing and dissemination	3.88 ± 0.69	3.85 ± 0.72	2.276	0.131
Opinion expression	3.36 ± 0.81	3.50 ± 0.80	24.407	0.000**

Notes: * $p < 0.05$, ** $p < 0.01$.

Table 8. Differences in information literacy levels by age group.

	Age (Mean ± *SD*)						
	18–29 (*n* = 1,679)	30–39 (*n* = 992)	40–49 (*n* = 240)	50–59 (*n* = 58)	60 and above (*n* = 14)	*F*	*p*
Self-directed information acquisition	3.84 ± 0.68[b]	3.98 ± 0.64[a]	3.98 ± 0.67[a]	4.05 ± 0.58[a]	3.79 ± 0.38[b]	8.167	0.000**
Accurate information filtering	3.87 ± 0.63[b]	4.03 ± 0.56[a]	3.98 ± 0.57[a]	3.98 ± 0.55[ab]	3.76 ± 0.61[b]	10.683	0.000**
Information credibility assessment	3.78 ± 0.75[a]	3.80 ± 0.73[a]	3.76 ± 0.71[a]	3.68 ± 0.84[a]	3.46 ± 0.66[a]	1.071	0.369
Information sharing and dissemination	3.82 ± 0.70[b]	3.97 ± 0.68[a]	3.86 ± 0.70[b]	3.78 ± 0.83[b]	3.26 ± 1.02[c]	10.088	0.000**
Opinion expression	3.36 ± 0.81[b]	3.56 ± 0.76[a]	3.41 ± 0.84[b]	3.23 ± 0.80[b]	2.71 ± 0.95[c]	14.116	0.000**

Notes: ** $p < 0.01$; different letters indicate significant differences ($p < 0.05$) in mean values (one-way ANOVA); mean values with the same superscript letters (a, b, and c) were similar, and no statistical differences were observed for these samples.

Table 9. Differences in information literacy levels across the educational background.

	Educational background (Mean ± *SD*)							
	Middle school (*n* = 13)	High school/ technical secondary school (*n* = 130)	Junior college (*n* = 402)	Bachelor's degree (*n* = 2,178)	Master's degree (*n* = 244)	PhD (*n* = 16)	*F*	*p*
Self-directed information acquisition	3.67 ± 0.56[b]	3.77 ± 0.70[b]	3.82 ± 0.67[ab]	3.92 ± 0.66[a]	3.99 ± 0.65[a]	4.13 ± 0.58[a]	4.187	0.001**
Accurate information filtering	3.77 ± 0.37[b]	3.74 ± 0.70[b]	3.83 ± 0.60[b]	3.96 ± 0.60[a]	3.97 ± 0.60[a]	4.21 ± 0.50[a]	7.214	0.000**
Information credibility assessment	3.38 ± 0.46[a]	3.67 ± 0.76[a]	3.66 ± 0.76[a]	3.81 ± 0.73[a]	3.81 ± 0.80[a]	3.84 ± 0.79[a]	4.276	0.001**
Information sharing and dissemination	3.54 ± 0.62[a]	3.77 ± 0.69[a]	3.77 ± 0.73[a]	3.88 ± 0.70[a]	3.93 ± 0.64[a]	3.96 ± 0.61[a]	3.431	0.004**
Opinion expression	3.60 ± 0.77[ab]	3.24 ± 0.81[b]	3.31 ± 0.80[b]	3.44 ± 0.81[ab]	3.53 ± 0.78[ab]	3.75 ± 0.76[a]	4.731	0.000**

Notes: ** $p < 0.01$; different letters indicate significant differences ($p < 0.05$) in mean values (one-way ANOVA); mean values with the same superscript letters (a, b) were similar, and no statistical differences were observed for these samples.

6. Conclusion and Discussion

This study adapted existing conceptual and measurement frameworks in science communication contexts, investigated the level of scientific information literacy among the Chinese public, and analyzed the demographic differences in scientific information literacy.

This study investigated the levels of each sub-dimension of scientific information literacy among the Chinese public. First, the results reflected two key sub-dimensions of scientific information literacy relatively lacking among the Chinese respondents: information credibility assessment and opinion expression. Information assessment and opinion expression represent much higher-order criticality than other sub-dimensions (Lin et al., 2013). In science communication, access to reliable scientific information sources does not equal a critical evaluation in an accurate or relatively unbiased manner (Howell et al., 2019), so information credibility assessment is important. Compared to information dissemination, opinion expression demands higher individual competency, representing the ability to participate in science communication interactively and critically in the new media environment. Second, the results indicated that the science communication environment in the new media context is also related to low information credibility assessment and opinion expression. On the one hand, the lack of control mechanisms is considered the most significant difference between content assessment in online and print environments. This leads to a massive "misinformation epidemic" when users select information resources that challenge their ability to evaluate information credibility (Metzger, 2007). On the other hand, although the internet can facilitate scientific discussion, audiences are less likely to engage with issues that are not important to them (Rosenthal, 2020). Another study has also argued that the internet is primarily used to search for general, factual, and specific information and ephemeral content (Voorbij, 1999). Thus, individuals have limited opportunities to express their opinions about scientific information through the internet, which might explain their lower scores in opinion expression than other abilities. Finally, the findings provided a reference for future priorities in building a science communication environment and the main focus of science information literacy education. Large-scale scientific information dissemination challenges people's ability to assess its credibility, a topic worth exploring both in the early days of the internet and the current new media environment (Keshavarz et al., 2020). On this occasion, adapting information literacy concepts into science communication contexts is important, and constructing a participatory science communication environment is essential to enhance people's ability to express their opinions. Many studies also suggested that participatory culture forms, such as online communities, Wikipedia, and social media, can provide opportunities for peer-to-peer learning, develop skills, and promote more authoritative citizenship (Jenkins, 2009).

The research question examined whether there are significant differences in the level of scientific information literacy among the respondents in terms of demographic information, such as gender, age, and education. The results indicated that men report higher levels of self-directed information acquisition, accurate information filtering, and opinion expression than women. The group aged over 60 tended to report the lowest level of scientific information literacy (all sub-dimensions), and the highly educated group tended to report the highest scientific information literacy. Regarding gender differences in scientific information literacy, men have more positive attitudes toward technology and tend to perceive themselves as more competent than women (Cai et al., 2017), leading to differences in self-reported results. The age and education differences in scientific information literacy found in this study also echo previous scientific and information literacy studies (Wang et al., 2022). In addition, the findings might reflect the characteristics of marginalized groups in scientific information dissemination. Previous research focused more on the deficit model but ignored structural inequalities and social issues of gender, race, and social status (Sturgis & Allum, 2004). Sections of the public excluded from science communication and not involved in science communication have been considered unexamined and negative in previous studies (Dawson, 2018). The Public Attitudes Towards Science survey in the UK reported that people from disadvantaged socio-economical backgrounds and women were described as people who knew little about science, distrusted science, or rarely participated in science communication (Castell et al., 2014). Research from the US suggested that people who are more likely to participate in science communication have higher education and household status (Klucevsek, 2017). In short, socially dominant groups are key participants in science communication (Dawson, 2018) and have higher levels of scientific information literacy. This study indicated that women, low educated, and older groups might have lower scientific information literacy levels and are likely to participate least in scientific information communication.

Back to the literacy needed in science communication in the new media environment, this study attempted to adapt the concepts and measurement frameworks related to information literacy into science communication contexts. The concepts of scientific literacy have evolved from the initial simple definition of knowledge to a better understanding of the complexity and difficulty of achieving scientific literacy (Klucevsek, 2017). Scientific literacy has also faced competition with many other types of literacy that the public should have and understand (Paisley, 1998). In the expanding digital world, this competition is directly reflected in the intersection of scientific and information literacy concepts. The intersection is manifested as the fact that information literacy is a prerequisite for audiences to understand scientific information, which is one of the most fundamental and continuous parts of the scientific process. For example, the ability to read and understand scientific articles and participate in scientific conversations requires locating and identifying articles through information literacy (Klucevsek, 2017). Although the public does not often read or need to understand scientific articles, they have become used to accessing scientific information on the internet. In China, 74% of respondents access scientific information through the internet and mobile internet, with 49.7% using the internet and mobile internet as their preferred channel (China Association for Science and Technology, 2021). Thus, information literacy-related concepts are important to promote the public understanding of science. In other words, information literacy can improve scientific literacy and help audiences become critical in thinking and communication. Scholars have argued that competencies and literacies required for individuals to be exposed to scientific information are also required for the next stage of the lifecycle of scientific information (Howell & Brossard, 2021). To build a more scientifically literate population, we have to consider applying different literacy concepts in scientific information communication. The intersection and combination of existing concepts of information and science literacy can help the public understand scientific information. Scientific information literacy should be a more meaningful means of understanding the impact of new media on scientific information communication.

7. Limitations and Future Research

There are several limitations of this study. First, we used self-reported measures to examine the level of scientific information literacy, which predicted the performance to a certain extent, but only provided a rough indicator of the effect (Honicke & Broadbent, 2016). Future research will consider other forms, such as open and closed questions, to measure scientific information literacy. Second, we aimed to adapt existing concepts and measurements related to scientific information literacy into science communication contexts, which still require more improvements in the future. Third, the gender differences in this study are slight, which is of little practical significance. Fourth, the convenience sample used in this study might cause the results to be limited in terms of general descriptions. In this study, there were more male respondents than female, which is contrary to the seventh Chinese population census results and might affect the findings in gender differences. Besides, the research sample has a higher level of education than the general Chinese population, which potentially impacts the measurement of literacy levels. Finally, the online survey conducted in this study cannot cover the groups who cannot use the internet but are exposed to scientific information. Future research will adopt a combination of online and offline surveys to investigate scientific information literacy more specifically.

Acknowledgments

The authors would like to thank Raquel Silva, the academic editors Julia Metag, Florian Wintterlin, and Kira Klinger, and the reviewers for their valuable support. This paper is supported by the Qinglan Project of Jiangsu Province of China.

Conflict of Interests

The authors declare no conflict of interests.

Supplementary Material

Supplementary material for this article is available online in the format provided by the author (unedited).

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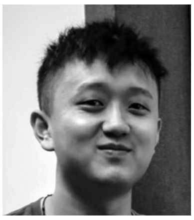

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