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Factors Influencing Public Perception of Science

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Factors Influencing Public Perception of Science

Abstract

Our literature review identified factors influencing public perception of science within the context of science communication. We analyzed 40 studies using an integrative literature review method and found that most research about public perception of science was conducted in developed countries' contexts. We identified five categories of factors that influence public perception: Type of science, audience beliefs, socio-demographics, source of communication, and environment. We observed the type of science is the fundamental factor that determines the influence of other factors. Audience belief factors are the most influential factor theme. We also noticed that factors act as confounding and/or mediating variables that cannot separate them as a single factor to identify individual influence. To show the factors and their degree of influence on public perception of science, we developed a conceptual framework called the "ring of public perception of science." The framework highlights the need for a holistic approach to examining the influence of factors affecting public perception of science. The proposed framework is based on a qualitative approach; further research is needed to validate relationships among these factors. Specifically, we recommend further research on context-specific factors because context is important to science communication, emerging environmental factors because of the changing landscape of science communication, and the use of social media to disseminate scientific information.

Keywords

Public perception, science communication, perception factors, science controversies

Cover Page Footnote/Acknowledgements

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Factors Influencing Public Perception of Science

Communicating science with policymakers and the public can be difficult in today's complex media-focused environment. In the science communication research agenda, *Communicating Science Effectively: A Research Agenda*, the Committee on the Science of Science Communication stated that new issues are affecting the scientific community, including formally engaging with the public regarding science, understanding the complexities of communicating science in regards to/about public controversies, and communicating science in complex and competitive media environments (NASEM, 2017, p. 4). The effect of the issues is exacerbated by consumers' tendencies to make decisions based on feelings and perceptions (Lundgren & McMakin, 2018) and not on scientific information (Broomell & Kane, 2017). In the same research agenda, authors described a need to investigate individual, social, and contextual perception factors that impact the communication of contentious and polarizing scientific controversies (NASEM, 2017) because perception-based decisions create challenges for the communication of science. Flynn et al. (2017) noted that misperceptions of science surrounding controversial issues (e.g., climate change, vaccines, and genetically modified (GM) foods) have often prevented evidence-based approaches from being accepted as fact-based information.

Misperceptions of science can have far-reaching economic and political implications within the agricultural industry. Gibson et al. (2020) noted that such misperceptions has limited sustainable farming practices that benefit both agriculture producers and the environment. Smyth and Lassoued (2019) described a similar international example and noted that Europe is devoid of agricultural breeding innovation because of scientific misinformation from the past 20 years. Misinformation about food and agriculture often provokes unnecessary fear of food innovations and, thereby, reduces opportunities for developing nutritious food with less environmental impact (Van Eenennaam & Werth, 2021).

We were interested in understanding the factors that caused people to believe scientific misinformation over scientific evidence. Thus, the purpose of our study was to identify factors that influence public perception of science and divert people's beliefs in science. Two objectives guided the study: 1. Review the literature to identify factors that influence public perception of science, and 2. Integrate perception factors into a holistic framework to illustrate the factors' connections and degrees of influence on public perception of scientific information.

To identify such factors, we first need to understand how people process information that changes perceptions about misinformation. "Perception is a process by which organisms interpret and organize sensations to produce a meaningful experience of the world" (Pickens, 2005, p. 52). Perception differs from attitude; attitude is a mindset that determines how people act in a particular way based on individuals' experiences and temperaments (Pickens, 2005). For example, Ho (2016) believed that "perceptions of mental illnesses (e.g., whether they are treatable) influence people's attitudes toward them (e.g., fear and stigma)" (p. 672). Attitude has three components: mental status (feeling), a condition (value or belief), and behavior (action) (Altmann, 2008; Pickens, 2005). Whereas, the perception process follows four stages: stimulation, registration (unique way of viewing), organization, and interpretation (McDonald, 2012; Pickens, 2005). Perception has two dimensions: physical and psychological (Qiong, 2017). The physical dimension is about how people convert outside stimulus into usable forms; It is highly dependent on how people acquire information. In the psychological dimension, people interpret received stimulus through their personal lens and then consider their beliefs, values, attitudes, needs, and interests (Qiong, 2017). In the perception process, people interpret stimuli different from reality and personal awareness of stimuli plays important role (Pickens, 2005). Thus, to identify factors affecting public perception of science, we considered the process of perception formation and factors contributing to each step in the perception process.

Because the scientific literature base for public perception of science is large, we chose to conduct a literature review to identify factors influencing public perception of science. For example, a search on Google Scholar using "public perception of science" yielded nearly 33 million articles. Torraco (2005) and Torraco (2016) explained that, when a research base becomes large, a need for a review, critique, and reconceptualization arises. Paré et al. (2016) noted that "literature reviews can play a significant role in advancing or disseminating knowledge, supporting evidence-based practice, developing new theories, and shaping future research studies" (p. 495). Additionally, literature reviews can help resolve inconsistencies in the literature and provide new perspectives for analysis (Torraco, 2016). Although a literature review was suitable for our study, we faced challenges in discerning which articles focused on factors affecting perceptions that directly opposed science. Using "public perception of science" and "misinformation" helped us manage the sample effectively, but we recognize our selection criterion may limit the generalizability of our findings. We believe our study, however, provides a simple, flexible conceptual framework to portray relationships between factors influencing public perception of science.

Method

We used the integrated literature review (ILR) method to identify factors that affect public perception of science and divert people's beliefs in science. Compared with other literature review methods (e.g., meta-analysis, systematic reviews), the ILR method allows researchers to incorporate diverse methodologies, both quantitative and qualitative, to help understand the context, process, and subjective elements of the topic (Doolen, 2017; Whittemore & Knafl, 2005). An ILR may produce biased results if reviewers do not follow transparent and organized frameworks to identify and synthesize the literature (Paré et al., 2016; Whittemore & Knafl, 2005). We developed our research protocol using the ILR method proposed by Torraco (2016) and refined it based on Paré et al. (2016) guidelines for systematicity and transparency to improve transparency in literature selection.

We performed the literature search in April 2020 using Google Scholar, ProQuest, Communication Source, Academic Search Ultimate, PsycINFO, and Social Sciences Citation Index. Searches were limited to literature published between 2009 to 2019. The 10-year frame was selected because increased use of social media during that time exacerbated the spread of misinformation or fake news (Bessi, 2017; Karlova & Fisher, 2013; Popat et al., 2017; Scheufele & Krause, 2019). Since 2008, American adults increased their social media use (Ortiz-Ospina, 2019; Pew Research Center, 2018). Scheufele and Krause (2019) noted the appearance of "fake news" in the U.S. and global newspapers increased dramatically after 2009. Therefore, analyzing literature between 2009 and 2019 helped us capture studies that specifically discussed public perception of science in contexts that could divert people's beliefs in science. We considered English only materials. We included refereed articles, theses, and dissertations, and excluded non-peer-reviewed articles, books, patents, and citations.

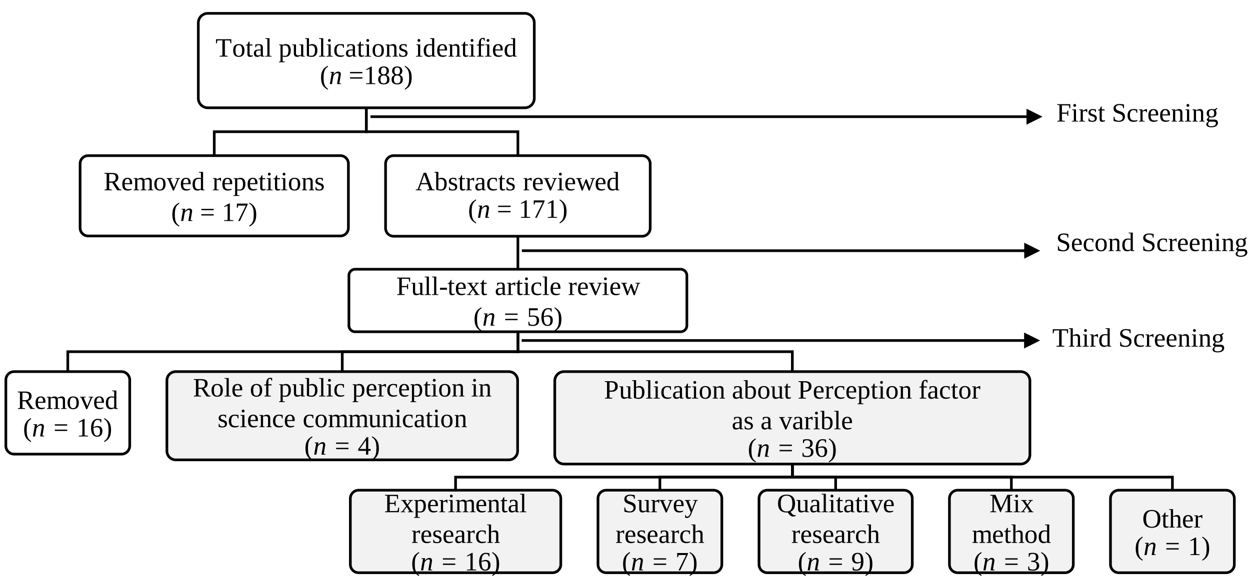
The literature search used "public perception of science" combined with "fake news" and "misinformation." Several scholars described misinformation as "fake news," "non-factual news," "misleading information," and "false news." We conducted the preliminary literature search using "non-factual news," "misleading information," and "false news," but it did not yield a robust number of studies (< 10). Thus, we combined "public perception of science" and "fake news" in the first search and "public perception of science" and "misinformation" in the second search. We assigned a unique identification number to each result and developed a matrix (Torraco, 2016) with publication titles, unique numbers, search terms, and filters.

We removed duplicates during the first screening. Next, we read abstracts, retained articles that met the inclusion criteria, and discarded articles that met the exclusion criteria. Articles with public perception of science and/or perception as a factor or variable of interest were selected. We excluded studies about public perception of non-science disciplines (e.g., public perception related to health communication between patient to caregiver or physician, consumer perceptions of commercial products—price and product labeling not related to scientific information). Finally, we read each article entirely and included those that experimentally or qualitatively analyzed or explained relationships between public perceptions and science-related factual or misinformation. We excluded 16 artifacts that did not explain the relationship between factors and perceptions.

To synthesize, we used latent content analysis (Fraenkel et al., 2012) to identify factors influencing public perception. We created a list of perception factors and descriptions of influence as reported in each study. We categorized them into themes and sub-themes based on similarity and relationship. Finally, we developed the conceptual framework by integrating and comparing each factors' influences on perception of science. Figure 1 illustrates the process of including and excluding studies.

Figure 1

Process of Including and Excluding Studies



Characteristics of Reviewed Studies

We reviewed the full text of 56 artifacts. Of those, 36 included factors influencing public perception of science as experimental variables or variables of interest; four discussed the role of public perception of science in communications but did not include factors influencing public perception of science when communicating science. Studies about factors influencing public perception of science included 16 that used experimental survey research, seven nonexperimental survey, nine qualitative, and three used mixed methods. Scholars conducted 63% of their studies in the United States and 33% in other countries (e.g., United Kingdom, China, Canada, Germany, Israel, Spain, Belgium, and New Zealand). Some studies focused on factors influencing public perception of science in a specific discipline of science while others focused on science in general (e.g., 28% focused genetically modified organisms (GMO), and 23% on climate change).

Results

We sought to identify factors that influence public perception of science and divert people's beliefs in science. From our analysis, four main themes and sub-themes emerged. The four themes were audience beliefs, audience socio-demographics, communication sources, and environment. Table 1 summarizes themes and sub-themes.

Table 1

Factors Affecting Public Perception of Science Identified from Inclusion Studies

Themes and sub-themes	Authors and year
Audience beliefs	
Religious beliefs	Morin (2018), Ho et al. (2010), Bass (2016), (Kahan, 2015a, and Kahan, 2015b, as cited in Bonney, 2018)
Political beliefs	(Kahan, 2015a, and Kahan, 2015b, as cited in Bonney, 2018), Bass (2016), Morin (2018)
Trust in science	Ho et al. (2010), Palmer (2018), Howell et al. (2018), Sonntag et al. (2019).
Perceived risks and benefits	Ho et al. (2010), Shoemaker (2018a), Nawaz et al. (2019)
Preexisting attitudes	Zhang et al. (2015), Lefevere et al. (2011), Martins et al. (2018), Landrum et al. (2018), Dixon (2016), Nagy et al. (2018), Lewandowsky et al. (2013), Bass (2016)
Audience socio-demographics	
Age	Cui and Shoemaker (2018)
Income level	Cui and Shoemaker (2018), Ruth et al. (2018)
Occupation	Mnaranara et al. (2017)
Gender	Cui and Shoemaker (2018), Ruth et al. (2018), Zhang et al. (2015)
Knowledge	Cui and Shoemaker (2018), Nawaz et al. (2019), Zhang et al. (2015), Bass (2016), Ho et al. (2010), Lakomý et al. (2019), Smith et al. (2011), Cataldo et al. (2019)
Communications sources	
Communicator characteristics	
Expertise/competence	Lefevere et al. (2011)

Themes and sub-themes	Authors and year
Credibility	Martins et al. (2018), Osman et al. (2018), Sarathchandra and Haltinner (2019)
Scientists' trustworthiness	Ho et al. (2010), Zhang et al. (2015)
Organizational trustworthiness	Landrum et al. (2018), Wilner (2018)
Communication medium characteristics	
Format: Debate	Morin (2018)
Format: Fact-checking videos	Young et al. (2017)
Format: Satirical television news	Brewer (2013), Brewer and McKnight (2015), Brewer and McKnight (2017)
Message characteristics	
Tone: Balance norm	Martins et al. (2018)
Tone: Moralized tone	Capurro et al. (2018)
Tone: Ethical and risk	Kastenhofer (2009)
Ambiguous message	Brewer and McKnight (2015)
Consensus message	Dixon (2016), Brewer and McKnight (2017), Lewandowsky et al. (2013)
Use of visual images	Gruber and Dickerson (2012), Li et al. (2018)
Environment	
Exposure to information	Clayton et al. (2019)
Type of exposure	Gesser-Edelsburg et al. (2017), Zoukas (2019)
Social bot	Ross et al. (2019)
Events related to science	Li et al. (2016), Suthanthangjai et al. (2013)

Type of Science

First, our analysis revealed that influence on public perception of science varies based on types of science communicated such as GMOs, nanotechnology, and climate change. For example, perceptions of scientific certainty were influenced by exposure to debate, and the influence varied based on issues discussed (Morin, 2018). Scientific certainty perceptions increased after exposure to debate on GMOs and evolution, but there was not the same effect on climate change (Morin, 2018). Perceptions of GMOs had a stronger association with the audience's knowledge level (Cui & Shoemaker, 2018; Nawaz et al., 2019), but perceptions of nanotechnology had weak (Zhang et al., 2015) or no association (Ho et al., 2010) Our findings are congruent with the American Academy of Arts and Science (2018)—perception factors have different influences on public perceptions depending on the type of science being communicated.

Audience Beliefs

The audience beliefs theme had four sub-themes: religious and political beliefs, trust in science, perceived risks and benefits, and preexisting attitudes.

Religious and Political Beliefs

Studies often examined changes in perception of science due to religious beliefs using evolution as a topic and political ideology using climate sciences as a topic (Bass, 2016; Bonney, 2018). Political ideology influenced perceptions when communicating about climate science (Bass, 2016) and religious beliefs affected perceptions when communicating about evolution (Kahan, 2015a, and Kahan, 2015b, as cited in Bonney, 2018). Morin (2018) made a similar conclusion: when a scientific subject becomes politically and/or religiously aligned with the audience's view, it is difficult to persuade individuals to change their perceptions of science. When examining public support for nanotechnology funding, Ho et al. (2010) found that religious beliefs had a negative association with perception. However, because these studies were conducted in the U.S., they have limited generalizability to other countries.

Trust in Science

Another sub-theme of audience beliefs was trust in science. It is "a multidimensional concept, which can be oriented toward diverse actors or areas, such as scientists themselves, and also scientists from different fields, scientific institutions, utilized methodology, or presented findings" (Lakomý et al., 2019, p. 249). In our study, we discuss trust in science based on how it is reflected in perception studies—trust in science as a field and trust in scientists. We discuss trust in scientists as trustworthiness, which is presented later in our study. Wong-Parodi and Bruine de Bruin (2017) stated that trust and emotions affect perceptions and willingness to implement recommended behaviors. Although Palmer (2018) noted having trust in science helps the audience identify conspiratorial information, such trust has beneficial and detrimental effects on perceptions of science. For instance, when pseudo-scientific information on controversial topics was available, trust in science negatively influenced public perceptions of science (Palmer, 2018). Moreover, Zhang et al. (2015) noted that support for nanotechnology in China was positively associated with people's trust in nanotechnology and people's knowledge and support of nanotechnology (Zhang et al., 2015). In this instance, the Chinese trusted a scientific process and supported its use although they lacked knowledge of the process itself.

Level of trust in science also affects public perception of science (Howell et al., 2018; Palmer, 2018). Palmer (2018) observed that respondents with high levels of trust in science tended to base their beliefs on scientific content when compared to those with low trust levels who did not base their beliefs on content. Similarly, Howell et al. (2018) found that the NASEM report affected public perception of GMOs and reduced risk perception of GMOs among those who had the lowest level of trust in science (Howell et al., 2018). Additionally, Sonntag et al. (2019) found that "the lack of confidence and trust in modern poultry farming systems had a major influence on the citizens' perception of poultry farming systems" (Sonntag et al., 2019, p. 211). The level of trust in science determines which way science communication changes audiences' perceptions.

Perceived Risks and Benefits

Perceived risks and benefits of scientific outcomes or technology shape public perceptions of science. In China, risk perceptions of GM foods were a contributing factor in determining public support of GM foods (Cui & Shoemaker, 2018). Nawaz et al. (2019) demonstrated that, when people identified the benefits of GM foods, their perceptions and willingness to consume GM foods increased. Meanwhile, in the U.S., Ho et al. (2010) observed perception of risks was negatively associated with public support for funding nanotechnology although the perception of benefits was positively associated. Zhang et al. (2015) found a similar observation in China where the greater the benefit/risk ratio, the more support was shown for nanotechnology. These studies support the argument that the perceived risk and benefit of science shaped public perceptions of GM foods and nanotechnology.

Our literature searches did not find studies that examined the effect of perceived risks and benefits on climate change perception as the main variable, even though it is a popular controversial issue. However, we found Lewandowsky et al.'s (2013) and Bass's (2016) studies that indirectly discussed perceptions of risks and benefits related to climate change. Lewandowsky et al. (2013) observed that free-market ideology had a higher level of effect on rejection due to the importance of fossil fuels. Bass (2016) noticed that, when citizens see economic impacts of climate change at the individual level (i.e., raise taxes on gasoline), their support for emission reduction policies relied more on their factual knowledge rather than their political ideology.

Preexisting Attitudes

Preexisting attitudes affect audiences' perceptions of science differently and have often been recognized as a moderating variable that influences public perceptions of science together with other variables such as credibility, consensus messages, and type of science being communicated. Concerning communicator's' credibility, Lefevere et al. (2011) found news stories that featured common people (known as exemplar) rather than scientists or politicians had the highest influence, and influence increases with preexisting beliefs. Likewise, journalists' and scientists' credibility was influential when their stories matched with readers' preexisting beliefs of the topics being communicated (Martins et al., 2018). Landrum et al. (2018) noted that preexisting attitudes of GMO safety were generally associated with perceived trustworthiness of researchers. Related to consensus messaging, Dixon (2016) found that levels of prior beliefs created different levels of influence when communicating consensus messages. For instance, respondents whose prior beliefs in GM foods were low were least influenced by the consensus message (Dixon, 2016).

Concerning moderating effect of preexisting beliefs and types of science being communicated, we found that Nagy et al. (2018) observed negative stigma around certain scientific issues as a result of preexisting beliefs in the Frankenstein myth (i.e., scientific research identified as dangerous because of irresponsible scientists). Lewandowsky et al. (2013) noted that people who believed that previous environmental problems had been resolved were less willing to accept climate science. Bass (2016) found that preexisting beliefs about the causes of climate change predicted support for climate mitigation policies.

Audience Socio-demographics

A few studies in our sample reported relationships between perceptions of science and socio-demographic variables (e.g., gender, age, income level, education, and/or knowledge). In China, Cui and Shoemaker (2018) found that, although age (being born before 1969) and income level had a negative association with attitude toward GMOs, gender was unassociated. In the U.S., Ruth et al. (2018) found that males had positive attitudes toward GMOs, while females had negative attitudes. Ruth et al. (2018) also noted that U.S. citizens who earned more than $75,000 annually tended to have positive attitudes toward GMOs. Contrarily, China's high-income earners tended to have negative attitudes toward GMOs (Cui & Shoemaker, 2018). Mnaranara et al. (2017) noted that in Tanzania occupation was related to the perception of GM foods.

Regulatory authorities and academicians had positive perceptions because of higher levels of awareness of GM foods and regulations while farmers and media professionals had negative perceptions because of risks and ethical issues related to GM foods (Mnaranara et al., 2017).

Most studies used socio-demographic data to explain the characteristics of the sample population and not as factors that influenced perception of science. We speculate this may be for two reasons. First, researchers did not identify socio-demographic variables as factors that influenced public perception of science. Second, research often reports statistically significant results but excludes nonsignificant results. Perhaps no evidence supported significant relationships between public perception of science and socio-demographic variables.

Knowledge

Knowledge can have positive or negative effects on perception of science. Concerning GMOs, as knowledge increased, support and/or acceptance of GMOs increased (Cui & Shoemaker, 2018; Nawaz et al., 2019). When communicating nanotechnology, knowledge was weakly associated with support among Chinese (Nawaz et al., 2019; Zhang et al., 2015), but no association existed between those variables when tested among Americans (Ho et al., 2010). Lakomý et al.'s (2019) review concluded that knowledge had a weak positive association with public perception of science. Furthermore, Smith et al. (2011) found that people perceived astronomical images differently based on knowledge levels. Experts looked at astronomical images from a data-orientation perspective and nonexperts perceived aesthetic or emotional values of the images (Smith et al., 2011). Cataldo et al. (2019) observed differences between credibility judgments of science news sources and educational stages. Based on our findings, we believe knowledge impacts perceptions of science, depending on the type of science being communicated and recipients' levels of knowledge. However, we noticed knowledge was measured differently across studies. Cui and Shoemaker (2018) measured knowledge of specific topics (i.e. knowledge about GMO); Nawaz et al. (2019) measured self-perceived knowledge of a specific topic (i.e. GMO); and Ho et al. (2010) measured general knowledge about science. Therefore, we identified the need for well-accepted protocols to measure one's "scientific knowledge" of topics being communicated when conducting perception research.

Communication Sources

Factors related to communicator characteristics, message characteristics, or medium of the message delivered are categorized into main themes as sources of communication. We identified three common sub-themes under communication sources: communicator characteristics, message characteristics, and communication medium characteristics.

Communicator Characteristics

We identified three influential characteristics related to the communicators that influence public perception of science : expertise, trustworthiness, and credibility. Communicators' expertise positively and negatively affected people's perceptions of science. For example, Lefevere et al. (2011) found that, when communicating scientific information about local issues, common people who appear in the news can have more influence than local politicians and scientists at local universities. Lefevere et al. (2011) also found people who shared similarity and trustworthiness with the audience and vividly presented messages were most influential, despite the fact they did not have technical expertise. Additionally, Osman et al. (2018) contented that source credibility is influential. For example, the public perceived scientists as more credible than governmental groups. Martins et al. (2018) revealed that, when communicating research about how media affects people, scientists and journalists' credibility was positively associated with attitude change. Respondents who positively viewed certain news organizations were more likely to consider science news from those organizations as more credible than those without positive opinions (Wilner, 2018).

Furthermore, communicator trustworthiness is closely related to general trust in science as noted earlier. However, we found specific studies that discussed trust in scientists and how it influenced public perception of science. For example, Ho et al. (2010) and Zhang et al. (2015) found that people who had high trust in scientists were more supportive of nanotechnology funding than those who had low trust in scientists (Ho et al., 2010). However, Sarathchandra and Haltinner (2019) stated that, when communicating climate science, people who did not believe in the anthropogenic effect of global warming did not trust scientists or scientific methods used in climate science research. The trustworthiness of an organization that conducts open and transparent scientific research practice was positively associated with public perception of GMO safety (Landrum et al., 2018) . This evidence shows trust in the communicator and the level of trust effects science perceptions.

Communication Medium Characteristics

Communication Format. Science communication appears in various formats, and we found studies on the effects of videos, print articles, debates, and satirical television news on the public's perception of science. Young et al. (2017) concluded that videos (humorous or non-humorous) were more effective than printed articles in reducing audience misperceptions because videos helped increase attention to the message and reduce message confusion. However, the humorous or non-humorous nature of the video did not affect perceptions (Young et al., 2017). Morin (2018) found that exposure to debate increased perceptions of scientific certainty related to GMOs and evolution but did not have the same effect on climate change. Satirical television news coverage of global warming affected perceptions of climate change (Brewer, 2013; Brewer & McKnight, 2015, 2017). Overall, studies tested the effect of the format using specific topics, but we were unable to select the most effective format for communicating science. However, communicators should consider communication format because it does influence perceptions of science.

Message Characteristics

The Tone of Communication. Scholars have found frame, ambiguous message, and consensus message reporting as influencing public perceptions of science. Kastenhofer (2009) studied how framing influences policymakers and society's perception of agribiotechnology and medical technology in Germany and Great Britain. In the early phase of technology development, ethical framing was dominant, but when technology moved to the market phase, risk framing was dominant (Kastenhofer, 2009). Content analysis of media coverage during the Disneyland measles outbreak showed that a highly-moralized tone changed risk perceptions and caused a regulation push that made vaccination mandatory in Canada (Capurro et al., 2018).

Martins et al. (2018) examined how conflicting sources reporting affected the public's perception of journalists and scientists' credibility and found that conflicting sources reduced public perception of scientists' credibility but not journalists' credibility. In a Brewer and McKnight (2015) study, the ambiguity of the presenter's message on controversial issues affected the viewer's interpretation of scientific information. They found *Colbert Report's* led to biased ideological processing because of message ambiguity but *The Daily Show with Jon*

Stewart did not (Brewer & McKnight, 2015). In summary, the literature suggests that framing and message ambiguity changed public perceptions. We believe that, when communicating controversial scientific topics, it is important to frame messages in a way that emphasizes scientific evidence.

Consensus Reporting. Several scholars found that, when many scientists agree on facts related to controversial issues (i.e., consensus message reporting), public beliefs about scientific issues improve. The effect of consensus messages on perceptions varies based on the prior beliefs (Dixon, 2016) and interests in the type of science being communicated (Brewer & McKnight, 2017). Dixon (2016) found that the consensus message had a positive influence on GMO beliefs, but those with low levels of prior GMO food beliefs were less influenced by the consensus message. Conversely, Brewer and McKnight (2017) found participants with the lowest levels of interest in climate change experienced the strongest influences from the consensus messages on climate change when compared to others. Lewandowsky et al. (2013) also described that acceptance of climate science can be influenced by consensus information. Therefore, we agreed with Martins et al ‘s (2018) suggestion to follow the “weighting evidence approach” when the majority of scientists agreed on scientific facts of a controversial issue.

Use of Visuals. The role of an image’s’ ability to change audience perception has been studied across specific contexts. Gruber and Dickerson (2012) examined how the use of brain images changed the audience’s perception. They concluded that images did not influence the perception regardless of its uses: functional magnetic resonance imaging (fMRI), artistic renderings, and an image from a science fiction film. Moreover, Li et al. (2018) found that graph format and graph interactivity were not related to perception of data credibility. Although these two studies did not find an effect on perception, we cannot conclude that images do not change perception because the absence of proof does not prove that it is true. Rather, we urge communicators to consider purpose of communication when using images or graphs because they help to convey meaning and clarify scientific information (Trumbo, 1999).

Environmental Factors

The fourth theme identified environmental factors that affect public perception. Under this theme, we identified factors that cannot be directly controlled by the communicator or audience. Exposure to information, social bots, geographic proximity to the event, the occurrence of an event related to science technology, competing for economics, and authority and/or government endorsement are environmental factors we identified in our literature search.

Exposure to Information

The quality of information that the audience has been exposed to can affect perceptions. For example, Clayton et al. (2019) noted the audiences who were exposed to false information were more likely to assume false statements as accurate than those who were exposed to true statements. Gesser-Edelsburg et al. (2017) found that public awareness of health issues varied depending on the type of exposure (web news, forum, Facebook, and blogs). News websites use different types of sources to report scientific facts and the quality of information varies across websites, even though the news is reporting the same event (Gesser-Edelsburg et al., 2017). Climate blog readers perceived blogs as unbiased factual information sources that provided information not available through mainstream media such as newspapers (Zoukas, 2019).

Social Bots

Compared with other communication media, social media have different environmental factors that influence perceptions of science. “Social bots,” automated actors or software-controlled profiles or pages, are one environmental factor that influences perception of science. Using the simulated model, Ross et al. (2019) found that “in a highly polarised (*sic*) setting, depending on their network position and the overall network density, bot participation by as little as 2-4% of a communication network can be sufficient to tip over the opinion climate” (Ross et al., 2019, p. 407). This evidence shows that social bots have tangibly influenced public opinion.

Events Related to Science

Science events trigger perceptions differently. We identified studies that described a science event, its geographic proximity, and when the event happened. Li et al. (2016) studied how the nuclear incident in Fukushima was discussed in Tweets in the U.S. and noted that Twitter users from states geographically closer to Japan discussed the incident more and were more concerned about the event. The same study looked at whether having nuclear plants in their state influenced opinion, but a correlation was not evident. Furthermore, Li et al. (2016) observed how negative sentiment and pessimistic views on nuclear accidents changed overtime and found negative sentiments become neutral comments and uncertain over time. Similarly, Suthanthangjai et al. (2013) examined the effect of changes in perception over time related to environmental reporting in New Zealand and concluded that overall perception is stable with few changes, but not statistically significant, however, they confirmed short-term variability in perception is possibly related to events.

Discussion

Our integrative literature review was designed to identify and synthesize studies about factors influencing public perception of science, particularly considering what factors lead to opposing beliefs in science, to create the “Rings of Public Perception of Science” (see Figure 2). From our review, we found that various factors have different levels of influence on public perception of science. Rings of public perception of science were arranged by level of influence. We speculated that inner rings (e.g., audience attitudes), more than outer rings (e.g., environmental), had a greater influence on public perceptions. However, the conceptual framework proposed does not reflect statistical comparisons of factors with other factors but does provides a foundation for understanding the interaction of factors and how they influence perception. We found that audience belief factors are the most influential factor theme because nearly 47% studies in our sample noted there is relationship between audience beliefs and perception. However, we argue that factors affecting public perception of science require a holistic approach to examine influence because the factors act as confounding and/or mediating variables that cannot be separated.

Figure 2

Proposed Conceptual Framework: Rings of Public Perception of Science.

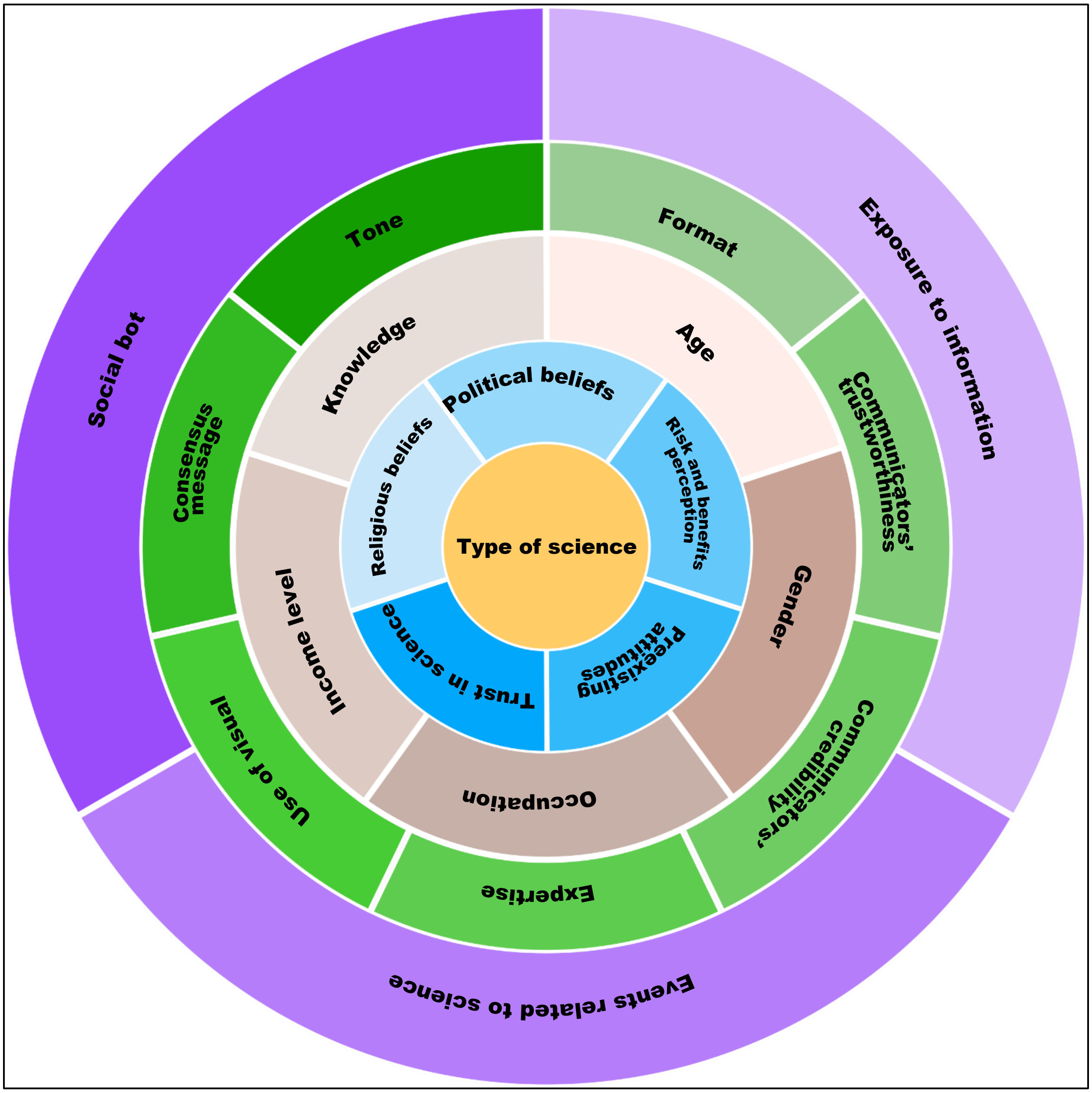


Figure Note. Each ring represents the main themes of perception factors identified from this review. The foundational ring (yellow) represents type of science, the blue ring shows audience beliefs, the brown ring represents sociodemographic factors, the green ring is communication source factors, and the purple ring represents environmental factors.

Type of Science

In our review, we found that the type of science being communicated plays a key role in determining which factors influence perception of science. Each discipline of science has unique rings that show how the different factors contribute to changing perceptions in particular scientific disciplines. For example, perceived risks and benefits were more influential when communicating about GMOs but not climate change. We do not see immediate risk or benefit of climate change until it has a personal effect such as a rise in gasoline prices. However, consuming GMO foods may have more immediate risk or benefit individually because personal health is more valuable than global climate change. Thus, the ring of perception on climate change would not reflect perceived risks and benefits as a key factor. Therefore, we placed type of science as the foundational ring of perception of science, which supports the findings of the American Academy of Arts and Science (2018) in its report that perception of science varies by discipline of science being communicated.

Seventeen of 36 studies in our sample noted preexisting attitudes as a variable that enhanced the influence of other perception factors. Recent science communication studies showed preexisting attitudes significantly influenced people's use of information when communicating about controversial scientific issues (Knobloch-Westerwick et al., 2015; Rowe & Alexander, 2017; Yuan et al., 2019). Thus, we placed the audience beliefs as the first ring (after foundational ring). Identifying audience beliefs as the highest influencing factor theme concurs with recent recommendations to improve science communication using the mental model approach instead of the knowledge deficit model, which prioritized appealing to audience beliefs more than providing factual information (Scheufele, 2013, 2014; Wong-Parodi & Bruine de Bruin, 2017). Recent scholarly recommendations to improve science communication have considered audience heuristics, biases, and values, which showed the key role of audience beliefs (Akin & Landrum, 2017; Landrum, 2017). Additionally, Koswatta et al. (2022) have shown that acceptance of scientific information related organic foods depends upon audience preexisting beliefs and perceived risk and benefits of organic and conventional foods, rather than factual knowledge or education. Therefore, we believe identifying audience beliefs as the highest influencing factor is well supported by our sample as well as recent science communication theories and literature. As a main influencing factor, we suggest exploring audience beliefs' effect on perceptions as a main independent variable of interest rather than moderating variable. We recommend such because a majority of studies in our sample examined the influence of preexisting attitudes on perception as a mediating variable.

We placed socio-demographic factors as the second layer of the ring because of the confounding influence of socio-demographic factors and audience beliefs. For example, Cui and Shoemaker (2018) noted that respondents' attitudes toward GM foods were correlated with age. Moreover, socio-demographic factors (e.g., knowledge) can lead to healthy skepticism about scientific facts and overturn the impact of audience beliefs. This idea is further supported by the finding that political predisposition is overshadowed by factual knowledge about climate science (Bass, 2016). Thus, we believe placing socio-demographics immediately after audience beliefs is appropriate. However, there is a need for future research to examine statistically the confounding influence of sociodemographic factors together with beliefs and confirm the strength of the relationship. In our sample, we did not find studies that considered race and its effect on perception or prior experience. Particularly, role of experience may shape people's attitudes toward the topic. Therefore, similar to Ruth et al. (2018), we also see the need to further examine how demographic factors affect the perception of science.

Although our review did not find evidence to support the impact of visuals on the perception of science, we found evidence that showed that communicator credibility and trustworthiness as well as format, tone, and consensus message considerably influence public perception of science. Thus, factors related to communication sources laid the foundation as the third layer of the perception ring. Martins et al. (2018) stated "media framing of scientific research clearly has the power to change minds after encountering just one story" (p. 114). Scheufele (2014) noted that media coverage primes attitude, while Yuan et al. (2019) found that communication styles significantly influenced perceptions. Bucchi (2017) emphasized the importance of credible and reliable information in changing the communication environment. However, we believe the influence of communication sources is less powerful than preexisting beliefs because the audience analyzes new information along with confirmation biases and then selects information that aligns with their beliefs (Knobloch-Westerwick et al., 2015).

The fourth ring is environmental factors influencing perceptions. Our review found evidence that environmental factors (e.g., exposure to information, social bots, science events) affect perception, which we presume were least influential for two reasons. First, in our sample, we could not achieve data saturation related to environmental factors. Second, these factors are context-bound and/or change over time. For example, Suthanthangjai et al. (2013) and Li et al. (2016) observed short-term variation in the perception of science with events related to science but the effect becomes neutral over time. Weingart and Guenther (2016) reported algorithms that personalized communication preferences and social bots influenced science communication. Scheufele (2014) contended that lay audiences do not attend to all available information but rather pay to attend to information created by mediated organizations (i.e., called "mediated realities"). He concluded that "mediated realities heavily influence both public perceptions of science more generally—fact-based or not—and public understanding of scientific topics" (Scheufele, 2014, p. 13588). Ongoing transformations of communication infrastructures create new factors influencing public perception (Castelli et al., 2013; Scheufele & Krause, 2019). Therefore, there is a need for qualitative research to identify emerging environmental factors that influence public perception of science.

Factors influencing public perception of science have been studied at two stages. The first stage examined associations or relationships between factors and perception (religious beliefs and knowledge). The second stage examined degrees of influence on public perception of science (high vs. low levels of trust in science). In-depth studies are needed to investigate levels of influence further. For example, exposure to information needs further research to examine how the frequency of news exposure affects the perception of science on controversial issues. Our review is limited to specific studies based on search criteria, but other studies may have investigated the degree of influence on perception that are not reported herein.

Our analysis found perceived risks and benefits of science were major influencing factors that are often studied in perception research. We identified a need for a clear definition of perceived risks and benefits as influences on perception. Perceived risks and benefits vary contextually (e.g., human wellbeing, personal health, environmental, or financial issues) in both association of specific disciplines and in effect on science perceptions. For example, perceived risks and benefits may arise from environmental concerns but may not from potential health risks associated with global warming. Technology application also needs further study. For example, the risks of using GMO technologies to produce food is perceived differently than using GMOs in nonfood applications (Cui & Shoemaker, 2018; Dijkstra & Gutteling, 2012; Knight, 2006).

In our sample, 63% of studies on factors influencing public perception of science have been conducted in the U.S. Therefore, when discussing the influence of political and religious beliefs on public perception of science, a limitation exists in generalizing our findings beyond the U.S. Because religious and political ideologies vary by country, their effects on public perception of science may vary as well. Lee et al. (2015) found factors that influence risk perception of climate change varied by country. We see the need for studies in other countries to increase global understanding of factors influencing perception of science. We identified the need for research in developing countries because new scientific technologies have the potential to improve the quality of life in those places, but acceptance of these technologies is largely based on perception (Peters & Slovic, 1996; Shew et al., 2018; Siegrist, 1999). For example, Mbabazi et al. (2016) found public perception of GMO and anti-GMO group activities were the main factors impacting biotechnology development in Africa, Asia, Latin America, and Europe.

With the increasing use of social media to communicate science, we speculate new factors (e.g., social media use, social networks, and following influencers) that impact perception of science. Therefore, we identified a need to explore new factors influencing perception because the landscape of science-related communication is ever changing. We propose conducting case studies to identify new factors because they are the best approach when "it is impossible to separate the phenomenon variables from their context" (Merriam, 2009, p. 43). Our suggestion aligns with Nisbet and Goidel (2007) who emphasized the need to conduct mixed-methods research to examine factors influencing perception at group, community, and national levels.

Rings of Public Perception of Science and Perception Process

We reiterate a need for a holistic approach to examining perception factors based on the perception process. People do not perceive all the information; they select information that is related to them. Placing type of science as the base layer and attitudes as the first layer confirms the selective process of perception where people convert external stimulation into meaningful experience based on interest (McDonald, 2012; Pickens, 2005; Qiong, 2017). People categorize information into meaningful patterns during the organization step (Qiong, 2017). Demographic variables (e.g., age, gender, and knowledge) help to create these patterns. Therefore, having demographic variables as the second layer aligns with the perception process. In the interpretation stage, people may interpret the same stimulus in a different way based on experience and cultural background (Pickens, 2005; Qiong, 2017). However, when communicators and their audiences share common experiences and cultural values, it is more likely to have the same path of interpretation (Qiong, 2017). Thus, having factors related to communicators and the environment as outer layers (3rd and 4th) aligns with the perception process. Particularly, Pickens (2005); Qiong (2017) noted that people's worldviews, beliefs, interests, values, and social organizations are the main factors that create perception diversity. Thus, we propose that examining perception based on the "Rings of public perception of science" will help communicators to see how perception diversity may change during science communication.

Use of Rings of Public Perception of Science to Improve Agricultural Communication

The use of genomic innovations, new breeding technologies, and innovative farming practices are more crucial than ever before to meeting food security challenges and addressing climate change. However, when new innovative technologies (such as new breeding techniques and genome editing methods for crop improvements) do not comply with public risk perception, regulators ban or restrict the use of the respective products (Gibson et al., 2020; Malyska et al., 2016). For example, Europe is viewed as the death place of agricultural breeding innovation due to strong public opposition due to misinformation and/or non compliance with public risk perception (Smyth & Lassoued, 2019). Therefore, we see there is a need for a comprehensive approach to understanding the public perception and how we communicate science in a way that helps the public make a sound judgment about science and its application. We believe our framework of rings of public perception of science provides the foundation for agricultural communicators to identify factors that influence public perception and formulate materials considering these factors. Ruibal-Mendieta and Lints (1998) noted that "technology-related opinions are subjective judgments, not strong enough to be characterized as firmly established beliefs and attitudes."(p. 383). Thus, we believe our framework provides a foundational map to understanding how several factors influence perception and cause the public to believe misinformation rather than scientific evidence.

Limitations

Our study has limitations. First, the literature search was limited to 10 years and the English-based literature. It used specific terms, search engines, and findings reported in peer-reviewed articles, dissertations, and theses. Second, we did not cover all published research on factors influencing public perception of science. Third, we analyzed selected literature using a latent content analysis, so the conclusions reflect our subjectivity, which is common for qualitative studies (Creswell, 2013). Fourth, we failed to achieve data saturation to support relationships between factors and perceptions and some observations were based on only one or two studies. Therefore, our categorization and placement of themes in the conceptual framework may not reflect the available literature on public perception of science or the statistical relationships among factors. Despite these limitations, our research is a first step toward developing a holistic approach to examining the factors that influence public perception of science.

Conclusion

It is difficult to include every factor that influences public perception of science because of the changing landscape in scientific research. Our review summarizes factors influencing public perception of science particularly those factors that divert people's beliefs in science evidence. Our study clarified that type of science is a fundamental factor that determines the level of influence on other factors and established a foundation for identifying the need for a holistic approach to understanding the influence of different factors. The proposed ring can be used to design strategies for communicating about controversial scientific issues. Public risk perception in agricultural breeding innovation, gene editing technologies for crop improvement, and innovative sustainable framing has influenced the development and use of such technologies (Gibson et al., 2020; Malyska et al., 2016; Ruibal-Mendieta & Lints, 1998; Smyth & Lassoued, 2019) We believe using rings of public perception of science to understand the complexity of public perception and developing materials that consider factors might help to minimize the public risk perception of agricultural innovation. Our study identified the need for future research on the degrees of influence made by each factor, future research in developing countries, and future qualitative research to identify context-specific factors. There is a need for identifying emerging environmental factors because of the changing landscape of scientific communication with the increased use of social media. Future studies should include statistical relationships among factors to verify the positioning of factors and rings proposed in this review.

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