Science Literacy in the Age of Disinformation: Building Bridges to Address the Complexity of the Challenge

Erasmo Moises dos Santos Silva and Agnaldo Arroio

Science education and media and information literacy (MIL) significantly contribute to the current landscape of contested knowledge surrounding science and scientists, as evidenced by movements against COVID-19 health protocols. Nonetheless, a broader view than that typically portrayed of complexity is required. This chapter aims to offer recommendations to avoid counter-productive approaches based on problematic assumptions, such as considering all types of untrustworthy information as *fake news*. Thus, this chapter aims to problematize views about the information disorder phenomenon in the context of natural science in Brazil by providing a complex and coherent vision of the issue in the context of natural science educators and education. For this purpose, the following questions are addressed: If not fake news, what concept(s) should natural science educators address in their practice? Why can not only ignorance explain the scientific informational disorders? What makes science and scientists vulnerable to information disorders? Why can (science) education not be the only solution to (scientific) disinformation disorders? To provide answers to these questions, this chapter poses scientific literacy and MIL as an urgency to sustain democracy, science, and public good in contemporary times.

Keywords: science education; information disorders; rake news; STEAM education; teaching practices.

Over the past years, scholars and teachers of science education have been grappling with a pressing question in the contemporary world: how may the natural science curricula be structured to help individuals tackle challenges in information disorders related to science such as cases of climate change denialism, anti-vaccination movement, and flat-earth belief? A number of specialists argue that the domain of natural scientific conceptual knowledge (e.g., the traditional contents of chemistry, biology, physics, and earth sciences) may help society address this contemporary challenge, because mis- and malinformation that involve science leads to erroneous scientific concepts (Fauzi et al., 2021). Others point out to the need of students to learn about the nature of science or how scientific knowledge is produced, communicated, and used to prevent the creation and spread of pseudoscientific information, which typically attempts to persuade people by claiming a false scientific status (Maia, Justi & Santos, 2021). Other debaters defend interdisciplinary approaches that connect the contents, goals, and competencies of science education to those of media and information literacy (MIL). They also advance the understanding of the role of modern media and the unforeseen possibilities of producing and accessing information (Höttecke & Allchin, 2020; Miller et al., 2021; Reid & Norris, 2016).

These three approaches for addressing information disorders – to use the concept suggested by Wardle and Derakhshan (2017) in the European context – reveal the multifaceted character of the problematic and raise the question of how information disorders require diverse pedagogical approaches. Notably, however, given the complexity of the problem, teachers and scholars in the natural science education community –influenced by references in the public political debate, which is frequently simplified – may fall for the simplification and polarization of discourse, such as taking all types of untrustworthy information under one concept, that is, the category of *fake news* (a more accurate term than "fake news," as will be addressed later). Indeed, when fake news became a catch-all term, experts have argued that it cannot encompass the different kinds of disorders related to the production, consumption, and dissemination of information, such as non-intentional misleading claims, true stories,

satires, and parodies (Habgood-Coote, 2018; Wardle & Derakhshan, 2017). In addition, the term has been observed to be contradictory in its essence. For example, in the practical handbook Journalism, *"fake news" & disinformation* (2021), specialists from different fields explain why debaters and discussants should not reiterate the concept of fake news as follows:

> It avoids assuming that the term "fake news" has a straightforward or commonly understood meaning. This is because "news" means verifiable information in the public interest, and information that does not meet these standards does not deserve the label of news. In this sense then, "fake news" is an oxymoron which lends itself to undermining the credibility of information which does indeed meet the threshold of verifiability and public interest — i.e., real news. (UNESCO, 2021, p. 7)

Apart from the terminology, other aspects of information disorders render the phenomenon increasingly complex than that typically portrayed in public. The objective of this study is to complexify the phenomenon of information disorder from the natural science perspective by providing educators with certain reflections selected to deepen and broaden the comprehension on the definition and understanding of the problem in natural science classes. The goal of this chapter is to discourage oversimplification in educational discourse in general and in science education in particular. Thus, the study challenges teachers and scholars to harbor coherent aspirations for aiding students in addressing the problem. This objective can be achieved by answering the following questions: What concept(s) should be considered instead of fake news? Why does ignorance not solely account for scientific informational disorders? In what ways are science and scientists also vulnerable to information disorders? Additionally, why is (science) education not the sole solution to (scientific) disinformation disorders?

Objective of this Chapter

This chapter aims to critically examine views about the information disorder phenomenon in the context of natural science education and/or the so-called science, technology, engineering, arts, and mathematics (STEAM) education, which provides a complex and coherent vision regarding the issue with consideration of the role of natural science educators. This text joins other initiatives on positioning scientific literacy and MIL in the contemporary world as an urgency. It prospects an adequate view on

how information disorders related to science circulate in society and – in certain circumstances – proposes what natural science teachers should (or should not) do about it. Similar to many analogous debates, at the end of the day, more questions may emerge than answers regarding the measures that should be undertaken in natural science classes given that the ultimate goal is to primarily add complexity to the issue. However, the professional discussion about the ongoing development is important.

This chapter commits to the approach of emphasizing the relevance of conventional perspectives on comprehending and addressing scientific informational disorders in line with insights from other studies. The latter advocates the transcendence of oversimplified and common-sense perceptions. To achieve this objective, this chapter draws on peer-reviewed publications dedicated to information disorder, education, and science communication. It encompasses diverse fields of knowledge, including science education, MIL, social communication, social psychology, epistemology, sociology, and philosophy of science. The chapter proposes a broad and in-depth description of "scientific informational disorder" without comprehensive intentions. The paper presents considerations from academic papers and news selected in an effort to problematize, ratify, and illustrate the arguments presented next. Lastly, it considers publications in English and Portuguese – the official language of Brazil – as well as the impact of science informational disorders on the social dynamics of this country.

First, we explore the major alternatives for the term fake news and identify the derivatives of the concept of information: disinformation, misinformation, and malinformation, as well as information disorder, which are transferred into the more particular context of scientific informational disorders. Thereafter, we proceed to the discussion of the other questions formulated to increase the understanding of science creators on potential approaches to the phenomenon. Producing pedagogical approaches requires the generation of pedagogical discourse that entails addressing values, attitudes, behaviors, and competencies, which makes advancing this type of qualitative inquiry and reflection important.

Alternatives to Fake News

As previously mentioned, although fake news has been integrated into the everyday vocabulary that stands for all types of "bad information" (Habgood-Coote, 2018) or "inaccurate things" (Tambini, 2017), the term is not based on a nuanced conceptual framework on the phenomenon of information disorders. Other terms, such as disinformation, misinformation, and malinformation, can fulfill this requirement (Wardle & Derakhshan, 2017). According to UNESCO (2018, p. 77):

> […] disinformation is generally used to refer to deliberate (often orchestrated) attempts to confuse or manipulate people through delivering dishonest information to them. This is often combined with parallel and intersecting communications strategies and a suite of other tactics like hacking or compromising of persons. Misinformation is generally used to refer to misleading information created or disseminated without manipulative or malicious intent. Both are problems for society, but disinformation is particularly dangerous because it is frequently organized, well resourced, and reinforced by automated technology.

This publication by UNESCO also makes reference to malinformation, which means "information that is based on reality, but used to inflict harm on a person, organization or country. An example is a report that reveals a person's sexual orientation without public interest justification" (UNESCO, 2018, p. 46). Malinformation is a subterfuge to play with the truth by considering a malicious goal achieved by violating a person's privacy. An example of a case of malinformation is the leakage of the personal information of Brazilian doctors by a Brazilian congresswoman – who feeds polemic against immunization – after the health professionals advocated in favor of children's vaccination against COVID-19 (Medeiros, 2022). After the leakage, groups of people attacked the professionals through social media in a clear attempt to strengthen a nonscientific point of view.

Using the two previous initial concepts and their meanings in the science communication context, Swire-Thompson and Lazer (2022, p. 125) define "misinformation as information that is contrary to the current scientific consensus and disinformation as having the added attribute of being spread deliberately to gain money, power, or reputation." However, identifying intentions from a piece of misleading information is not always unequivocal (De Ridder, 2021) such as in the case of conspiracy theorists who deeply believe (and are engaged in converting others) that

the earth is flat. Alternatively, a naive perception of conspiracy theories is not recommended, because they hold the potential to cause harm to the individual and the community aside from their real intentions. McIntyre (2019, p. 695) argues that,

> the flat earthers may not be hurting anybody directly but the confusion and doubt they spread helps to create a culture of denial that could cost lives indirectly by affecting congressional decisions about climate change and family decisions about vaccination.

Apart from the difficulty of identifying real intentions, disinformation, misinformation, and malinformation form a very useful framework for the phenomenon of scientific information disorders. The reason is that their respective meanings enable the elucidation of the people and forces involved in the occasional manipulation and misleading of others. For example, the deliberate attempts of tobacco corporations to mislead the public and deny well-established scientific knowledge about the risks of smoking are well known (Oreskes & Conway, 2011). In this previous episode of disinformation, profit-making intentions overlapped with the well-being of people.

Problematizing intentions to mislead or harm hidden in claims regarding science and scientists enables students and teachers to go beyond the simple task of marking as true and false information having scientific knowledge as rule and principle. The recent politicalization of socioscientific issues, such as climate change, vaccination, and nuclear power, confirms the importance of extending our action to more elements of information disorders. Recognizing and understanding concepts, such as disinformation, misinformation, and malinformation, can serve as an essential first step.

Scientific Informational Disorders

People engaged in consuming and sharing information disorders are typically described as irrational and highly influenced by appeals to emotions over reason; therefore, they are unable to understand natural science contents and engage in logical reasoning. In fact, the perception that information disorders are the result of irrationality and ignorance is very influential in debates on the role of natural science education and challenges related to information disorders (Goldenberg, 2016). In

summary, the image is seemingly that lay people are relatively deficient in competencies and abilities and are illiterate about certain knowledge and practices about natural science. These stereotypes extend beyond education boundaries that are very present in scientific divulgation strategies.

In this regard, in 2016, the Oxford English Dictionary selected the term post-truth as the word of the year, which denotes circumstances in "which objective facts are less influential in shaping public opinion than appeals to emotion and personal belief" (Oxford English Dictionary, n.d.). Oxford's definition of post-truth reiterates the cited perception that public audiences are essentially irrational; nowadays, more than ever, emotion, bias, and personal conviction have crowded the rationality and objectivity of people (Feinstein & Waddington, 2020).

Nevertheless, precaution must be taken about the previous argument on ignorance, especially when the discussion in in social debates exclusively center on the attempts to label one's opponents as irrational or ignorant. In the first place, stupidity and irrationality are features that no person is normally willing to accept, and simplifying the origins of informational disorder at this extent may even lead to worse problems. McIntyre (2019) warns that "parents who have questions about the safety of vaccines are often scolded by their physicians and told they're being irrational" (p. 696). However, according to McIntyre, this approach discourages parents and typically makes them search for alternative specialists (e.g., anti-vaxxers gurus) to obtain answers to their questions. Highlighting that people who hesitate to get vaccines or vaccinate their children do so not out of ignorance or irrationality is important. Instead, they perceive the risks of vaccines in terms that differ from those than science, whose ponderings on efficiency and uncertainty considers the population level (Sharon & Baram-Tsabari, 2020). This broad scientific discourse fails to convince these people, because they consider vaccine safety in terms of the particular health conditions and other particular features of their children such as genetic heritage and first-year development (Leach & Fairhead, 2007).

Through analyses of studies that conducted interviews on British parents in community-based postnatal groups in the early 2000s, Goldenberg (2016, p. 566) states that,

> [....] This effort by parents to figure out their own children's risk of adverse events should not be read as ignorance of science or as an anti-science view. Instead parents appear to be incorporating established knowledge that immune responses do vary and are trying to fill the knowledge gap regarding preceding or causal events.

In fact, framing the informational disorder problem by establishing ignorance or the lack of scientific literacy as its roots apart from simplifying it places science education in a privileged position, because the solution would rely nearly exclusively on educating people. However, this is insufficient for the solution of the causes. Goldenberg (2016) states three reasons for the refusal of the public to accept the scientific majority opinion, which can explain their tendency to give credit to scientific information disorders. The first is the most common, which has been presented and discussed: the general population cannot comprehend the scientific content of the consensus. The second is that the lay public is unable to comprehend the epistemic values of widely-held expert opinion. Here, a common understanding is that the second reason is also related to the ignorance argument in that, thus far, it refers to the lack of knowledge or competencies regarding the elements of scientific epistemology and practices, which can be taught and learned in natural science classes (Hottecke & Allchin, 2020; Miller et al., 2021; Reid & Norris, 2016). The last reason is also the last-considered one and refers to the recent weakening of the trust relationship between science and lay people, which casts doubts on scientific consensus and its epistemics weights.

In fact, the hypothesis that lay people lack the knowledge or the cognition (the ignorance argument) possessed by scientists, such that lay people are predictably vulnerable to believe and share scientific informational disorders, has substantial evidential support (Gomes, Penna & Arroio, 2021; Roozenbeek et al., 2020). Gomes, Penna and Arroio associate low levels of formal schooling with increased chances of believing in erroneous scientific information as per the following reports (in which only one of them is true): the death of bees due to genetically modified corn, a supposed machine that separates colorful balls using quantum physics, the potential of developing eye cancer by using cell phone in the dark, and an alleged virus infection that causes ulceration in the body and originates through contact with a species of cockroaches.

Alternatively, several lines of research have reiterated the evidence that cultural, political, and social affiliations influence the interpretation of people of scientific findings, especially in the case of socioscientific issues. The cultural cognition thesis (CCT) explains this phenomenon by positing "a collection of psychological mechanisms that dispose individuals selectively to credit or dismiss evidence of risk in patterns that fit values they share with others" (Kahan, Jenkins-Smith & Braman, 2011, p. 148). Supporting the CCT propositions, Kahan and coleagues (2012) provide evidence that concerns about climate change decreased among US Americans with the increase in science literacy and numeracy. Moreover, cultural affiliation influenced positive awareness among them than did scientific reasoning capacity. The study also demonstrated that attitudes toward climate change are polarized among people with more schooling, at least in the United States.

The previous finding does not present any unedited argument, which links subjectivities and historical and cultural contexts to the sense making of people about science. For example, Boulware and coleagues (2003) identified patterns of trust in components of the US healthcare system according to the race of respondents. Basically, African Americans presented low levels of trust as a potential result of a "legacy of racial discrimination in medical research and the health care system." In Brazil, partisan affiliation also seemingly influenced the perception of the population of scientific risks regarding COVID-19. Using an anonymous mobile location, card transaction data, and election information in 2018, the researchers documented a significant decrease in social distancing in pro-government regions after president Bolsonaro most visible events in the beginning of the COVID-19 pandemic advising the Brazilians against self-isolating behavior and policies (Ajzenman, Cavalcanti & Da Mata, 2020).

Notably, the lack of scientific literacy and cultural affiliation are seemingly coherent for explaining the people's perception of and interaction with science and risks and for providing a reasonable explanation of the elements that influence the circulation of scientific information in society. For example, one may not expect that students will comprehend the role of expertise and consensus and the critical role of credibility in scientific communication without knowledge about scientific concepts and the nature of science. Such comprehension is indispensable to avoid being misguided by the idea that climate change is a scam, hoax, or fraud (Allchin, 2005).

Although this work is not dedicated to solutions to the information disorder problem, sharing preliminary insights on addressing it with consideration of unique culture and values is important to enable the science education community to view it through a broad and complex lens. Feinstein and Waddington (2020) advise that, "If we wish to change how people grapple with scientific knowledge, we must understand their social and cultural positionality" (p. 6). Kahan and coleagues (2012) add that, "as citizens understandably tend to conform their beliefs about societal risk to beliefs that predominate among their peers, communicators should endeavor to create a deliberative climate in which accepting the best available science does not threaten any group's values" (p. 734).

Scientists as Vulnerable to Information Disorders

Undoubtedly, science offers powerful insights that help people act in and understand the world. This notion explains why science occupies a privileged epistemic position in modernity. However, scientific enterprise faces a parallel set of information disorder, which affects science development and may even worsen the general scenario of disinformation and misinformation if such disorders are *leaked* to the general public (Swire-Thompson & Lazer, 2022).

One of the most emblematic and disrupting episodes of disinformation about scientific practices became known as the Piltdown Man. In 1912, an amateur antiquarian and solicitor named Charles Dawson claimed to have discovered evidence of the *missing link* between man and ape. After contacting and convincing English paleontologist Arthur Woodward about the breakthrough discovery, archaeological evidence was collected of a human ancestor that supposedly lived 500,000 years ago. The findings obtained significant acceptance from the scientific community. However, 40 year later, with the arrival of new dating technology, the remains of the Piltdown Man were identified as artificially forged by the assemblage of an orangutan's jaw and the skull of a human. According to the British Natural History Museum of London (n.d.), "scratches on the surfaces of the teeth, visible under the microscope, revealed that the teeth had been filed down to make them look human […] Most of the finds from the Piltdown site had been artificially stained to match the local gravels." In 2016, another investigation indicated that Charles Dawson may be the mastermind behind the hoax and "his hunger for acclaim may have

driven him to risk his reputation and misdirect the course of anthropology for decades" (De Groote et al., 2016, p. 2). Notably, in the case of the Piltdown Man, science was used afterward as a remedy to unmask the hoax, although scientists were unable to identify disinformation before it was taken as a legitimate scientific theory.

One may argue that what this previous event is illustrative of scientific information disorder in that the anthropology science community was a victim of an *outsider* who was willing to put his name in the history of science by resorting to unscrupulous methods. However, this form of disorder is not rare among specialists, because "scientists compete for eyeballs just as journalists do. They face incentives to hype their work and to selectively publish those findings that are surprising and clickable" (West & Bergstrom, 2021, p. 1). In 1998, British gastroenterologist Andrew Wakefield and colleagues hypothesized a causal link between measles, mumps, and rubella (MMR) vaccine and autism in a study on 12 children, which was published in the prestigious medical research journal Lancet. The investigation was highly controversial due to its flawed methodology and speculative findings. Goldenberg (2016) underlines that Wakefield's study was developed with a nonsignificant number of patients and without a control group and departed from an uncritical approach that considered the testimony of parents who believed that MMR was the case of autism in their children. After the publication and intense media coverage, the health research community worldwide systematically discredited the study; in 2010, *Lancet* retracted the publication (Goldenberg, 2016). As a result of a four-month investigation conducted by British reporters, Wakefield was accused of receiving money as part of a legal action taken by the parents of the children against the MMR vaccine company (Embree, 2004).

Obiter, examples regarding the limitations of how science and scientists work are plenty, even among notorious professionals. The most prominent one may be Dr. Linus Pauling, a Nobel Prize winner in chemistry, who started a campaign for promoting the unsubstantiated proposition that vitamin C was an effective treatment for cancer and other illnesses. In terms of Pauling's case, Swire-Thompson and Lazer (2022, p. 128) comment that,

> … scientific expertise is extremely domain specific, and people who appear to have expertise can often do the most harm. […] if a cardiologist makes recommendations about climate change, the audience can see that this is an opinion rather than expert advice.

Without a doubt, science has problems; however, this notion does not imply that it is broken, which is an irresponsible inference made by eager denialists that depart from the failures and limitations of scientists and science. "Far from it. Science is the greatest of human inventions for understanding our world, and it functions remarkably well despite these challenges" (West & Bergstrom, 2021, p. 1).

With the emergence of the Internet, changes in the information production scenario have intensified the problems of the scientific information ecosystem. During the COVID-19 pandemic, publications with controversial claims and without systemic peer review were published online without restriction. Two cases stand out. The first was an allegedly scientific study posted on BioRxiv, which is a preprint platform for biology studies. The study alleged that SARS-CoV-2 is unlikely to be fortuitous in nature (BioRxiv, n.d.). The second refers to a two-page document shared on the academic social media ResearchGate (n.d.) and proposes that SARS-CoV-2 escaped from a laboratory in Wuhan, China. Despite the unsubstantiated arguments, the first document received intense media attention, which was retracted after intense repercussions; the second document became very influential within conspiracy circles (West & Bergstrom, 2021). Notably, MIL in cooperation with scientific literacy, which are both dedicated to the production of scientific knowledge and penetration into society, provides numerous contributions in this respect. This multidisciplinary approach may provide people with a critical view on scientific knowledge and its divulgation. The reason is that, today (maybe more than ever), scientific communication and media regulation tools (e.g., peer-review systems, paper quality parameters, and gate-keeping efforts by media outlets) dedicated to maintain a healthy scientific information ecosystem are insufficient or ineffective to a certain extent.

Indeed, science suffers from a series of limitations and problems that rarely give rise to scientific misinformation and disinformation: from predatory journals, publication bias, and pseudoscientists to misinformation and disinformation spread by legitimate scientists (for more examples and complex discussion, see Swire-Thompson & Lazer, 2022; West & Bergstrom, 2021; Saltelli & Funtowicz, 2017). However, why should the natural science education community take the problems of information disorders in scientific practices seriously? In this regard, Swire-Thompson and Lazer (2022, p. 132) make an interesting causal relation: "[…] If we do not improve the scientific information ecosystem, people will reduce

trust in all science, regardless of quality." In fact, a number of studies associate Wakefield's study and its intense repercussions worldwide to the low rates of MMR vaccine uptake and multiple breakouts of measles since the beginning of the 21st century, especially in Western Europe and North America (Hussain et al., 2018).

Despite its problems, the generalist perception that the public looks to science for accurate information even in times of constant and systematic attacks remains accurate. However, this reliance is highly dependent on trustiness, which is influenced by the production and circulation of scientific information in society (West & Bergstrom, 2021). Disinformation and misinformation produced in scientific practices could easily undermine this trustiness relation, which impacts science financing and its commitment to public good. As a result, this scenario may be catastrophic.

Science Education — Not the Only Solution

Education plays a pivotal role in helping people navigate through an era marked by significant and influential levels of information disorders. However, the expectations of scholars and educators from education are seemingly excessive, or, in certain cases, incoherently elevate education as the only long-term solution to information disorders. Problems related to the current informational age are part of a phenomenon that is sufficiently complex to not only rely on the efforts of formal education (Feinstein & Waddington, 2020).

Awareness of the extent to which science education may be effective is important given the complexity in which information disorders are embedded. For example, science teachers could cover natural science contents that will help students identify the flaws and health risks in the suggestion by Donald Trump that inoculation of disinfectants in people could kill SARS-CoV-2 and clear the lungs (Clark, 2020). In another scenario and based on the nature of the scientific approach, teachers could tackle problems associated with the lack of evidence and consensus of discourses that defend the administration of hydroxychloroquine and ivermectin in patients with COVID-19. Nonetheless, considering MIL, the last two initiatives could even be enriched by increasing the aware of students of elements that are typically used to increase the *credibility* of health-related claims such as logical reasoning and appeals to emotions

and authority (Locatelli, 2021). However, these approaches cannot be extended to elements whose actions will be more significantly affected by institutional regulation and stakeholder awareness. The Cambridge Analytica scandal, which involved the data collection of more than 50 million Facebook users to influence the 2016 US presidential election (Wong, 2019) illustrates the constraints of education and the importance of heavy regulations on data privacy and protection on the Internet.

Essentially, information disorders are not a problem exclusively for (science) education. This argument relies on scholars who link the contemporary phenomenon of information disorders to social changes such as recent partisan approaches of news media (Iyengar & Massey, 2019), the emergence of political polarization on climate and energy policies (Fraune & Knodt, 2018), and changes in the cultural status of science (Feinstein & Waddington, 2020). Therefore, caution must be taken regarding the idea that education alone can solve the problem given the complexity of information disorders regarding its cause–effect relationship. Notably, we highlight that this work does not deny education as an indispensable resource for addressing informational disorders. Once again, education plays a major role but needs to be accompanied and reinforced with the engagement of other actors and institutions.

> Education alone does not offer the long-term solution to the post-truth era. Education cannot regulate social media or prevent foreign disinformation campaigns, it cannot change laws to make policy elites more accountable to citizens, and it cannot eliminate the structural factors (entrenched special interests, gerrymandering, systematic disenfranchisement) that exacerbate political polarization. What education can do is help people cope in this fragmented and chaotic landscape of contested knowledge, in which some of the old institutional supports stand in need of repair or replacement. (Feinstein & Waddington, 2020, p. 3)

Awareness the limitation of education in this issue is crucial. Otherwise, society will be placing the onus of responsibility only on people who, once educated, will bear the responsibility to appropriately address information disorders. From this perspective, Feist and Waddington (2020, p. 2) poses a rhetorical question to the natural science education community: "If navigating the post-truth era is the responsibility of (properly educated) individuals, why fix the institutions?" Science educators need to be aware that systematic propositions are likely to exert much larger impacts and apply this awareness to teaching–learning practices.

For this reason, addressing informational disorders is also a problem for scientists, technology companies, news outlets, social media platforms, universities, research databases, and policy-makers.

However, others may expect that appropriately literate citizens will critically transform institutions and establish changes in the economical, societal, and political spheres, thus, mending the current chaotic landscape of contested knowledge. Although the previous argument makes sense, acknowledging that a citizen and critical perspective, which is subtended to a number of expected roles of education, is not an intrinsic condition to it is necessary for obtaining support in critical pedagogies (as an example). Instead, it is a political one that opposes itself to other established perspectives to maintain or drive social actors to positions of power or submission. The initiatives of Russia's so-called ministry of enlightenment in the areas they occupy in Ukraine illustrate this educational perspective. It demonstrates how an education system under state power can be used to disinform: in occupied areas of Ukraine's south, history classes are being taught differently using textbooks that make false statements about pre-war events (Devlin & Korenyuk, 2022). In other words, recognizing that education, apart from its constraints in helping citizens address information disorders, may be used to increase disarray is vital.

In this sense, Arroio (2020) reinforces the importance of education and the need to increase the number of studies on disinformation and education. In fact, these studies remain scarce, and only a few are focused on identifying disinformation among students and even less focus on teacher training and the impacts on their practices. This unfortunate scenario illustrates the urgent need for discussion on the role of MIL (Arroio, 2017), because a portion of the population with low levels of education is evident. As such, disinformation that stimulates intolerance and hate speech easily manipulates this low capacity for critical thinking (Arroio, 2019). Thus, science and MIL are imperative for nurturing *truth* in contemporary society.

Conclusion

This objective of this chapter was to address the information disorder phenomenon in the context of natural science education, which renders this phenomenon more complex that its typical portrayal even in a number of academic circles. The current study takes scientific information disorders

as objects of analysis and considers that a more complex and in-depth view about the issue may benefit the natural science education community in understanding and addressing the problem in classrooms. Importantly, this chapter, as a professional reflection, is a timely invitation to educators to acknowledge the disinformational complexity of science education and recognize the significant contribution of natural science and/or STEAM education and their pivotal role in rendering democratic societies less vulnerable to the risks of falsehood and fraud. Nowadays, fact-based thinking and inquiry do not justify themselves due to their intrinsic relationship with the natural world. Although science education requires social imagination to incorporate the social world and its structuration into its discourse. For example, deliberate attempts to segregate historical minorities, disrupt democracy, and discredit scientific knowledge are very influential and are shaping social dynamics worldwide, making some states that modernity is suffering from a *truth decay*. Therefore, a definitive need exists for additional articulated and critical approaches, which implies the fight for truth, science, and democracy.

This chapter initially intended to answer questions in a pedagogical context to resist oversimplification. It aimed to explore methods for addressing the informational disorder phenomenon in the context of natural science and/or STEAM education to strengthen the epistemological foundation of science education. As demonstrated by this chapter, this concept can be vulnerable due to the dependency on public debates. Moreover, several elements should be considered and integrated into the framework, such as the role of technology in scientific informational disorders, the expectations of people about science, facts and truth, and the relationship of science with other knowledge areas in democratic societies. The fact that the study overlooked these elements in this chapter does not mean that they are less important. Thus, we encourage readers to consider a broader perspective than that presented here. Moreover, we endeavor to contribute to driving scholars and teachers away from counter-productive approaches, which are based on problematic assumptions about scientific information disorders, and to promote effective approaches for addressing this complex challenge.

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