Post-Truth and Education

STS Vaccines to Re-establish Science in the Public Sphere

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Accepted: 2 October 2021 / Published online: 21 October 2021 © The Author(s), under exclusive licence to Springer Nature B.V. 2021

Abstract

Post-truth is a social condition that threatens the trust in science and people’s critical thinking. This paper analyzes some of the educational responses to post-truth, claiming the potential contributions of Science and Technology Studies (STS). Some of the responses based on traditional epistemology, characterized as *epistemological vaccines*, are contrasted with some of the possible responses based on a more complex and interdisciplinary knowledge of science and technology. It is argued that epistemological vaccines, despite having an enormous value in fighting against post-truth, are insufficient to transform this social condition and its implications for science and technology. It is sustained that a social epistemology and, moreover, an expert interdisciplinary approach to the knowledge of science and technology, such as the one offered by STS, is required to consolidate stronger educational strategies, formulating *STS vaccines*, that could be useful as a counterweight to understand and deconstruct post-truth. Given that the STS academic field has developed a good account of how scientific facts and social trust in science are constructed, it also has the capacity to show how post-truth and alternative facts are constructed, unmasking for whom it is important that we decry science. The conclusion points toward the urgency to rethink the current influence of the STS field in the educational context to relocate the STS education.

1 An Introduction to the Age of Post-Truth

Along with the COVID-19 pandemic which emerged in 2020, we also witnessed what the World Health Organization called an *infodemic*, “…fake news spreads faster and more easily than this virus, and is just as dangerous…” (Barzilai & Chinn, 2020, p. 107). This massive distribution and public acceptance of misinformation, along with the denial of well-established scientific claims and facts, are increasingly common practices that date back years and have been shaping a growing global context known as the *age of post-truth* (Chinn et al., 2020a; Fuller, 2018; McIntyre, 2018).
The Oxford English Dictionary declared “post-truth” as the word of the year in 2016. The term was defined as “Relating to or denoting circumstances in which objective facts are less influential in shaping public opinion than appeals to emotion and personal belief” (The Oxford Dictionaries, 2016, pant 1). In a post-truth era, there is a widespread confusion and an apparently epistemological disagreement, “…over what is known, how to know, and who to trust…” (Chinn et al., 2020b, p. 51). For Jandrić (2018), post-truth mixes data, information, knowledge, wisdom, but also, facts and emotions, reason and instinct. Post-truth is a social condition that threatens people’s abilities to distinguish true or more accurate statements about the world, eroding personal and collective decision-making in health, environmental, political, social, or economic issues (Barzilai & Chinn, 2020). This condition tends to grow due to the socio-technical development characteristic of digital societies, which facilitates and accelerates the circulation of huge amounts of mass information in social media (Feinstein & Waddington, 2020), but also due to political factors interested in manipulating this information for partisan purposes, or due to economic interests of companies seeking to increase their profits. In the age of post-truth, a social scenario is being outlined in which (Chinn et al., 2020b): trust in science has declined; social acceptance of misinformation and disinformation, mostly around politically or socially sensitive issues, such as vaccination or climate change, has increased; rejection of well-established claims and scientific facts supported by evidence has increased; personal experience, beliefs and opinions have been supported above scientific facts; anyone claims an opinion and functions as an expert; and social fragmentation and polarization of information consumption has increased, generating echo chambers or closed systems of information sources adapted to personal preferences, emotions and worldviews (Barzilai & Chinn, 2020; Feinstein & Waddington, 2020).

In the age of post-truth, two notions confl ate, frequently amplifying the spread of fake news: misinformation and disinformation. Misinformation is information that is false, but the person disseminating it believes it to be true; whereas disinformation is information that is false, and the person who is disseminating it knows it is false, so it is a deliberate, intentional lie, created by malicious actors to harm a person, social group or institution (Ireton & Posetti, 2018).

Sismondo (2017b) identifies five related ways in which post-truth manifests and amplifies itself in the public sphere: (i) when the feelings and emotional resonances predominate over the factual basis of an assumption about the natural or social world; (ii) when opinions and desires of what people want to believe predominate over the facts; (iii) when public figures take advantage of the widespread public inability to differentiate between fake news and truth and make false statements regardless of social impacts; (iv) when “bullshit” (Sismondo, 2017b, p. 588), dishonesty and demagoguery are normalized as part of public life; (v) when fake news and “do-it-yourself investigations” (Sismondo, 2017b, p. 588), are multiplied due to the increasing distrust in traditional media.

Peters et al. (2020) have postulated a viral theory of post-truth to explain the bio-informational spread observed during the COVID-19 pandemic. According to these authors, both post-truth and the pandemic share a viral character, in the sense that both have the ability to replicate themselves and make copies, spreading and establishing patterns of mass circulation in human populations. Although the purpose of this text is not to establish an epidemiological model of social propagation of post-truth, the work of Green et al. (2017) is a clarifier regarding the relevance that human mediation could have at the cascade formation processes, through interpersonal ties and social interactions, involved in the person-to-person transmission of misinformation and disinformation. Green et al. (2017) argue that gun violence follows an epidemic-like process.
of social contagion that is transmitted through networks of people by social interactions; they found that models incorporating social contagion (individuals influencing one another’s behavior) and demographics (e.g., age, sex, and neighborhood residence) predicted future gunshot subjects better than models based on social contagion or demographics alone.

The importance of the active role and the mediation of humans in the viralization of fake news has also been identified in the research developed by Vosoughi et al. (2018). Exploring the differential diffusion of all the verified true and false news stories distributed on Twitter from 2006 to 2017, Vosoughi et al. (2018) found that false news diffused significantly farther, faster, deeper, and more broadly than true news in all categories of information, and these diffusion dynamics were more pronounced for false political news than for false news relating to other categories, such as terrorism, natural disasters, science, urban legends, or financial information. In contrast with the expected behavior described by Peters et al. (2020), in which viral media do not distinguish between information and knowledge and could circulate and replicate any information regardless of its quality and truth value, Vosoughi et al. (2018) found how it was not robots nor viral network structures that were involved in the cascades that accelerated the spread of false news, but humans were more likely to spread them. As an alternative explanation for this differential diffusion, Vosoughi et al. (2018) argue that false news were more novel than true news, and inspired fear, disgust, and surprise in replies (whereas true stories inspired anticipation, sadness, joy, and trust), so people were more likely to share novel information because novelty attracts human attention and is more likely to be retweeted.

Undoubtedly, a major understanding of how post-truth is replicated and distributed socially is necessary to design effective and more robust preventive measures; beyond the educational actions that could be proposed, we need different and complementary approaches (psychological, sociological, anthropological, economical) to investigate the factors of human judgment that drive the spread of true and false news, even more so regarding the negative effects that post-truth has had in society. Vosoughi et al. (2018) warn, for example, about how false news could result in the misallocation of resources during social or natural disasters or the misalignment of business or political key decisions.

Many practices that once enjoyed a certain social prestige—such as protection of the free press, respect for the law, scientific expertise—in the age of post-truth have been strongly eroded and qualified as political practices (Giroux, 2018; Hoffman, 2018; McIntyre, 2021). Certainly, these institutions have been historically in tension with different kind of interest. A free press, for example, has been considered as one of the principles of democracy, but at the same time it has been also a myth, since in all democratic countries, political and economic pressures have limited the free press, subordinating it to the powers and interests in turn (Schenkel, 2005), particularly in those that have lived through authoritarian regimes, dictatorships, and military governments, as in the case of most of Latin American and Asian countries throughout the twentieth century (Sánchez & Gil, 2018). In the age of post-truth, the undermining of these institutions, combined with the global power of digital media, has created a fertile space for the amplification of misinformation and disinformation, and a general distrust in science.

The public adoption of alternative facts above scientific ones has relevance not only intellectually, but educationally and in the future of societies, since denying climate change or even the existence of the COVID virus, for example, threatens the survival of human beings (Lima et al., 2020) and also damages democracies, since these require informed citizens and public and educational spheres that “…uphold standards of truth, honesty, evidence, facts, and justice…” (Giroux, 2018, p. 198).
The ideological denial of scientific facts is, for McIntyre (2018, 2021), one of the results of admitting, increasingly without rigor, confirmation bias and a reasoning based on ideologies, generating polarization in audiences convinced that scientific facts are such only to the extent that most audiences agree or disagree ideologically with them. For Barzilai and Chinn (2020), the origin of post-truth is related to the difficulty involved in the definition of truth in epistemology, where theories such as coherentism or pragmatism seem to have relativized the meaning of truth. Notwithstanding the epistemological difficulties for its characterization, it is undeniable that the statements qualified as true, highly reliable, or scientific have a social and instrumental value for decision-making in individual and collective life (Villoro, 1982). Nevertheless, they are always tentative and subject to revision, so the social defense of science should be the responsibility of all, and especially of education and science, technology and society studies (STS), as will be argued throughout this text.

As Giroux (2018) states, it is necessary to reconnect democracies with the virtue of truth-telling and with political and economic justice, and an alternative way to achieve this is by vindicating education and its social sense as a valuable institution and cultural force with the capacity to eradicate post-truth. The role of education against post-truth is fundamental insofar as the new modes of illiteracy, which, in the view of Giroux (2018), promote consumption and self-interest, have become a form of political repression that discourages questioning, informed judgment and critical agency, depoliticizing people, and facilitating the reproduction of domination.

According to Giroux (2018), education requires a: “…new language for addressing the changing contexts and issues facing a world in which there is an unprecedented convergence of resources—financial, cultural, political, economic, scientific, military, and technological—increasingly used to exercise powerful and diverse forms of control and domination…” (p.205). I argue that this educational language could well be nurtured by the STS field, as it meets the criteria envisioned by Giroux (2018), in the sense of being a self-reflective and directive language, which recognizes pedagogy as a political action to develop subjectivity and epistemic agency, and which makes transparent how knowledge relates to and co-produces with power and society.

This paper aims to critically analyze some of the educational responses to post-truth from the point of view of the potential contributions of the STS academic field; so it first presents a literature review about how education has responded to post-truth, and then it argues for the relevance of adopting an STS approach to enrich the most common educational strategies reported in the literature. The text is organized as follows: “Section 2” describes some of the main educational responses that have been promoted in the current educational context to address post-truth, showing a predominance of epistemological strategies. Based on the contributions of traditional epistemology and psychology to the understanding of how a science denier behaves, how do we know, and how education could facilitate an apt epistemological performance of an individual, the educational focus has been located in the achievement of epistemic aims by employing appropriate and reliable epistemic ideals and processes. Given their strong foundation on traditional epistemology, the most common educational strategies against post-truth that are reported in previous research are characterized, in this section, as “epistemological vaccines.” Subsequently, it is argued that these “epistemological vaccines,” despite having an enormous value in the fight against post-truth, are insufficient to transform this social condition and its implications on science and technology. “Section 3” proposes that in the educational context it is not enough to resort to a traditional epistemology to unveil the lack of epistemic support of post-truth, but rather a social epistemology is required, or more so, an expert
interdisciplinary approach in the knowledge of science and technology such as that offered by STS, to consolidate educational strategies with greater solidity, which would serve as a counterweight to stop post-truth; that is, we need a science education endowed with “STS vaccines.” “Section 4” shows how the same conceptual and methodological tools developed by STS, which for some authors have contributed to the emergence of post-truth, are the same that could provide strategic guidelines to eradicate post-truth and reverse the current discrediting of scientific practices. STS educational strategies against post-truth or “STS vaccines” articulate the contributions of the sociological, political, anthropological, economical, historical, and epistemological dynamics of science, facilitating a more comprehensive explanation around how scientific knowledge is developed, stabilized, and established. Since the STS field is the one that has shown how scientific facts and social trust in science are constructed, this paper argues that the STS field could also show how post-truth and alternative facts are constructed, and whose interests are behind post-truth, causing the public’s distrust in science.

2 Educational Responses to Post-Truth: Epistemological Vaccines

In a context in which vaccination is one of the main alternatives to face the COVID-19 pandemic, and in which climate change threatens with new pandemics and natural catastrophes (Beyer et al., 2021), science denial and distrust require solutions from education, and particularly from science education, as one of the institutions with the greatest possibilities of contributing to combat post-truth.

While it is true that education alone could not offer long-term solutions to fight post-truth, given that it does not depend on it to regulate mass media and social media or disinformation campaigns and the structural and political factors that exacerbate audience polarization, education indeed could contribute in various ways to re-establishing trust in science and the defense of evidence (Feinstein & Waddington, 2020). Certainly, educational responses to post-truth have been very diverse and heterogeneous; however, Barzilai and Chinn (2020) have systematized educational responses to post-truth into four lenses, identifying some of the ways in which these educational actions could aggravate or mitigate post-truth problems. These authors also recognize that the multiple ways of dealing with post-truth have been dependent on their context and the different pragmatic and social conditions in which each educational process takes place. The lenses proposed by Barzilai and Chinn (2020) are (i) “Not knowing how to know” (p.110); (ii) “Fallible ways of knowing” (p.112); (iii) “Not caring about truth (enough)” (p. 113); and (iv) “Disagreeing about how to know” (p. 114).

These different ways of dealing with post-truth are not mutually exclusive and, as Barzilai and Chinn (2020) note, these responses show that the epistemic development needed to deal with post-truth requires considering the multifaceted and adaptive nature of epistemic performance, encompassing strategies ranging from digital literacy to teaching about the nature of science, including the strengthening of metacognitive processes.

(i) Not knowing how to know: includes educational responses that consider that post-truth is the result of gaps in knowledge and reasoning skills needed to evaluate the information circulating in different spheres, including the digital one, so their focus is on training in such skills as fact-checking online claims, evaluating memes, identifying media biases, and digital and media literacy, among others.
According to Barzilai and Chinn (2020), the educational responses that have been most implemented and empirically studied correspond to this category, that is, those strategies focused on filling knowledge gaps and on the development of reasoning skills. One of the most relevant examples is McIntyre’s work (2019; 2021). McIntyre has devoted much attention to compiling psychological, sociological, political, and experimental studies concerning the possibilities and conditions for changing erroneous beliefs based on the presentation of facts and evidence. For this author, contending against post-truth implies not only working with the content of science, but also with the method of thinking behind science denial, through implementing strategies that contribute to unjustified beliefs change and the defense of scientific reasoning. According to McIntyre (2019, 2021), recognizing the most common tactics used by science deniers to discredit scientific facts—though insufficient to eradicate post-truth—facilitates having some general strategy to challenge misinformation and stop its distribution, thus mitigating its negative effects. The five tactics on which the author focuses are “(1) Belief in conspiracy theories; (2) Cherry-picked evidence; (3) Reliance on fake experts (and dismissal of actual experts); (4) The committing of logical errors; (5) The setting of impossible expectations for what science should be able to achieve” (McIntyre, 2021, pp. 195–196).

(ii) Fallible ways of knowing: includes educational responses that consider that post-truth results from cognitive biases and limitations that are amplified in informational environments, producing erroneous judgments, so their focus is to strengthen thinking and metacognition skills, maintaining epistemic vigilance and monitoring the reliability of the information being analyzed.

In this category, we could mention Schmid and Betsch’s (2019) study. This research is one of the first to provide experimental evidence that it is possible to fight against misinformation regarding scientific topics (McIntyre, 2021). Schmid and Betsch (2019) tested four strategies to change the misbeliefs of those who have been exposed to scientific misinformation: (1) offering no response that refutes the misinformation; (2) developing a topic rebuttal, which consists of providing correct factual information to subjects to correct the misinformation; (3) developing a technique rebuttal, i.e., uncovering the technique of science denial, out of the five tactics listed by McIntyre (2021), is the one that is used to sustain the misinformation in order to uncover and refute it; and (4) using a combination of both types of rebuttal. Schmid and Betsch (2019) found that a public debate with a science denier has a damaging effect on audiences, causing a change in their positive attitudes and intentions about science. The rejection effect increases when no response is implemented to refute a science denier. Technical rebuttals were equally effective as topic rebuttals and both proved their ability to mitigate science denial, allowing science advocates to opt for one or the other depending on their expertise and confidence on a particular topic. The combination of the two showed no additional benefit to the mitigating effect of science denial.

(iii) Not caring about truth (enough): includes educational responses that consider that post-truth derives from a lack of commitment to the pursuit of epistemic aims and ideals and reliable ways of knowing, putting personal political and ideological preferences above facts; the focus of these responses is on reactivating epistemic disposition and agency, motivating attitudes of intellectual humility, honesty, curiosity, open-mindedness, perseverance, impartiality, objectivity, as well as promoting the effort to evaluate evidence and corroborate information.
In this category, we could place Nyhan and Reifler’s (2019) study, who explored the concept of identity threat to refer to the tendency that, if someone finds information that they consider threatening towards their identity, even if this information is scientifically sound, it will be rejected by that person (McIntyre, 2021). Nyhan and Reifler (2019) identified that the mode of presentation of correct information was a relevant aspect to adopt; this finding suggests that to eradicate post-truth, it is not enough to have correct factual information, but the emotional, psychological, and social context in which the different beliefs are formed is very important, as this determines what information could be considered as threatening to the identity of a person who is a member of a particular culture or collective. This implies that correcting erroneous scientific information is not equivalent to changing personal worldviews or identity paradigms (McIntyre, 2021).

McIntyre’s (2019, 2021) work could also be located in this category, when this author states that the personal context in which the presentation of facts and evidence takes place plays a fundamental role in contributing to diminish the increasing science denialism, together with the cultivation of attitudes of respect, patience, understanding, and with the commitment that scientists should develop in defense of science. At the core of these attitudes, McIntyre places humility as a determinant attitude to distinguish between those who defend scientific facts and those who deny them, while arrogance is a barrier that prevents eradicating misinformation and combating the post-truth that circulates virally in mass and social media. A similar approach based on the cultivation of intellectual virtues and development of identity in science can also be found in the analysis developed by Lapsley and Chaloner (2020).

Arrogance is one of the barriers identified by McIntyre (2021) to the kind of trust, engagement, and commonality of belief that we need to defeat the science denial characteristic of post-truth. According to McIntyre (2021), scientists consider science deniers to be arrogant when they believe that (a) one’s own knowledge is superior to scientific knowledge, even when they lack training on a topic; (b) scientists must respond to every dubious claim made by science deniers and to all objections, even if they are mis- or dis-informed; (c) scientists are corrupts mobilized by political or financial interests in their research; (d) science deniers are “more scientific than the scientists” (p.195), because they consider alternative facts and a diversity of information sources, and because they possess some truth that no one else knows. Similarly, science deniers consider scientists to be arrogant when they (a) insist that they already know all the answers, ignoring uncertainties; (b) consider only scientific data, ignoring another information sources; (c) consider any questioning to their work as irrational or ideologically motivated; (d) do not admit debating with science deniers or the possibility of being wrong. The transformation of these arrogances implies the reestablishment of constructive dialogues between science deniers and those who sustain, produce, and defend science.

(iv) Disagreeing about how to know: includes educational responses that consider that post-truth derives from the lack of a shared epistemology and the increasing influence of alternative and competing epistemologies, so the focus of these responses is to teach that there are different legitimate epistemologies, each one aligned with different purposes and aims, evaluative ideals, criteria, and epistemic processes, and that recognizing and sustaining this pluralism does not imply adopting an epistemological relativism.

In this category, we could locate the study conducted by Chinn et al. (2020a), for whom one of the main challenges in facing post-truth lies in the lack of preparation to recognize that many epistemic disagreements are rooted in not knowing how to distinguish the
different legitimate ways of knowing, and what kind of knowledge is valuable or reliable. According to Chinn et al. (2020a), it is important to differentiate between basic epistemic disagreements (which involve the permanent discussion about facts that is proper to the dynamism of science, with an emphasis on scientific contents) and deep epistemic disagreements (which involve differences regarding the procedures for knowing that are considered legitimate, emphasizing how to know). Deep epistemic disagreements represent educational opportunities for dialogue and criticism because they involve debating and making visible what the aims of a knowledge generation process are, what are the criteria to evaluate evidence for that knowledge, and what are the processes that are considered reliable to follow for producing and validating that knowledge. In short, they involve the review and examination about how to know at the center of the problem (Chinn et al., 2020a).

For Chinn, Barzilai and Duncan, promoting apt epistemic performance requires shifting the focus from a content-centered education, promoting cognitive engagement, as well as regulation and metacognitive reflection in an adaptive manner to different situations, towards a new focus on describing different ways of knowing, evaluating them, and inquiring about them. An apt epistemic performance is understood, therefore, as the successful achievement of epistemic aims and goals by employing the most reliable epistemic ideals and processes in different situations (Chinn et al., 2020b).

Chinn et al. (2020a) propose incorporating into education an instructional approach named explorations into knowing, which develops collective and individual skills to make visible the epistemic assumptions on which the circulating affirmations are justified and negotiated; that is, to recognize the multiple background epistemologies. This instructional approach consists of promoting an educational and cognitive commitment to epistemic performance, generating attitudes of curiosity, inquiry, and intellectual responsibility to regulate and understand that any epistemic performance requires both metacognitive skills and permanent collective discussion to resolve epistemic disagreements, adapting this performance to different situations, domains and scientific areas. Exploring different ways of knowing is also an opportunity to vindicate epistemic values that have been marginalized in education, such as reliability, generativity, epistemic justice (Chinn et al., 2020a), and pluralism.

Some of the epistemological aspects of the science contents—for example, the criteria for evaluating the quality of evidence, or the epistemic aims and ideals that guided the processes of knowledge—are often implicit in current curricula and are not usually explicit in teaching. Chinn et al. (2020b) argue for the relevance of making them explicit to support a sound understanding of different epistemologies. This would enrich the learning of skills to identify why science is a reliable social practice to produce knowledge, which are the different expertises that are relevant within a topic, the degree of consensus achieved, the quality of the communication channels of that knowledge to circulate, recognizing the degree to which certain social processes and contexts make science reliable in comparison with another forms of knowledge. In sum, these authors propose to make epistemological performance a key competence across the curriculum.

Even though these educational responses, grouped into four lenses, are fundamental and necessary to fight post-truth, they are incomplete and insufficient, as they omit the social character of knowledge and other characteristics of scientific practice that explain how scientific knowledge is generated and circulates, always mediated by and intertwined with society. If one feature of the age of post-truth is the distrust in epistemic systems such as science, the challenge of education is to contribute to reestablish it, showing how these epistemic systems socially produce and distribute knowledge, and how their
trustworthiness resides in the social (Levy, 2007). Of course, this also entails recognizing the social biases that systems such as science have generated throughout history, by gender, race, social class, or the epistemic injustices created or the exclusions of certain voices, in order to correct them and to co-produce new social and epistemic practices; as Chinn et al. (2020b) point out “…It is vital to examine not only virtuous institutional practices but also vicious ones…” (p. 57).

Most of the strategies exemplified above, and which I call “epistemological vaccines,” though pertinent and useful for identifying truth and contend post-truth, are based on traditional epistemology, so, as Jandrić (2018) argues, they are insufficient because they deal primarily with the individual, and post-truth is an inherently social phenomenon. Instead, post-truth should be addressed using the approach of social epistemology, which investigates the collective production of scientific knowledge and its social consequences, for example, on issues such as democracy, the free press, or ethics (Jandrić, 2018).

Feinstein and Waddington (2020) share this criticism. For them, most of the alternatives developed by education are limited because they focus their attention on preparing people to use the epistemological tools of scientists to recognize what is true, forgetting that science does not offer a foundational truth, and also because these strategies ignore the fact that people always relate to science as members of a social and cultural group, in conjunction with other members of these groups, and not in isolation. Furthermore, science does not have the capacity to solve all personal and civic problems, but only a part of them, hindering to appreciate its public value. For these authors, responding to the age post-truth requires focusing on the question of how education could foster an appropriate use of science in a specific cultural context.

Thus, Feinstein and Waddington (2020) distinguish between an internalist and a contextual approach to science teaching. On the one hand, the internalist approach focuses on teaching the key contents of science and the idealized features of the inner workings of scientific practice, and in consequence it responds to post-truth by presenting cases of the superiority of science and the robustness of its knowledge. The contextual approach, on the other hand, emphasizes the relationship between science and other domains of everyday life, and its response to post-truth consists of clarifying the relationship between science and everyday life and examining when and how science can be useful. Feinstein and Waddington (2020) also distinguish between an individualistic approach that will prescribe a response to post-truth focused on inoculating students with accurate conceptual content and sound reasoning skills, and a sociocultural approach that will seek to improve socially shared practices to collectively make sense of and take advantage of scientific knowledge.

Given the current predominance of internalist and individualist strategies for combating post-truth, according to Feinstein and Waddington (2020), a more robust adoption of a contextual and socio-cultural approach is required in order to normalize and clarify that: scientific knowledge should be understood as the most reliable knowledge at a given time, but it is subject to refutation and change; that science does not offer solutions to all personal and civic problems; and that science takes its meaning and social interpretations in specific contexts in which it plays the role of only one of the inputs needed for informed decision-making (Feinstein & Waddington, 2020).

If the aim of fighting post-truth is to change the relationship between science and the public, it cannot be ignored the social and cultural positionalities and matrices from which people relate to science and from which scientific evidence is evaluated. Belief changes and the rejection of fake news do not happen in isolation; rather, they are intertwined with people’s cultural identities and epistemologies, as well as their social interactions and the worldviews they inhabit. These cultural and social contexts constrain and facilitate making
sense of science, so social and civic discourse must be incorporated as a part of the epistemological strategies proposed in education to help students generate and reestablish trust in science, and to recognize its relevance to their individual and collective needs and interests (Feinstein & Waddington, 2020).

This understanding of the social dimension of science, along with its economic, political, historical, ethical, ecological, and other multiple dimensions that configure the diverse contexts of scientific process, has been the main focus of the STS academic field. One of the main conclusions of this field has been accounting for the co-production of science and society. STS has demonstrated that at the same time that the social and cultural contexts configure, enable and limit the scientific practice, the contexts are themselves a driven force reconfigured by science, changing society, and its identities, materialities, values, worldviews, and, generally, the intersubjective and interobjective relationships that humans establish with each other and with the world. However, these theoretical contributions derived from the analysis of scientific practices, that have clarified the complexity of their relations with the social (Law, 2017; Soler et al., 2014), seem to be absent in the educational field. Even though STS has built a long trajectory in education, and very particularly in science education, configuring the so-called STS approach in education (Aikenhead, 1997; Yager, 1990; Pedretti & Nazir, 2011; Ozgur et al., 2017), STS contributions in the post-truth debate seem to be disarticulated in educational contexts. Perhaps because STS education has been diversified in multiple innovative pedagogical strategies (Pedretti & Nazir, 2011), such as the socioscientific issues—SSI—(Sadler, 2011; Zeidler et al., 2005), place-based education (Buxton, 2010), science education in context (Brzezinski & Silva, 2018), science education as practice (Stroupe, 2014), among others, this approach has been blurred in the last years, losing its identity and relevance.

As Peters (2018) points out, “... it is not enough to revisit notions or theories of truth, accounts of “evidence” and forms of epistemic justification as a guide to truth; we need to understand the broader Orwellian epistemological implications of post-truth politics, science, and education...” (p. 149). The epistemological vaccines that could be fostered in education do prepare us very well to understand the nature of misinformation and the possibilities for correcting it, but we also require other types of educational vaccines that allow us to identify how science and post-truth are or not similar and what makes post-truth different from scientific productions, in order to decide whom and why to trust. The following section develops the relationship between the STS field and post-truth to argue that STS has much to contribute to education. Then, in “Section 4,” I present the three main analytical strategies derived from this interdisciplinary field that could be incorporated into education as STS vaccines against post-truth.

3 Social Studies of Science and Technology, and Post-Truth: Educational Implications

STS is an interdisciplinary field that explores the ways in which science and technology shape the world, objects, values, institutions, in sum, society and culture, and vice versa, that is, how society and culture are shaped and constituted by science (Mansour, 2009). Through the study of scientific practices (Law, 2017; Soler et al., 2014), STS has unveiled that science, technology or society cannot be studied in isolation, as they are mutually produced and constitutive of each other (Subramaniam et al., 2017), and that this historical co-production of epistemic, technological, and social orders endows knowledge processes
with a situated and performative character through which societies configure and reconfigure our identities, bodies, and cultures (Felt et al., 2017). The role of STS in the emergence of post-truth, expressed as a social climate of science denialism and alternative facts generation, has been discussed by authors such as Sismondo (2017a, b); Lynch (2017); Collins et al., 2017); Fuller (2018), Hoffman (2018); and Katic (2020).

Katic (2020) synthesizes these debates into three broad possibilities that explain the relationship between STS and post-truth. In the first possibility, he assumes that science studies played a role in post-truth and therefore must transform its assumptions. This stance has been defended by Collins et al., 2017), who argue that STS revolutionized science by proposing the democratization of knowledge, putting scientific expertise up for debate, and showing how politics and the social influence science. In contrast to Sismondo (2017a, 2017b), these authors claim that the symmetry principle of the strong program of the sociology of knowledge encourages the skepticism about experts and opened the cognitive terrain to all forms of politics, including populism (Collins et al., 2017).

The symmetry principle is one of the four postulated by Bloor (1976) as a part of a sociology of knowledge. According to Bloor, the social study of knowledge should be symmetrical in its style of explanation, that is, “… the same types of causes would explain, say, true and false beliefs…” (Bloor, 1976, p. 7). The other principles are those of causality, impartiality, and reflexivity. According to Lynch (2017), symmetry refers to the effort of sociological analysis to seek socio-historical explanations for any belief, regardless of its epistemic status, whether it is true, successful, rational, or not. Symmetry, of course, does not mean resorting to epistemological relativism or dismissing the true, rational, or successful character of a belief given its social nature. In other words, the social nature of knowledge does not imply its falsity or disbelief, just as the symmetrical orientation of an analysis of knowledge does not imply the democratization of science (Lynch, 2017).

Collins et al. (2017) argue that because STS has a specialized understanding of the organization and values of science and is an expert field of scientific expertise, it could make a distinctive contribution—not available to other political actors—in contending post-truth. STS should question the work required to sustain post-truth and examine how this work relates to or differs from that required by scientific knowledge. STS analysis would allow us to understand that science is not just another form of politics and that post-truth is not based on the expertise of science; likewise, STS would outline possible ways to resist the populisms that support post-truth and alternative facts (Collins et al., 2017). In the view of these authors, STS should therefore rethink itself as a field of Studies of Expertise and Experience (SEE)—what is known as the third wave of STS (Collins et al., 2017; Caudill et al., 2019)—and should rethink and defend the value of experts in democratic societies too (Collins et al., 2020).

As a second possibility to investigate the relationship between STS and post-truth, Katic (2020) gathers those authors who consider that STS caused post-truth, but does not need to charge or apologize, that means, nothing could be done about this consequence except to assume the responsibility of academia. In this position, he places the contributions of Fuller (2018), who points out that epistemic democratization caused a questioning of scientists that was and is exploited by right-wing politics. Through the tasks of examining the black boxes that sustained the construction of scientific facts, and of accounting for the processes of negotiation, disputes, resistances, consensuses that come into play in the conformation of networks of human and non-human actors, STS contributed to generate the skepticism towards expertise and scientific authority that currently prevails. Fuller (2018) argues that post-truth is the result of universalizing the principle of symmetry of the strong program of the sociology of knowledge and that
the way out is to accept that knowledge is a social and political game of power that must be played with the same rules of politics.

Finally, as a third possibility, Katic (2020) postulates those authors who refer that STS has no relationship with the development of post-truth. In this position he places the contributions of Lynch (2017), for whom there is no evidence that sustains links between STS and post-truth, because although STS accounts for how scientific knowledge is constructed, post-truth claims (for example a published tweet postulating an alternative fact) is not knowledge and because, ultimately, STS’ ideas and concepts are not being used by those who produce and disseminate post-truth. For Katic (2020), post-truth should be seen not as an attack on science, but rather as an opportunity to refresh the questioning of whose interests science is serving, and to rethink the political consequences of assuming a radical constructivism and relativism in science studies.

Sismondo (2017a, b) could also be placed among those authors who argue that STS is not responsible for the development of post-truth, since epistemic democratization cannot be simplified to fake news and post-truth. Sismondo (2017b) recognizes that the construction of knowledge and the development of technoscientific infrastructure requires a particular social organization, structures of effort and validation, and particular assemblages and configurations of practices, discourses, and institutions; and he notes that all knowledge produced by STS is also a potential solution against post-truth and could be very useful to understand the epistemic competition between fake and real news and to reject technocracy or the image of expertise as sectarian. His position is that STS has made it possible to show how the scientific is demarcated from the non-scientific and how the epistemic authority of science is achieved, so this field could shed light on the factors that produce and sustain post-truth and that make it similar or different from science.

For Hoffman (2018), post-truth has put STS studies in the difficult position of defending the legitimacy of science, recognizing the complex and contingent character of construction of scientific facts. In his view, STS seems to have contributed to sowing a form of populism, in the sense that, with a strong commitment to social constructivism, STS adopted as one of its arguments the need for a “democracy of knowledge” and “citizen scientists” (Hoffman, 2018, p. 446). In its efforts to show that science and politics were imbricated, STS may have promoted the misinterpretation that both science and politics share the same processes of justifying the legitimate. This author argues that STS is not responsible for this moment of post-truth that is so closely linked to Trump’s government in the USA, because the discrediting of science that accompanied this administration responds rather to a strategy of demagoguery (Hoffman, 2018). This strategy consists of a leader identifying with common people, mobilizing outrage against an elite in society, convincing them that said elite is taking advantage of society; subsequently, the demagogue generates a visceral connection with these followers, fostering their anger and resentment; finally, the demagogue engages in a concerted effort to create confusion and thereby breaking down existing institutions, norms, and the law (Hoffman, 2018).

In contrast to this position, Collins et al. (2017) argue that STS is not a democracy-promoting political movement, but an academic field specialized in understanding the nature of knowledge, and as such, it has political consequences. Consequently, this field has the responsibility and the possibility of finding ways to justify and guide the choice among competing forms of knowledge as inputs to inform public opinion and policies, without falling into advocacy for a technocracy, but also without giving further guidance to enhance the political, decontextualized and relativistic misuse of some of its theoretical contributions.
Hoffman (2018) adds to the critique made by Marres (2018) about fact-checking services to correct fake news or internet rumors, because they produce a reliance on technical tools that distract attention from the public crisis around evidence. These technologies that regulate the circulation of online content and the selection of information sources reinforce the normative problem of non-distinction and blurred boundaries between false and true, reliable and unreliable, valuable and non-valuable, without questioning how information is structured and disseminated on the Internet and how the social media ideological bias could be influenced and transformed.

When we assume in the educational context one of these three possibilities about the relationship between STS and post-truth, the implications are very complex and heterogeneous, but in general terms, could be synthesized as follows: If the second possibility is assumed, it implies accepting that knowledge is a social and political power game that must be played with the same rules of politics, so STS in science education becomes indistinguishable from political education, and similarly the STS field runs the risk of being reduced to political science. Although it is true that the STS approach in science education includes a strong component of political and citizenship education, the interdisciplinary study of science that the STS field proposes cannot be reduced only to these political and power components (Hodson, 2020). While students’ capacity for political and/or moral reasoning can be fostered through the STS educational approach, to achieve an understanding of contemporary science and why it is trustworthy, it is not enough to develop a political literacy reducing STS to the knowledge of how to participate in democratic deliberations, how to distinguish and deal with disagreements and conflicts between political ideologies, or having an awareness or an understanding about the power in science, society and in the public life, deploying the knowledge and skills to debate and to deal with political adversaries (Hodson, 2020; Lo, 2017).

In contrast, assuming either the first or the third possibilities implies adopting a much more integrative perspective of science and science education, more appropriate to the contributions of the STS field, which allows for a more precise and realistic understanding of how scientific knowledge is constructed, and why it is not limited to only recognizing the political dimension of science. STS includes other major categories coming from economics, history, sociology, anthropology, and philosophy of science that are necessary for learning about science and scientific practice, to understand at least:

…the characteristics of scientific inquiry, the role and status of the knowledge it generates, the social and intellectual circumstances surrounding the origin and development of important scientific theories, the ways in which the scientific community establishes and monitors professional practice, including clear understanding of the linguistic conventions for reporting, defending, scrutinizing and validating scientific claims, and awareness of the complex interactions among science, technology, society and environment… (Hodson, 2020, p. 594).

In this way, choosing between the first or the third possibilities entails adding to a different STS conceptual vocabulary and tools. As Gorur et al., (2019) warns, STS is an active academic field that is continuously diversifying, so inside it there are a wide range of theoretical and methodological approaches and disagreements among scholars. Adopting the first possibility or the third one, reflects part of the STS’s debates and dynamism.

In general terms, we could say that if the first possibility is assumed, in which the STS field should be rethought as a field of Studies of Expertise and Experience (SEE) and defend the value of experts in democratic societies, the STS approach in science education would stress how expertise should function in public policy contexts. This requires
learning an analytical perspective of scientific facts, capable of distinguishing between two different institutional practices in the decision-making process regarding a scientific issue: a technical phase and a political phase (Caudill, 2020). In the technical phase, it is developed a political process that is internal to scientific practice, in which expert advice could be provided from two sources: from formally trained scientists or experience-based experts, who are identified as contributory experts (insofar as they can contribute to the relevant field), and from relevant interactional experts, who could be non-scientists, or scientists from another field (insofar as they know the language of a domain and can interact with core scientists). In the political phase, external to the scientific process, all citizens in a democracy have an equal stake, and the right to participate along with the governmental institutions to make a political decision concerning a scientific fact (Caudill, 2020).

This STS position has been successful in reaffirming the importance of expertise, and clarifying the “architecture” of expertise and experience (Caudill, 2020), but the problematic aspect is that it implies that always it is possible to distinguish both phases in the scientific practice; in other words, there is an empirical and clear frontier between the internal and the external dynamics in the science, and each one of the moments of the constitution of a scientific fact, could be easily approached in the educational context. Much of the work of tracing the practices of knowledge-making has demonstrated that this division is not given, but also a socio-material construction (Gorur et al., 2019).

If the third possibility is assumed, the STS emphasis would be on recognizing relationality; that implies teaching students how “science is a practice of fabrication and objectivity” (Decuypere, 2019, p. 141) and how relations make the practice. In this possibility, scientific facts as well as post-truth should be empirically examined to understand how different actors and agencies were related, engaged, and implicated each other, explaining the way facts (whether they are true or false) have come to be the way they appear. Here, stressing the importance of articulations and relations is at the heart of the making of scientific practices and it is a way to unmask how the scientific facts (as well as post-truth) are never just “… ‘out there’ […] they need to be produced, worked on, reinforced, stimulated, configured…” (Decuypere, 2019, p. 139). In other words, STS in this approach has a great potential to reestablish public trust in science, because it is not only about expertise, but also includes a description of how scientific practice (and post-truth) is related and assembled into the social through the generation, mobilization, stabilization, contestation, translation, and circulation of knowledge (Gorur et al., 2019).

STS in the educational context has the potential to dismantle scientific facts (and also post-truth), but it is important to say that its strategies are not monolithic. However, STS vaccines share a common feature: their STS roots, which means: “…a unified effort ‘to strip science of its extravagant claim to authority’ by demonstrating that the scientific enterprise was not merely influenced by, but actually constituted by, social structures—scientific facts were to some degree socially constructed, not discovered…” (Caudill, 2020, p. 14).

STS has developed analytical and practical tools to understand the ways in which science and technology are co-produced with people, their subjectivities and societies; it has also provided a broad understanding of the long work involved in producing and disseminating scientific facts and how scientific knowledge serves certain interests, agendas, and institutional actors. Similarly, this field of studies could account for how alternative facts, fake news, and scientific misinformation are constructed, disseminated, mobilized, and used politically, unveiling the unmasked interests that sustain and multiply them (Hoffman, 2018). In sum, STS could inspire the formulation and design of educational STS vaccines against post-truth.
4 STS Vaccines Against Post-Truth: Contributions from the STS Field for the Educational Context

To shape STS vaccines against post-truth, I argue that many of the conceptual and methodological tools developed by the STS field could be adopted by an educational context in the form of a generic pedagogical path. This path derived from some strategic lessons learned by STS regarding the nature of science could be summarized into three complementary and interconnected guidelines, on which some authors have already been working in science education, as will be shown below. So, an STS vaccine could be formulated following this path:

1. Re-establishing trust in science, through 2. broadening interdisciplinary knowledge (or the STS view) about it, in order to 3. unmask the assembly of agencies or science-society networks of co-production that shape, stabilize, and sustain scientific facts (and alternative ones) as we know them.

These strategic guidelines could be concretized in a single instructional principle that has been promoted by STS education: to teach science just as the scientific practice that it is. In other words, to teach science recovering the contributions developed by STS, an interdisciplinary field that has dedicated many efforts analyzing scientific practices as they are, but not as they should be, like classical philosophy of science used to study them (Hodson, 2010; Soler et al., 2014; Stroupe, 2014).

4.1 Re-establishing Trust in Science

The description of the features that make science a reliable practice to generate knowledge has been addressed by authors such as McIntyre (2019), Oreskes (2019) and Zimring (2019), who share a genuine concern for the current erosion of science and the urgency to illustrate why it was constituted as a trustworthy practice. Through institutional practices such as peer review or extended evaluation, declaration of conflicts of interest, or critical dialogue, scientific activity was historically shaped as a social practice of “correcting errors” (Allchin, 2020, p. 606) of statistical type, cherry-picking of data, confirmation bias, ideological bias, among others. The generation of mutual trust among scientific communities and between them and society was possible thanks to the scientific attitude of openness to change, commitment to new empirical evidence, as well as the institutionalization of both the reduction of error propagation and the interdependence of scientific communities for the identification of individual biases and for the imposition of sanctions to regulate scientific practices, among other factors (Allchin, 2020; Hörtecke & Allchin, 2020).

Oreskes (2019) argues that the recapitulation of these attributes that describe science would allow to recover trust in it, particularly, if two of the basements that historically support the scientific endeavor are recognized: (a) its sustained engagement with the empirical world and (b) its social character. The latter has been misrepresented by science deniers, forgetting that the social should not be confused with corruption or displacement of rationality, but rather that it is the virtuous way in which science is constructed as a practice. Through historical cases studies, Oreskes (2019) highlights that consensus (as a social condition of knowledge), the participation of diverse and heterogeneous scientific communities, methodological openness and flexibility, together with expertise or qualified experience, are some of the attributes of scientific practice that sustain and explain its trust (Allchin, 2020). The social and institutional character of these practices guarantee that
personal judgments and opinions, as well as individual preferences and values, do not dominate over the rest and be controlled intersubjectively, to a significant degree, by trained collectives, who have credentials that reflect processes of socialization and qualification that identify them as experts in a field. In this sense, consensus is among experts, since science, as Höttecke and Allchin (2020) point out “…is not a democracy of casual personal opinion…” (p. 647).

In the age of post-truth, it is common to find an apparent public controversy on a topic that has a high degree of consensus among scientific and expert communities, and in these cases, Oreskes (2019) warns us, that it is very important to inquire about the particular interests that contribute to fabricate and sustain these controversies in the public space. This author offers us a set of questions that allow us to identify a knowledge process to know its reliability:

…Do the individuals in the community bring to bear different perspectives? Do they represent a range of perspectives in terms of ideas, theoretical commitments, methodological preferences, and personal values? Have different methods been applied and diverse lines of evidence considered? Has there been ample opportunity for dissenting views to be heard, considered, and weighed? Is the community open to new information and able to be self-critical? Is the community demographically diverse: in terms of age, gender, race, ethnicity, sexuality, country of origin, and the like?...
(Oreskes, 2019, p. 129).

With these questions, anyone could have minimum criteria to assess the information that is publicly offered as scientific or unscientific to decide whether it is trustworthy or not, since the scientific character depends on critical and diverse scientific communities that correct each other (Oreskes, 2019). Instead of asking what is science and what is evidence, it becomes more pertinent to ask who is a scientist or an expert and who could one trust to evaluate certain evidence (Allchin, 2020; Höttecke & Allchin, 2020); similarly, but on the side of post-truth and alternative facts, the relevant questions become: Who is interested in damaging public trust in science? and How do they do it and for what purposes? Thus, the counterstrategy to post-truth proposed by Oreskes (2019) is to expose the conflicts of interest, ideological biases, and economic motivations that underlie science denial, showing how science discredit is and has been a political strategy that has the intended consequence of making societies distrust it. This undoubtedly requires a deep understanding of the social, political, anthropological, economic, historical, and epistemic dynamics of science, and from my perspective, this understanding is largely held by the experts in the STS field.

4.2 Broadening Interdisciplinary Knowledge (or the STS View) About Science

STS vaccines have an interdisciplinary nature that stems from the interdisciplinary character of their main active ingredient, STS research studies, which were classified in 2001 as an “intersecting field” rather than a discipline (Jasanoff, 2010, p. 191). Jasanoff (2010, 2013) gives an account of the emergence of STS interdisciplinary activity as a field that grows up in the spaces in-between established disciplines, evidencing the existence of unresolved and agonistic relations between STS and its cognate fields, such as history, sociology, anthropology, politics, economics, and philosophy. She described three phases in the history of the field, and she also argues for the critical importance of pedagogy in the formation of interdisciplines, in this case, embodied in the development of STS teaching.
programs and departments. Jasanoff (2013) describes STS as an interdisciplinary field insofar as it possible to trace and to identify the three logics that, according to Barry and Born (2013), guide and give identity to said interdisciplinarity: the logics of accountability, of innovation, and of ontology. The logic of accountability involves a range of practices and technologies of government oriented towards the conduct of research and which render the interdiscipline communicable and comprehensible (including voluntary agreements, websites, legislation, public inquiries, public consultations). The logic of innovation refers to new knowledge practices and technologies that become possible, desirable, and visible and that have an inventive potential. The logic of ontology encompasses a diverse range of rationales, techniques, practices, and interventions “...leading to the generation of novel problems, objects and relations of research, as well as interdisciplinary subjectivities...” (Barry & Born, 2013, p. 18).

At its origins and through these three logics, STS delimited a new territory of intellectual creativity, with new questions and answers that were a result of merging, at least, two streams of scholarship to explain what science is and how science works: that one focused on nature and practice of science and technology, and that one concerned with the impacts and control of science (Dear & Jasanoff, 2010; Jasanoff, 2010, 2013). Throughout its history, STS has reconfigured the relationships among disciplines (Dear & Jasanoff, 2010; Mitcham, 2003), changing the disciplinary knowledge and the research frontiers on science and technology. STS has generated novelties to account for the relations between science, society, culture, politics, religion, law, and art that cannot be explained only as a consequence of pre-existing forces to the interaction between different disciplines (Barry & Born, 2013). STS has given rise to new questions and answers to problems about science and technology, which could not be answered with only the classical philosophy of science, or the history of science, or the sociology of science. Through an interdisciplinary work, STS fostered the constitution of new forms of thought and inquiry, new objects of study, new methods, subjects, practices, and relations of knowledge irreducible to previous disciplines (Jasanoff, 2010, 2013). STS novelties remain expressed in a wide repertoire of innovative approaches, each one with their own set of conceptual tools and strategies, such as, for example: the social construction of scientific and technical realities, feminist studies of science, actor-network theory, laboratory studies, controversies analysis, the public understanding of science, expertise and public participation studies, anticipatory governance, and political economies of knowledge (Rohracher, 2015; Sismondo, 2010).

Any of these interdisciplinary approaches have broadened the knowledge about science and could be imported to the educational context (Weinstein, 2008) to be used with the pedagogical objective of re-establishing trust in science and fighting against post-truth. For example, by using STS, the problem of post-truth could be analyzed as a problem of science communication, as Hörtecke and Alchlin (2020) propose, or like a problem of the public understanding of science, as Kienhues et al. (2020) suggest.

For Kienhues et al. (2020), science education should not be limited to the teaching of science, reduced only to scientific content, but should also teach about science; that is, how scientific knowledge is generated and developed, a premise that has long been a marker of STS education (Aikenhead, 1997; Gordillo, 2017; Hodson, 2020; Pedretti & Nazir, 2011). The reestablishment of trust in science, for these authors, goes through sealing three gateways for post-truthism, or misunderstandings about science which are frequently used to provoke its public rejection, and that have to do with (i) the intricacies between evidence and values: studies of science have shown that science is not a value-free activity, that both epistemic and non-epistemic values participate in it, and that this does not translate into a lack of objectivity; (ii) the social nature and distribution of knowledge: the fact that
scientific knowledge emerges from negotiations, disputes, and agreements among scientists and that it is unevenly distributed in society, implying dependence on groups of experts according to each field of specialization, are both characteristics that should not lead to distrust in science but, on the contrary, to trust in its intersubjective and negotiated nature, and (iii) the limits of science: the fact that science cannot provide a solution to all problems, but constitutes an input for decision-making, added to the assumption that scientific knowledge is provisional, subject to revision and uncertain, should not translate into a total distrust and discrediting of science. Scientific evidence is always tentative and often conflicting, and its uncertainty is not synonymous with distrust; in fact, the attitude of criticism, doubt and skepticism should be considered a virtue of science, as it allows for its dynamism and questioning (Kienhues et al., 2020; McIntyre, 2019; Schmid & Betsch, 2019).

Science education should address these three aspects as a social protection from post-truth, showing how multiple values participate in the generation and distribution of knowledge, how the process of generating specialized knowledge requires a conversational and dialogic process, in which there is a strategic division of epistemic labor among different experts who interact, criticize and review each other in different ways (through congresses, journals, forums, among others) and stating that science involves uncertainty, risks and that those who consider that science is always the only and best answer to all social problems have fallen into a scientism that even scientists do not sustain, because it represents a dogmatic attitude (Kienhues et al., 2020; McIntyre, 2019). Certainly, STS education offers the possibility of addressing this complexity of science-in-action (Hodson, 2010, 2020; Pedretti & Nazir, 2011), challenging traditional images of mystified science and showing that the rejection of scientific activity has direct and indirect negative consequences on society (Kienhues et al., 2020), but it is necessary to reactivate its power against the increasing decry of science.

In the same line of thought, Höttecke and Allchin (2020) relocate the problem of post-truth to the interface of science with society, as a problem of science communication, because it is the node where different interests that have intervened in causing this cultural change seem to be mediated. For Höttecke and Allchin (2020), in the era of social media, science education must be reconceptualized in such a way that students have better tools to distinguish credible knowledge from false claims, alternative facts, misinformation, and others that circulate online. According to these authors, it is necessary to broaden the content of what is known as the nature of science (NOS) and to start working with the notion of the “…nature of science in society (NOSIS)…” (p. 644) that includes aspects of how science is communicated to the public, “…its mediation, communication mechanisms and manipulation…” (Höttecke & Allchin, 2020, p. 641). These authors claim that students need media literacy as a part of the teaching of the nature of science in society and that it should be focused on learning about communicative practices and their current patterns such as algorithms to aggregate news, echo chambers, filters, bubbles, spirals of silence, false consensus effects, fake news, and intentional disinformation.

The nature of science addressed in traditional science education often is limited only to teaching students knowledge as the product of a consensus among experts, so it should be complemented by an expanded nature of science in society, which aims at the study of scientific practice. Part of this scientific practice should encompass the interpretation of science in the media, i.e., the communication of science. Höttecke and Allchin’s proposal (2020) is interesting because it emphasizes the urgency of studying the route of mediations that knowledge follows “from test tubes to You Tube” and “from lab book to Facebook” (p. 644) to analyze how it retains its integrity and reliability and what is the social architecture that ensures and justifies trust in this knowledge. It is no longer possible to speak
of a simple model of dissemination and diffusion of scientific knowledge, since “…knowledge becomes actively transformed, reconfigured, and recontextualized as it travels through communication networks…” (Höttecke & Allchin, 2020, p. 644). Certainly, STS has a long trajectory in which it has rightly focused its attention on analyzing the social and cultural mediation and transformation of scientific claims, including their uses, recreation, resignification, misunderstanding, and misuses by social groups.

4.3 Unmasking the Assembly of Agencies or Science-Society Networks of Co-production

Lima et al. (2020) think that post-truth has benefited from a reduced view of the nature of science in the public sphere and from erasing the network that sustains scientific propositions. Science education should therefore engage more with the contributions of STS field and contribute to citizens developing a critical position in the contemporary socioscientific scenario.

For Lima et al. (2020), post-truth has recovered the rupture between the emotional and personal beliefs, and facts. This rupture goes back to the dichotomies between society and nature, ontology and epistemology, inside and outside science, and fact and value on which much of the classical scientific and philosophical discourse of science was built previous to the emergence of STS. The introduction of the concept of scientific practice in the field of STS has allowed to transcend these dichotomies and achieving a better understanding of what scientists really do (Law, 2017; Soler et al., 2014).

Lima et al. (2020) urge to recapitulate the criticisms of the classical visions of science that resulted from the sociology of science, the strong program and semiotics, for example. Among them, Latour’s proposal on Actor-Network Theory stands out, because it explained scientific activity as a set of five processes that configure all scientific practice and which comprise (i) the mobilization of the world, which involves laboratory practice, that is, the mobilization of different actants or the articulation of different propositions; (ii) autonomization, that is, the search for colleagues who work in the field and could stabilize propositions; (iii) the creation of alliances that enable the financing and development of research; (iv) the public representation, which allows scientific practice to be validated before society; and finally (v) the nodes that links between the above processes (Lima et al., 2020). These networked processes involve the participation of actors from different areas of society, in such a way that society merges and co-produces with the scientific order and vice versa. This implies that there no longer is an inside and an outside of science, because in science-in-action the social actors are mobilized throughout scientific practice, so that the political is involved in and constitutive of these networks. However, the creation of the scientific facts and their political and social nature does not diminish the validity of science, but rather ensures it, since it has been constructed through the nodes of practice (Lima et al., 2020).

Conceptualizing the scientific process in this way, as Lima et al. (2020) recapitulate, leads us to rethinking the meaning of post-truth no longer as an opposition between truth and falsehood between knowledge and belief or fact and fetish, but as competing propositions, where the alternative proposition is much less articulated than the scientific proposition: “…In the case of global warming, for example, groups financed by sectors economically interested in the subject support their proposition as if it were equivalent to the results obtained by the whole scientific community, trying to impose a false controversy…” (Lima et al., 2020, p. 206). Dismantling this belief entails showing that the network of
the scientific proposition articulates more propositions, that is to say, it has an envelope of greater space-temporal validity, than its antagonist.

Lima et al. (2020) criticize the instrumentalist and informative approaches of science programs, in which the processes of controversy, articulation, and disarticulation behind some proposition or actor-network, are presented in classes and textbooks already stabilized and erasing the network that articulated them, informing students only of the existence of that statement or of an actor in isolation, without articulating the assembly that generated them. This informative presentation gives the scientific contents an air of neutrality and objectivity that are not characteristic of real science and prevents the visibility of the network that supported these actors and on which the validity of science is based. Thus, affirming that the Earth is not flat at school, without knowing what and how this proposition was articulated, weakens the full understanding of the network that articulates every scientific proposition and, in sum, of science as a practice. Instead, Lima et al. (2020) argue that it is necessary to generate didactic strategies that make visible the controversies and evidence that support scientific ideas, showing that their stability is due to the articulation of networks of experimental data, theories, materials, equipment of laboratory and field and scientists, among others, that means “…opening the black box of science…” (Latour, 1988, cited in Lima et al., 2020, p. 214).

Latour’s networks intertwine the social and the natural and stabilize them in such a way that there is no ultimate source of knowledge that could be referred only to the social or only to the natural. Tracing of the heterogeneous actor-networks allows us to examine the different articulations and connections among society-nature-science that could range from, for example, chemical links to legal instruments, and where a proposition or actor “…exists only through articulation with other propositions…” (Lima et al., 2020, p. 209) or actors. The Actor-Network Theory (ANT) is then another tool derived from STS whose adoption in the educational field would allow fighting more effectively to post-truth. Particularly, an ANT’s central tool is “controversy mapping,” which according to Elam et al. (2019) could be incorporated into the science classroom to analyze the mutual entanglement of science and society. From my point of view, this strategy represents a good example of an educational STS vaccine against post-truth.

It is important to distinguish between controversy mapping and the socioscientific issues—SSI—(Sadler, 2011; Zeidler et al., 2005). SSI is a current of STS education (Pedretti & Nazir, 2011, 2016) that appeared in the literature in 1986 (Sadler & Dawson, 2012) and represented a possibility to achieve change from the conventional culture of science education (Sadler, 2011). In the Zeidler et al. (2005) perspective, STS education had become relatively diffuse and it seemed to be limiting itself to emphasizing the interrelation between science-technology-society and the societal context. Although it included ethical dilemmas or controversies, Zeidler et al. (2005) considered that STS education does not necessarily exploit “…the inherent pedagogical power of discourse, reasoned argumentation, explicit NOS considerations, emotive, developmental, cultural or epistemological connections within the issues themselves…” (p. 359). In contrast, the emergence of SSI represented a reconstruction and evolution of the STS model that integrated ethical dimensions of science as well as the moral and emotional development of students (Zeidler and Nichols, 2009).

SSI use controversial scientific topics (Levinson, 2006), personally relevant, controversial, and ill-structured, with the pedagogical objective of fostering students to discuss, dialogue and debate, in order to propose possible solutions to such controversies (Owens et al., 2017), and to reason morally about them in a context that requires specific scientific information that allows making decisions based on an ethical evaluation of controversies.
While attending to the students’ progressive development—cognitive, moral, emotional and character—(Sadler & Dawson, 2012), SSI also allows for the study of scientific concepts and the social, economic, and cultural contexts and processes of the science (Pedretti & Nazir, 2011, 2016; Sadler, 2011; Zeidler and Nichols, 2009; Owens et al., 2017).

In contrast, controversy mapping is “an ‘educational version’ of ANT” (Elam et al., 2019, p. 62) whose focus is on analyzing the production and stabilization of social and political entities as much as scientific and technological ones (Elam et al., 2019). The pedagogical goal of controversy mapping is not fostering individual capacities for decision-making or moral reasoning, as in SSI, but to capture the dynamics of co-production of science and society, exploring, visualizing, and describing the complex fabrication of the facts (Elam et al., 2019).

Controversy analysis, as described by Latour (1987), entails following actors (scientists, entrepreneurs, community members, government representatives, objects, knowledge from multiple disciplines), describing how they interact with human and non-human agencies, and how they trace networks, stabilizing facts and artefacts. Controversy mapping does not intend to close controversies, but rather lets them express themselves and flow to identify in them how the social is constructed. In this sense, it highlights its usefulness and relevance to understand how science and post-truth are socially constructed and sustained. Latour (1988, 2008) has insisted a lot that the social is not the answer to the why of science and to the why of scientific facts being as they are, it is to say; the social is not what explains (explanans), but it is what must be explained (explanandum). The clues offered by Latour (2008) for understanding the social construction of knowledge can provide a guidance on how to achieve this objective. According to Latour, to analyze controversies we should (1) not assume that in the social there is only one association principle, but rather we should use controversy analysis to map social connections and relationships; (2) consider that actions are the nodes that allow us to understand the construction of scientific facts, and that the analysis of controversies must investigate which agencies are involved in a course of action, how they encounter through the nodes, and how they are mobilized and translated by different actors; (3) consider that an action implies human actors, objects and, in short, material culture; (4) consider that any fact has been constructed in a complex articulation of cultural, material, and social practices and relationships and that all facts are always presented to us hiding those traces and assemblages; and finally, (5) write risky explanations that allow tracing the relationships and actor-networks that make a social practice of which we generally only see the results and products, such as science or post-truth (Latour, 2008).

Of course, both strategies—SSI and controversy mapping—do not exclude each other and could even be complementary (Bencze et al., 2020; Chowdhury, 2016). As Pedretti and Nazir (2011) and Bencze et al. (2020) argue, SSI is closely linked to STS education, and after all, it is one current in which STS education has been diversified. Just as a reminder, the other STS educational currents identified by Pedretti and Nazir (2011) are (i) the application/design current, which stresses the relationship between science and technology through technological design projects in science education; (ii) the historical current, which focuses on the historical dynamics of scientific ideas; (iii) the logical reasoning current, which considers the moral, emotional, and epistemological development of the students, and that corresponds to the SSI approach; (iv) the value-centered current, which studies science as a value laden activity and as part of a values education; (v) the sociocultural current, which teaches science as a social institution, internally organized and externally embedded in society; (vi) and the socio-ecojustice current, that focuses on promoting in the students a sense of social and environmental justice, which could be later be
translated into activism and social action. The six currents coexist, overlap and inform one another (Bencze et al., 2020; Hodson, 2020).

Each current has its own focus, aims of science education, dominant approaches, and pedagogical strategies (Bencze et al., 2020; Pedretti & Nazir, 2011), but all currents share fundamental aims linked to the STS field and its contributions to recognize the relevance of the study of science in-the-making (and not ready-made), the complexity of scientific practice, and the importance of reconceptualizing science education incorporating the wide STS conceptual repertoire (Bencze et al., 2020). Given their STS roots, I consider that anyone of these STS currents could be educationally useful as an ingredient of an STS vaccine against post-truth, as long as it is very clear in that its main pedagogical objective should be (1) Re-establishing trust in science through (2) broadening interdisciplinary knowledge (or the STS view) about it, in order to (3) unmask the assembly of agencies or science-society networks of co-production that shape, stabilize, and sustain scientific facts (and alternative ones) as we know them.

5 Final Considerations: Rethinking the STS Approach in Education

The documental review of educational responses to post-truth denotes a greater presence of traditional epistemological initiatives. These are mainly directed to prepare students for an apt epistemic performance that endow them with an understanding of the multiple ways of knowing, cultivating intellectual virtues, fostering greater epistemic vigilance to identify misinformation, and increasing the possibilities of correcting it. Although necessary, these educational responses, characterized in this text as epistemological vaccines, are insufficient to contend post-truth. Not only because of the limited role of education in the change of multiple factors that are producing and sustaining post-truth and alternative facts, but also because they are educational responses that do not deepen the social and collective character of science and technology. Being a social process, post-truth, like science, requires complimentary educational responses that recover interdisciplinary contributions derived not only from traditional epistemology, but also from the articulation of the history of science, anthropology of science, sociology of science, economics of science, and in sum, from STS.

STS analysis could contribute enormously to education in the age of post-truth because it has developed a wide conceptual repertoire and it has a long history examining scientific controversies, techniques of experimental replication, consensus building, the ways in which scientific institutions maintain credibility or lose it, as well as the production of legitimacy and epistemic authority. Today, all this stock of interdisciplinary knowledge could be useful to unravel post-truth, showing that it follows a different pathway on its construction and in its purposes, with respect to science. As Hoffman (2018) states “… STS is well-equipped to document the efforts of the demagogues trying to recreate the world in their gaudy image…” (p.451), so the knowledge that STS has constructed around how politics and power are intertwined in the co-production and dissemination of scientific facts and technological developments (Hoffman, 2018) could be considered an active ingredient of the vaccines against post-truth.

Despite having generated a strong pedagogical tradition, such as STS education (García-Palacios et al., 2001; Gordillo, 2017), which in the nineties enabled the development of innovative science curricula in many countries (Yager, 1990; Yager & Blunck, 1992; Fernandes et al., 2014), today the STS approach in education seems to have been
weakened or disarticulated. In the Mexican case, for example, to achieve the insertion of the STS approach in education, international cooperation was particularly important (Osorio, 2019), and although it was considered a relevant approach to improve science education, the curricular analysis of STS programs in the Mexican high school shows its increasing elimination. For example, in the subject “Science, Technology, Society and Values” of the Mexican technological high school, the critical study of science and technology no longer occupies a central place (Valladares, 2021). It could be interesting to explore if a similar situation is also extensive to the curricula of other contexts in Latin America, Asia, and in the rest of the world. In the case of Pakistan, Jessani (2015) has reported different challenges that hinder adopting this approach in education. The four areas that will completely need to be revamped according to STS approach in Pakistan include the examination system, which is very much focused on theoretical and factual knowledge and represents the main barrier to STS implementation; science textbooks, which are still pre-dominantly focused on scientific content and concept; science teacher education programs; and available resources and school facilities, that need to be adequate for STS integration. It could be interesting to study if and how the barriers of implementation or the gradual dilution of STS in some curricula or the diversification of the STS approach in science education (Bencze et al., 2020; Pedretti & Nazir, 2011) explain the current need to find new educational responses to post-truth that require a rearticulation and revitalization of what once has been achieved by STS field in the educational context (Ozgur et al., 2017; Chantaranima & Yuenyong, 2014; Chowdhury, 2016).

Throughout this text, I have tried to recover some of the known richness of the STS field to illustrate its potential to redesigning science education and making more powerful vaccines for post-truth. Even though STS has a long tradition in education, and it is considered as a vast set of ideas, principles, and pedagogical practices that overlap and imbricate each other, in which different currents that are not mutually exclusive coexist, and where these diverse STS education currents represents “…potential routes available to teachers and academics as they navigate the STSE waters…” (Pedretti & Nazir, 2011, p. 603), STS seems to be an old-fashioned approach.

STS education sustains the vision of achieving a change in the educational status quo by promoting a post-positivist vision for the science, situating it in the political, social, technological, cultural, ethical, and economic contexts with which science is co-produced. However, STS education seems to be blurring at present, and its interdisciplinary nature appears to be reduced to traditional epistemology. We need to remind that STS education generated an engagement with a science education more focused on understanding scientific practice and its relationship with technology, society, and with multiple intricacies, interests, and agencies that crossed it and build it (Aikenhead, 1997; Pedretti & Nazir, 2011). Recovering this view of a science-in-action and in-networks, and in-practice, is a necessary component to reinforce the formula of vaccination against post-truth. In that direction, this text intends to be an invitation to continue analyzing STS interdisciplinary conceptual and methodological tools and their implications in education. Particularly, it is an invitation to examine the different trajectories that STS has followed in the educational systems of different countries to identify and rethink which aspects of this approach have prevailed, which have not worked and why, and how STS education could contribute to transforming the generalized social condition of denial of scientific facts, eradicating the increasingly common habit of uncritically assuming alternative facts that are more in line with ideological preferences and personal opinions, but go against all empirical evidence.
Authors’ Contributions  Not applicable

Funding  This research was supported by UNAM-DGAPA-PAPIIT IG400920.

Data Availability (Data Transparency)  Not applicable

Code Availability (Software Application or Custom Code)  Not applicable

Declarations

Conflict of interest  The author declares no conflict of interest.

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