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Research on COVID-19: A Microcosm to Discuss Scientific Work in Science Teaching from a Latourian Standpoint

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Abstract:

It is proposed the description of the "circulatory system" (*sensu* Latour) of technoscience around COVID-19 - in particular regarding the development of vaccines and scientific evidence on treatment - as a didactic study case for Science Teaching, showing how current events can and should also be mobilized for the critical understanding of the Nature of Science in the classroom. From the description of the various actors involved in the COVID-19 event, we discuss how it is possible to articulate scientific knowledge and critical discussions about the Nature of Science to mobilize scientific literacy - that is, the mastery and internalization of a properly scientific way of reading the natural and social world, rejecting denialism and absolutism about a supposedly univocal and linear science. The goal of reaching scientific literacy can be developed by using the case study presented here, facilitating the articulation of these elements of science education through a contemporary episode. Thus, it is expected that the content and reasoning proposed in this paper can be used as a theoretical basis to be used in the classroom and can be adapted to a methodology that the teacher and students feel more comfortable with and to the educational context in question.

Keywords: COVID-19; Bruno Latour; Helen Longino; Circulatory system of technoscience; Science teaching

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Introduction

The importance of overcoming a content-driven approach in science education has long been emphasized, especially in understanding scientific work, the provisional nature of scientific knowledge, and the role of the internal logic of science and the external context in decisions

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about scientific theories, models, and hypotheses. This understanding is not restricted to the training of future scientists, but mainly to scientific literacy as an instrument of citizenship (Yurij Castelfranchi and Fernandes 2015). Before we advance in this text, we follow Chassot's definition of *scientific literacy* as follows: "being scientifically literate is to be able to read the language [of science]" (Chassot 2003, 91), understood as the language that men and women build to explain the natural world.

Despite this notion, there is not necessarily agreement on the minimum elements of scientific work (Bejarano, Aduriz-Bravo, and Bonfim 2019). One perspective that is gaining ground among educators is *Whole Science*, which suggests as minimum elements "of the reliability dimensions of science" (Allchin 2013, 24): an observational dimension (with observation and measurement, experiments, and instruments); a conceptual dimension (with patterns of reasoning, historical dimensions, and human dimensions); and a sociocultural dimension (with institutions, biases, the funding of research, and science communication).

Several attempts have been made to describe some of these elements in science teaching (Izquierdo-Aymerich and Adúriz-Bravo 2003), mainly by using events from the history of science (Matthews 2015). The use of contemporary events is rarer, but the COVID-19 pandemic presents an important case for reflecting the role of various elements of scientific work in everyday life and their appropriation by science education (Reiss 2020). In this paper, we propose an analysis of the sociocultural dimension of scientific discourses on COVID-19, vaccination, vaccine development, and drug efficacy through the lens of "science's blood flow" (*sensu* Latour) as a way of improving critical science teaching.

Among the elements cited by Allchin (2013), the sociocultural dimension is often the least explored, in part because the sociology of science view is often interpreted as *relativistic* (Bunge 1991). In addition, there seems to be confusion between *descriptive* and *normative* aspects of the sociology of science - the notion that describing science as influenced by external factors and highlighting the role of the sociocultural dimension somehow means *relativizing* scientific knowledge or asserting that science *must be this way* (Allchin 2004). An important contribution to give nuance to the debate can be found in the work of Helen Longino (1990).

Longino argues that external ("sociocultural") factors interact with factors internal to the sciences (the observational and conceptual dimensions elaborated by Allchin (2013)) to determine which theories and hypotheses advance. Her *contextual empiricism* assumes that social values are fundamental to justifying scientific knowledge as objective. The observations and data produced by scientists are not themselves evidence for or against a particular hypothesis; rather, the relevance of any particular data or observation is decided by the assumptions of what types of data can support each type of hypothesis (Longino 1990). Even when the relevance of a piece of data is defined, there is still a logical gap between the empirical evidence and the justification given to the theories (the Duhem-Quine thesis). This logical gap must, in turn, be filled by assumptions about what kinds of reasoning are legitimate, helping scientists use evidence to decide which hypotheses are true (Longino 1990). Longino (1990) argues that these assumptions are not only based on internal factors but, importantly, on external factors as well.

Many interpretations of the underdetermination problem led to counterproductive relativism, as do the difficulties in producing an answer to what kind of evidence is needed to judge the truth or falsity of a hypothesis (Estany 1999). An intermediate way out is also suggested by Helen Longino: the use of *diverse* perspectives to criticize scientific hypotheses and theories can guarantee objectivity and the status of scientific theories to some of these hypotheses (Longino 1990). A hypothesis becomes knowledge when scrutiny from diverse perspectives supports objectivity (Crasnow 1993). Similarly, values that are not necessarily internal to science are crucial to objectivity, and science can be objective *precisely* because it is not value-free (i.e., because external factors influence it) (Longino 1990). Critical dialogue within the scientific community can allow it to overcome some biases (Eigi 2012).

An associated conception, with a much greater focus on the sociocultural dimension of scientific work, can be found in the formulations of Bruno Latour, especially in his books *Science in Action* (Latour 1988), *Pandora's Hope* (Latour 1999), and *Reassembling the Social* (Latour 2007). Latour's approach is a radical empiricist one and, therefore, compatible with the contextual empiricism of Helen Longino. Both understand the scientific endeavor not as a matter of discovering fundamental truths about the world, but of stabilizing phenomena through the wider interaction between actors in the network. For both Longino and Latour, constructivism is not about how Kantian categories determine the world, but how interactions with the world surpass the mere representational. Thus, for both Latour and Longino, the classical dichotomies evoked by scientists are not given, but constructed; the question ceases to be one of merely "un-naturalizing" or "unmasking" these constructions and turns to which of these constructions are more productive and politically acceptable, given the values that are negotiated and renegotiated between scientists and the wider milieu.

The present work aims to describe a use of Latour's technoscience blood flow in understanding and describing the actors involved in formulating the scientific understanding of the COVID-19 event, including the public health strategies and the development of vaccines, as a tool for science education. Latour's technoscience blood flow has been presented before, but this work brings a current example that has affected the entire world, showing science under construction. Furthermore, the case study presented and discussed here based on the sociological basis of Latour can be adapted to different methodologies and educational contexts as a way of helping the teacher to bring current and controversial scientific topics to the classroom, as a way of exemplifying to the students how science is actually constructed.

Thereby, initially, the blood flow (circulatory system) of technoscience, proposed by Latour, is presented. Then, the construction of the scientific facts involving COVID-19 is discussed on the theoretical basis mentioned. After that, the implications of using discussions of this nature for science teaching are developed. Finally, the final considerations of the work are presented.

Technoscience's Blood Flow

For the late anthropologist, philosopher and sociologist of science Bruno Latour, in order to understand the science-making activity, it is necessary to strip ourselves of any preconceptions and ideas of cold, impartial and objective science so that we can understand that scientific activity is, in fact, dynamic and alive. In this sense, the first necessary rupture is with the subject-object dichotomy: starting from the adoption of the idea that scientific activity occurs from interactions between humans and nonhumans – that is, all actors in the network, such as objects, mathematical formulas, nonhuman living organisms, and even abstract "institutions" such as the market, economy, church, etc., with no differentiation between them, and no privileged position (Latour 2007). What exists are associations in a network, a tangle of propositions which describe the ways of constructing scientific facts. Latour calls this network a socio-technical network formed by heterogeneous links, which encompass social and economic relations as well as cognitive developments. The comparison with a network occurs precisely to show that if one of the actors (whether human or nonhuman) in the process is disconnected, the whole network changes or, in some cases, ceases to exist (Latour 2007).

To guide the understanding of the construction of science, again using analogies with networks, Latour (1999) points out five main activities in the development of scientific work:

peers, allies, mobilization of the world (or instruments), public representation, and links or nodes. For him, it is as if these five elements were the "blood flow" or circulatory system of science: there is no vascularization without the veins, or the blood, or the heart; all are equally important.

Instruments, also called by Latour (1999) the *mobilization of the world*, are the way in which nonhumans are inserted in discourse and how instruments are used to mobilize the world. In this sense, from these instruments, the world is converted into arguments, giving scientists authority and certitude to talk about a certain subject. The second activity refers to peers, or *autonomization* (Latour 1999), and is also essential for the scientific activity to develop. For Latour, autonomization refers to how an area becomes independent with its own evaluation criteria. *Alliances* are the third activity of the circulatory system. It is necessary to make the funding public interested and mobilized to invest in scientific activity. In this sense, the scientist needs to have the ability to persuade and attract attention, and it is not only the attention of the peers inside the laboratory, but of those outside, as a way to ensure the existence and continuity of that science (Latour 1999). Such alliances do not necessarily interfere in an experiment, for example, or in data, but on the contrary, they accelerate the blood flow of this system through this unnatural but inevitable partnership. As the case of COVID-19 illustrates, however, one can also speak of *foes*, those that oppose and critique findings from laboratory life, or who are not (yet) fully turned into allies.

In addition to the alliances, in which convincing is necessary, a fourth scientific activity that also depends on convincing (but this time of the "lay public") is *public representation*. Even if the instruments pointed to new knowledge, there was funding and acceptance by peers, still, such novelty would affect the daily life of the population only to the extent that it is publicly represented. At this stage, the dissemination of new knowledge to civilians, reporters, the curious, etc., is necessary for it to be accepted as science. The fifth scientific activity Latour (1999) describes is the *links* or *nodes*, which relate specifically to conceptual content. Latour compares this activity to a very tight node in a network, which is responsible for holding together very heterogeneous sources. However, just as you cannot separate the heart in a circulatory system, you cannot separate the nodes from the rest of the vascularization, as if the "scientific" contents were on one side and the context on the other: the heartbeats and pumps blood through the veins and arteries, and if any of these parts fail, the whole system fails.

The asepsis that scientists try to do in describing scientific work, placing the conceptual contents in a place free from the "pollution" of the sociocultural world, actually brings about a simplistic misconception of how scientific work actually occurs, leaving aside the connections with peers, the public, with alliances and instruments, which, in turn, bring the conceptual contents into the discourse, and into the world (Richard and Bader 2010). A concept becomes scientific not because it is detached from its context, but because it is closely linked to everything it involves, to the rest of your circulatory system (Latour 1999). This is similar to Longino's (1990) idea that objectivity in the construction of scientific discourse is actually dependent on "bringing together" multiple perspectives, including then "external" factors (context).

The laboratory, for example, is a network (Latour and Woolgar 1986) that organizes outsiders, those loaded with the "cultural" and "social" worlds, and categorizes, and translates, infers about, and produces scientific facts by returning its results to the world outside the laboratory. "Returning", here, refers to autonomization and public representation (Latour 1981).

It is possible to identify the elements of the blood flow of science described here in classic episodes of the construction of scientific knowledge throughout the history of science, such as Galileo and heliocentrism (Feyerabend and Hacking 2010), Joliot and artificial radioactivity (Latour 1989), Newton and the construction of the laws of motion (Sitko and

Silva 2021), Priestley and photosynthesis (Matthews 2015), among many others. However, such episodes occurred in periods that were different from today's, not only in the cultural, but also in the economic and political senses. This can lead to doubts regarding the applicability of such scientific activities in the contemporary world, marked by the digital age and the consequent acceleration of information circulation (Yuri Castelfranchi and Pitrelli 2009), by epistemic and epistemological disputes about what counts as "science" and "scientific fact" (Moura, Nascimento, and Lima 2021), and by denialism (Leung and Cheng 2021).

In this sense, aiming at the understanding of contemporary scientific activity, we can imagine the possibility of going through the vascularization of a knowledge still under construction, having access to the instruments, allies, public, scientists and colleagues in real time, observing the scientific fact still under construction (Latour 1999). In the next section, we will trace the "blood flow" of the research episode for creating COVID-19 vaccines, leading to the goal of providing a technoscientific event to be discussed in the classroom as a way to mobilize science teaching.

The Construction of a Scientific Fact in Real Time: The Case of COVID-19

The COVID-19 pandemic represents an interesting case study for the classroom, in which the virus, prevention of infection, vaccine and drug development, etc, are *hybrids*, in a sense presented by Latour (2012) in *We have never been modern*. Hybrids get entangled between politics, technique and science, always-already involved in collectives and objects, and thus there is no way to separate social context, power interests, and the production of scientific concepts. Moreover, it would not be possible to reduce scientific facts to sociopolitical dimensions, because it is populated by objects mobilized to construct it (Latour 2012). The social context of the 21st century will never be the same after it is constructed by those (people, industries, politicians, market) affected by COVID-19; people redefine themselves, their politics, their interests. And this means that the disease, and even more so, the production of vaccines, becomes incomprehensible if its social and political dimension, its financiers, and its infected are removed: without people infected, what impact would the disease have? What would be the need for vaccine research? If the virus did not provoke these disruptions in politics, the economy and the health system, it is possible that it would not even emerge into discourse, nor would it come into existence (Bump, Baum, Sakornsin, Yates, and Hofman 2021).

Several studies regarding diagnostics (Hanson et al. 2021), treatment (Chilamakuri and Agarwal 2021), prevention (Wilder-Smith and Freedman 2020), and possible cures for COVID-19 (Rodriguez-Guerra, Jadhav, and Vittorio 2021) have been conducted since late 2019. In this text, however, we will restrict ourselves to discussing one of the preventive processes against virus infection: the development of vaccines.

The studies mentioned are not limited to pipettes, centrifuges, microplates, syringes, and charts. Many actors needed to act in this episode so that vaccines could be developed. At first, the virus needed to be known, that is, it was necessary to mobilize instruments that would bring it into the discourse. We can consider the World Health Organization (WHO) report of January 05, 2020 (https://www.who.int/news/item/29-06-2020-covidtimeline), describing the outbreak of cases of what later came to be identified as the new coronavirus in Wuhan (China), as the kick-off (or, in Latourian terms, instrument) that allowed us to grasp some of the characteristics of the new actor. It is important to stress the "some", because the fact is still under construction, and the virus still has facets unknown by humans. Moreover, we stress the "new" actor given the catastrophic dimension that the COVID-19 pandemic produced and the many differences this outbreak had with previous pandemics, including increased capacity to produce vaccines, but also the speed and reach of infection given a globalized world.

On January 9, 2020, WHO reported that Chinese authorities communicated a newly identified coronavirus as the cause of the outbreak of respiratory illness cases in Wuhan. In the following days, a series of guidelines were produced and disseminated containing key technical aspects, including infection control and prevention (World Health Organization 2020b), laboratory testing (World Health Organization 2020c), and clinical management (World Health Organization 2020a). However, for WHO to confirm the existence of the virus, the case was already autonomized by the scientific community.

In the same period, the World Health Organization posted on social media that it had received genetic sequences of the new coronavirus (World Health Organization 2020d) and, two days later, published a protocol for diagnostic detection of the new coronavirus using RT-PCR (Corman et al. 2020) (exercising the activity of public representation).

To better understand the new actor, genome sequencing of SARS-CoV2 was performed, which provided not only a greater understanding of the structure of SARS-CoV2 and its relationships to other coronavirus species (Touati et al. 2020), but mainly more refined diagnostic detection protocols (Guan et al. 2020) and, later, the description of variants (Duong 2021). In addition, rapid sequencing was instrumental in developing vaccines (Li et al. 2021). This characterization of the virus, through the mobilization of sequencing, is one link or node, that is, it is the conceptual part of this network of this flow.

In addition to data on SARS-CoV2, another instrument that brought the new actor into the world is quite distant from the laboratory: the statistics of hospital admissions and deaths, which grew daily, until starting to fall due to vaccination and social distancing measures (Suthar et al. 2022); a decline can be observed at the end of January 2022 (https://covid19.who.int/). However, as health systems faced growing pressure from patients with respiratory problems, more ICUs were requested, more deaths added up, and the virus "gained" more existence.

Such instruments also help in the execution of another important activity of scientific work, which is public representation. The same statistics that brought the virus to the discourse are now distributed in the collective as a way to seek popular acceptance and awareness (Vergara, Sarmiento, and Lagman 2021). Likewise, the conclusions about its form of action in the human organism, transmission and lethality, coming from the genetic sequencing, were also made public, so that the seriousness of the pandemic could be understood (Leung and Cheng 2021). And this is a fundamental activity, because if the public does not accept the fact, science cannot be developed (a fact that occurred with Galileo, when he presented his results of observing the moon through the telescope (Latour and Woolgar 1986)).

Both instruments and public representation are important for the establishment of alliances (Yurij Castelfranchi 2002). If governments do not accept the problem, for example, and do not invest in public policies to confront the virus, the development of vaccines (and its use) and other forms of prevention (such as the use of masks and social distancing) simply do not happen. This is not the same as saying that "public communication" is sufficient to mobilize governments to implement policies, as the case of Bolsonaro in Brazil makes clear (Lopes and Leal 2021). If the pharmaceutical industry does not know genetic mapping and statistics, it will not test the products created by scientists (vaccines), or these products might not even have the opportunity to be created.

If corporations (not necessarily in the health field) do not know the statistics, they will not project the long-term economic losses due to the future economic, personnel and resource crisis that would result from a health crisis. In this case, these companies will not offer resources and alliances for scientists to manufacture vaccines. Again, this is not to say that public communication is sufficient to mobilize the health industry to ally with scientists to offer resources to manufacture vaccines, but it is necessary. In this sense, public representation helps to produce allies. Moreover, as we have also pointed out, *foes* are also produced, many of which in the scientific community and allied professions (in Brazil, for example, a group of physicians, the 'Doctors for Life', which were against COVID-19 vaccination strategies, were highly influential in the federal government; Ferrari et al., 2022).

Once the funds had been collected and resources amassed, studies and testing of the vaccines began to take place. Several laboratories around the world worked tirelessly and came up with different products, which all show some degree of effectiveness against the virus. And who will ultimately attest which product works and which doesn't? The peers, who are part of yet another scientific activity brought by Latour (1999).

It is the peers (or autonomization) that will peer-review the gene sequencing papers, the *in vitro* and clinical tests done by other scientists, and that will finally validate if the product created can be considered an effective vaccine against COVID-19. After being validated at the level of scientific journals (and, frequently, preprints; Vlasschaert, Topf, and Hiremath 2020), it is necessary to pass through the sieve of larger organizations: the WHO, worldwide, and national regulatory agencies at the country level.

It is important to note that in the sequence of activities presented here, there seems to be a certain order for the scientific activities to occur, but it is just a way of writing; if one were to read the paragraphs randomly, one would see that the order of the factors mentioned does not matter because they occur *concomitantly* during the production of the scientific fact.

Once the elements of this blood flow of the instant of the production of vaccines are described, it is possible to perceive a transition of flow to another direction, which is the vaccination campaign - that has also been a scientific and political problem faced in many territories (Vergara et al. 2021). Indeed, this represents, as Vergara et al. (2021) suggest, a sociocultural and sociopolitical situation that involves another set of actors in the network – specifically, while the development of vaccines involves primarily scientific communities and their alliances with the pharmaceutical industry and governmental agencies, the second is more related to public acceptance of the produced vaccines. Due to such fact, the public representation needs to exercise a much more insistent "publicity" about the scientificity of the fact constructed in the laboratory (the vaccines), counting on the support of peers and instruments, characterized by drops in the number of infected and deaths among the vaccinated public. Nonetheless, vaccine and COVID-19 denialism have become a major problem worldwide, especially in marginalized communities - due, in part, to what has been called "epistemic ignorance" (Timmermann 2020). In this sense, it can be said that the scientific community produces allies, but also *foes*. In fact, Latour expressed concerns about the misappropriations of the critique of science that he built:

> In which case the danger would no longer be coming from an excessive confidence in ideological arguments posturing as matters of fact—as we have learned to combat so efficiently in the past—but from an excessive *distrust* of good matters of fact disguised as bad ideological biases! While we spent years trying to detect the real prejudices hidden behind the appearance of objective statements, do we now have to reveal the real objective and incontrovertible facts hidden behind the *illusion* of prejudices? And yet entire Ph.D. programs are still running to make sure that good American kids are learning the hard way that facts are made up, that there is no such thing as natural, unmediated, unbiased access to truth, that we are always prisoners of language, that we always speak from a particular standpoint, and so on, while dangerous extremists are using the very same argument of social construction to destroy hard-won evidence that could save our lives. Was I wrong to participate in the invention of this field known

> as science studies? Is it enough to say that we did not really mean what we said? Why does it burn my tongue to say that global warming is a fact whether you like it or not? Why can't I simply say that the argument is closed for good? (Latour 2004b, 227)

We see here that if the goal is to provide an episode of technoscientific development to facilitate critical science teaching, it is important to consider the distortions that can arise from assessing Latour's and Longino's position as "relativistic". Thus, it is important to show how the support of alliances, which involves the major companies responsible for producing and distributing the vaccines, and especially the governmental bodies, is crucial for the blood flow. If any of these elements fail, it is as if one of the veins or arteries is blocking the blood flow. For example, if governments spread the wrong message and do not ally themselves with what the scientists say, the vaccine network breaks down, this scientific fact diminishes, and, in turn, the viruses gain more existence. We now turn more explicitly to the implications of this episode for science teaching.

Implications for Science Teaching

Science, as is often seen in the school environment, has not brought the expected results from the point of view of scientific literacy (Fourez 2002) – that is, while report after report shows that students might be able to talk about scientific "facts", they do not seem capable of using this information to decode the language of science and to critically understand the world through scientific lenses (see, e.g., Stacey, 2010). In this sense, many attempts have been made to renew teaching, such as the use of problems involving Science, Technology, and Society (STS) (Désautels 2008). In this kind of critical teaching, it is paramount that real and current issues are discussed, as a way to mobilize a non-naive conception of science. It is understood that the goal of this type of teaching is not to make science in the classroom, as scientists do, but to cultivate a more critical and engaged view of scientific knowledge and its current productions (Izquierdo-Aymerich and Adúriz-Bravo 2003).

As Richard and Bader (2010) argue, many science education researchers realize that understanding scientific studies can help students to better understand various practices of science, and to better articulate this understanding in science education. It is in this sense that we look for an alternative for teaching science, using problems of technoscience from a social, current point of view (that is, not only from the history of science, but also from cases that can help to understand how science is practiced today (Weinstein 2008)), which includes science studies – the name introduced by Latour (1999) to refer to the work that philosophers and sociologists of science do, which is, in short, to study how the science enterprise works, that is, to understand how scientific facts are created while they are still under construction.

Latour's formulations can be understood as a "post-constructivist" framework as applied to science education (Wink 2020) – especially since *Pandora's Hope* (Latour 1999) and *Politics of Nature* (Latour 2004a), in which Latour proposes a way in which human discourse and activities can be allied to the properties and the agency of the natural and social worlds in the construction of knowledge. Wink (2020) argues that this post-constructivist approach lends science educators a way out of the constructivist/realist tension: "One possible place to study how humans and nonhumans interact in education is to consider how concepts in science, which might seem linked to constructivist discourse, actively engage with objects in the world" (Wink 2020, 4273). This is consistent with Chassot's (2003) concept of scientific literacy as the mastery of the language of science.

Attempts to engage science education with Latourian thought have been made before, especially in the case of a "school science" (*sensu* Izquierdo-Aymerich and Adúriz-Bravo 2003). Rezzadori and Oliveira (2021) described how Actor-Network Theory, fully described by Latour (2007), can be used to understand the dynamics of a Chemistry school laboratory. They argue that school laboratories can also be understood as a network composed of several elements and that overlooking this socio-technical network, as well as the elements to which laboratories are connected, makes it difficult to understand the dynamics of science education in these contexts. Importantly, then, this post-constructionist approach allows researchers and educators to better understand how knowledge construction in the classroom (or laboratories, in that case) is entangled in a network that surpasses school science, even though school science can be understood as a pedagogical transposition of professional science.

Despite not using Latour's circulatory system, Christodoulou et al. (2021) show how Latour's model provides a superior theoretical framework for interpreting the participation and discourses of diverse actors. The study of a problem such as COVID-19, and the process of producing and distributing vaccines, goes along with what these authors are looking for. The context of vaccine denialism and distorted opinions regarding the efficacy of preventive and curative treatments for COVID-19 (Hallal and Victora 2021) brings up the importance of critical contextualization in science education, especially regarding the STS relationships (Liu 2012), from a Nature of Science perspective and its implications for school science (Adúriz-Bravo 2004). Lima and Nascimento (2021) argued that, in the context of denialism, science education needs to "land" (*sensu* Latour (2020)) and, for that, it is necessary to forge diplomatic alliances with actors of the old "constructivist/realist" axis of tension. Latour promotes a new way of understanding science through the mutual and constant transformation of the scientific and the social worlds (Richard and Bader 2010), which can be beneficial for science teaching in order to avoid the arbitrary distinction of society and science as two distinct and non-communicating entities (Yurij Castelfranchi 2002).

This approach to education could promote in students not only an interest in science, but especially critical attitudes towards the misuse of science in a consumerist and technocratic society, as well as a recognition of the social in the operational processes of research. Reiss (2020) suggested that the COVID-19 pandemic, incorporating historical knowledge from previous pandemics, should be included in science education as a way of deepening understanding of the Nature of Science and deepen the ethico-political discussions that students typically meet in science classes. Again, our case of COVID-19 is a promising example, as it clearly shows the uncertainties, the social, the collective, the virus and the financing all in the same frame, breaking with the naive dichotomy between science and society.

The circulatory system model of science is useful for this purpose of critical science teaching, as it assists in the process of revealing the social character of the construction of scientific knowledge for classroom use, facilitating its reconstruction (Izquierdo-Aymerich and Adúriz-Bravo 2003), since it reveals all the actors and their actions as the scientific fact is constructed. However, the educational intent is that it can be used as it is most convenient for the teacher and for the educational context.

Concluding Remarks

The case of discoveries surrounding COVID-19 and the development of vaccines present one case of how critical science can be presented in the context of science education, one that instigates curiosity, motivation, interest, and engagement of students in situations that involve scientific knowledge, and especially their relationship with the world around them. This has been done in a few works before, as in Rezzadori and Oliveira (2021) and in Christodoulou et al. (2021), and from which now we present a current case where the science is still in construction involving the COVID-19 case.

In this sense, we emphasize here the importance of developing a critical conception of school science, starting from the proposition of an operational definition of the social construction of science, bringing as an example one based on the blood flow model/circulatory system of science proposed by Latour (1999), in order to promote a conceptualization of science as a social enterprise.

The definition of the social construction of scientific discourse provides a basis for an alternative to renewing the image of science taught at school, in consonance with technoscience, i.e., with current problems that involve the students' environment. It is in this sense that we discussed COVID-19 and the production of vaccines as a way of seeking to bring school science to reality, to make it relevant and motivating to the students' understanding of the production of scientific facts, and to try to reveal several facets of the social nature of science.

With that, it is expected that more and more problems like these be addressed in the classroom using a critical theoretical framework, such as the Latourian one presented here, in order to present how scientific work operates while science is still being built, breaking with the dichotomy between science and society, and overcoming a naive and simplistic image of how science is done.

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