Teaching about the social embeddedness, creativity and tentativeness of science through news articles on COVID-19

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Abstract

Scientific literacy has become central to science education and science education research several decades now. Although there may be different views about the meaning of the term, there is a broad consensus that scientific literacy includes an adequate understanding about the nature of science (NOS). NOS seems to be a hard topic for students and teachers. A popular approach to NOS teaching and learning is the 'general aspects conceptualization of NOS', which is based on conceptualizing NOS through partial, general aspects that may refer to the nature of scientific inquiry and the nature of scientific knowledge. These aspects are often introduced to students in a contextualized way, thus they may be integrated in lessons based on current scientific work. One way to do it is through news articles with scientific content. In our study, 16 educational sciences students were engaged in small-group and whole-class discussions in order to collaboratively respond to questions about issues raised in a news-based text highlighting the influence of the COVID-19 pandemic on scientific research. Our results showed that the social embeddedness of science as well as the tentativeness of scientific knowledge and the creativity needed for its production, were successfully illustrated by the students.

Keywords
Nature of science, COVID-19, socio-cultural embeddedness, tentativeness, creativity

Résumé

Depuis plusieurs décennies déjà, la littératie scientifique s'est rendue un élément essentiel de l'enseignement des sciences et de la recherche sur la didactique des sciences. Bien qu'il y ait des points de vue différents sur la signification du terme, il existe un grand consensus sur le fait que la littératie scientifique inclut une compréhension adéquate de la nature de la science (NOS). La NOS semble être un sujet difficile pour les apprenants et les enseignants. Une approche populaire de la didactique et de l'apprentissage de NOS est la «conceptualisation générale des aspects de NOS», qui prend appui sur la conceptualisation de NOS à travers des aspects partiels et généraux lesquelles peuvent faire référence à la nature de la recherche scientifique et à la nature du savoir scientifique. D'habitude, les apprenants sont initiés à ces aspects d'une façon contextuelle. Ces derniers peuvent donc être intégrés dans des cours qui tiennent en compte des travaux scientifiques actuels. Une manière pour cette mise en place est à travers des articles de presse récents de contenu scientifique. Dans notre étude, 16 étudiants des sciences de l'éducation ont participé à des discussions en petits groupes et en classe entière afin de répondre de façon collaborative à des questions portant sur des sujets tirés d'un texte d'actualité valorisant l'influence de la pandémie COVID-19 sur la recherche scientifique. Nos résultats ont montré que l'intégration sociale de la science ainsi que le caractère provisoire de la connaissance scientifique et la créativité nécessaire pour sa production, ont été illustrées avec succès par les étudiants.

Mots–Clés
Nature de la science, COVID-19, intégration sociale, caractère provisoire, créativité

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Introduction

Scientific literacy has become central to science education and science education research several decades now (Abd-El-Khalick et al., 2017). A consensual definition of scientific literacy is actually missing, but one could roughly claim that science literate

people should possess knowledge *in* and *about* science, and also have the ability to use this knowledge for coping with socio-scientific issues and making informed decisions in their context (Norris & Phillips, 2003). So, first of all, conceptual understanding in science needs to be coupled with epistemological one, and this need brings nature of science (NOS) at the heart of science education and science education research as well (McComas & Clough, 2020). Coming up with a broadly accepted definition in the case of NOS is not easier than in the case of scientific literacy. However, as McComas et al. (1998, p. 4) put it, NOS concerns 'what science is, how it works, how scientists operate as a social group and how society itself both directs and reacts to scientific endeavors'. In a word, NOS concerns the kind of knowledge scientists produce and the way they work to produce this knowledge (Lederman, 2019).

Although very important for students, NOS seems to be hard to understand and hard to teach as well (Jordan & Duncan, 2009; Kremer et al., 2014). Students tend to conceptualize science as an endeavor which seeks for a truth that is real and objective. Scientific knowledge is considered independent of the socio-political context in which it is produced and students have difficulties in recognizing the connection between science and scientists' creativity, imagination or presuppositions (Sandoval, 2005). On the other hand, teachers may also show a limited understanding of NOS (Morrison et al., 2009), or they may fail to effectively include NOS in their teaching even if they do have an adequate NOS understanding (Bell et al., 2000). A study investigating the practices of a group of motivated and qualified teachers revealed that although many of them thought that they were teaching NOS, they actually were not (Capps & Crawford, 2013).

A popular approach to NOS teaching and learning is the 'general aspects conceptualization of NOS', which is based on conceptualizing NOS through partial aspects that may refer to the nature of scientific inquiry (NOSI) as well as to the nature of scientific knowledge (NOSK) (Kampourakis, 2016); for instance, through aspects like the empirical basis of science, the tentativeness of scientific knowledge or the creativity involved in its construction (McComas & Kampourakis, 2015; Lederman & Lederman, 2014). This approach has been criticized for not highlighting the differences among the various science disciplines, as well as for not being exclusively bound to the scientific endeavor since some general NOS aspects may characterize other human endeavors as well (Irzik & Nola, 2011). However, despite the possible drawbacks, using the 'general aspects approach' is considered to be helpful for the advancement of students' understanding about NOS (Kampourakis, 2016), especially if the target NOS aspects are *explicitly* introduced to students as such. Research has shown that although in some cases it is believed that students develop NOS understanding when NOS aspects are implied through e.g. inquiry-based science activities at school, NOS teaching should be explicit in order to be effective (Lederman et al., 2014).

The general NOS aspects are often introduced to students in a contextualized way.

This actually means that they are associated with particular scientific content (Koksal et al., 2013). More specifically, they may be integrated in student-led lab inquiries, like for instance a starch digestion inquiry or a steel wool burning one (Yacoubian & BouJaoude, 2010); in lessons based on the history of science, like for instance the discovery of DNA structure (Dai et al., 2021); or in lessons based on current scientific work, like for instance an epidemiologic research concerned with possible links between cell phone use and cancer risk (Cakmakci & Yalaki, 2018). NOS aspects integration in lessons based on the history of science could be attempted through scientists' biographies, e.g. those of Isaac Newton, Louis Pasteur, Marie Curie or Albert Einstein (Hwang, 2015), historical accounts of the development of significant technologies (e.g. the history of vaccines' technology from 17th century until today; Lee & Kwok, 2017) and literary stories, e.g. stories presenting fictional conversations between eminent scientists such as Charles Darwin and Joseph Dalton Hooker (Ampatzidis & Ergazaki, 2023). On the other hand, NOS aspects integration in lessons based on current scientific work could be attempted through media excerpts and science-related news articles, e.g., health news claiming that tofu might harm memory in elderly people (Leung et al., 2015).

Using science-related news articles seems to be a good idea, since bringing contemporary science into the classroom might help students to bridge the gap between school science and real world (Jarman & McClun, 2001). It is also believed that introducing NOS aspects this way may enhance the attractiveness and relevance of NOS to students and thus promote their understanding about it (Cakmakci & Yalaki, 2018). Researchers who advocate the use of science-related news articles in NOS teaching argue that their use may easily be integrated in science curriculum since they illustrate NOS aspects in various research fields. Moreover, it is rather simple to select articles that could engage students in actively exploring one or more NOS aspects at the same time; in fact, many articles may be used to refer to different NOS aspects in the same context, which makes it possible for teachers to discuss more than one NOS aspect by using the same article. On the other hand, science-related news articles make it possible for teachers to address the same NOS aspect in quite different contexts as well (García-Carmona & Acevedo Díaz, 2016).

Considering the above, we decided to draw on science-related news articles in order to design a learning environment that could offer students the opportunity to think and discuss about specific NOS aspects. The news articles we decided to work with concern scientific research about COVID-19. Since the onset of the pandemic, there have been published several research papers about COVID-19 in science teaching and learning (e.g. Archila et al., 2021; Han-Tosunoglu & Ozer, 2022; Saribas & Çetinkaya, 2021), whereas only few of them addressed NOS in particular (e.g. Demirdöğen & Aydın-Günbatar, 2021; García-Carmona, 2021; Maia et al., 2021). Maia et al. (2021) analyzed selected scientific publications and reports from the general media that had to do

with COVID-19, the virus causing it, and the development of treatments and vaccines against it. According to the results of their analysis, the COVID-19 pandemic provides a rich socio-scientific context for familiarizing students with NOS and helping them to enhance their scientific literacy. Finally, since this disease became a main concern of lay people worldwide, we thought that students themselves would probably be more interested in exploring NOS in this particular context.

So, in this paper we report on a small-scale, pilot implementation of a NOS learning environment that draws on science-related news about COVID-19 in order to engage students in exploring three NOS aspects: (a) the socio-cultural embeddedness of science, (b) the creativity that underlies science, and (c) the tentativeness of scientific knowledge. What actually concerns us here is not to evaluate the impact of the learning environment on students' initial understanding about NOS but merely to shed light on whether it could work as a context for NOS exploration by students.

Methods

The implementation of our 'COVID-19 news articles'-based learning environment about NOS was carried out during the academic year 2020-21 with second year university students of educational sciences (age 19-21), after being approved by the Department's ethics committee to which we submitted our research proposal. Students, who were attending an optional, biology course offered online because of the pandemic, volunteered to take part after they were given (a) the necessary information about the study (e.g. its purpose, the role they were expected to have in it, the time they would need to spend), as well as (b) the reassurance that they were absolutely free to withdraw whenever they felt like doing so. The participants had not received any formal teaching on NOS up to that point, whereas they were rather active in terms of raising/answering questions in the course's regular classes and they were also familiar with group work. The first session was performed with sixteen students. Twelve of them continued in the second session and six continued in the third one as well. We think that the decrease of the participants' number has possibly to do with the turbulence the pandemic added in students' everyday lives and not with the learning environment itself; those who participated consistently seemed to be rather enthusiastic with their work in it.

In all sessions, students were required first to read a text we created by combining excerpts from COVID-19 news articles retrieved from online science news sources (see below), then to collaborate in pairs in order to explore issues raised in the text and respond to relevant questions (see below), and finally to participate in a whole-class discussion at the end of the session. It should be noted that our texts and the associated questions have been examined by a third biology education researcher who validated them as appropriate contexts for exploring the target NOS aspects. More-

over, it should be noted that students collaboratively worked with the texts by using the chat tool of the Upatras e-class platform, whereas they uploaded their pair's final responses (which constitute our data here) at the same platform by using the essay tool. The responses were examined by both the authors in order to reach consensus on whether students were able or not, to link text information about science in the time of COVID-19 with the target NOS aspects and thus infer that science (a) is embedded in the socio-cultural context in which it is conducted, (b) is underlined by scientists' creativity, and (c) produces knowledge that is prone to change.

The target NOS aspect of the first session was the socio-cultural embeddedness of science. The first part of the text we created for the students highlighted the fact that many researchers around the world have set their research interest on COVID-19. For instance, students read about Roser Valenti, a quantum physics expert who turned her modelling skills from studying states of matter, to simulating the course of the COVID-19 pandemic (Gibney, 2020). They also read about a survey which was conducted by a research team from the Harvard University with a sample of 2500 researchers in Europe and North America and came up with the conclusion that 32% of the participating researchers changed their research agenda in order to contribute to the research about the pandemic (Yong, 2020). The second part of the text was concerned with the fact that COVID-19 has changed the way science is carried out, especially regarding the communication of the results. For example, students read the words of Dr. Ryan Carroll, a Harvard Medical professor involved in corona-virus research, who explained that although scientists usually work in secret, since published research can lead to grants and promotions, in the case of SARS-CoV-2 research scientists around the world are openly sharing their data. As highlighted in the text, the pandemic has pushed biomedical research towards more open practices like publishing preprints and providing open data to all researchers working on COVID-19 (Apuzzo & Kirkpatrick, 2020). In order to help students explore the target NOS aspect of this session after reading the text, we had them discuss how the pandemic, which is a huge challenge for the society, has affected (a) the direction of scientific research (Q1), (b) the way that scientific research is conducted (Q2), as well as what the pandemic's impact on (a) and (b) implies for NOS (Q3).

The target NOS aspect of the second session was the role of creativity in science. The first part of the text we created for the students highlighted the fact that, at the onset of the COVID-19 pandemic, scientists examined possible treatments by repurposing drugs developed for other diseases. For instance, students read about the idea of a research team to try treating COVID-19 patients with nitric oxide, a gas that is often used for breathing disorders. Moreover, they read about the use of cancer drugs for dealing with the damage that COVID-19 does to the immune system (Park, 2020). The second part of the text had to do with the fact that in December 2020, 11 months after

the coronavirus genome was mapped, there were already more than 150 research projects running for the development of a vaccine against SARS-CoV-2. Although all these potential vaccines may be grouped based on their target (i.e. on whether they concern the entire virus, molecules or even portions of molecules expressed on the surface of the virus) and on the technology they use to achieve immunity (i.e. on whether they are DNA vaccines, mRNA vaccines, protein vaccines, inactivated virus vaccines), they all have features that make them unique. The text ended with the comment that watching the different methods and techniques used in the race to develop successful vaccines against SARS-CoV-2, one cannot but praise human creativity (Forni & Mantovani, 2021). In order to help students explore the target NOS aspect of this session after reading the text, we asked them to discuss about which features of scientists' personalities should be activated so that (a) they could envision the use of drugs originally designed to deal with other diseases, in the treatment of SARS-CoV-2 (Q1), and (b) they could develop so many different vaccines against SARS-CoV-2 (Q2). Finally, they were asked to discuss about what this implies for NOS (Q3).

The target NOS aspect of the third session was the tentativeness of scientific knowledge. The first part of this session's text focused on the fact that what scientists believed about the role of children in the transmission of SARS-CoV-2 has changed in the course of the pandemic. At first, in most countries schools closed in the fear of a great transmission among young students. However, later on, several scientists claimed that an increasing body of data showed that children were at lower risk of getting infected with coronavirus and transmit it to others, thus it seemed that schools could reopen (Mallapaty, 2020). The second part of the text emphasized that what scientists believed about the transmission of SARS-CoV-2 has changed as research data accumulated. For example, students read that during the first months of the pandemic, scientists thought that one should have symptoms of the infection in order to be able to transmit the virus; however, studies have shown that people may spread the virus even before developing symptoms (Lord, 2020). Finally, after reading the text, students were asked to discuss about why scientists changed their original ideas about children transmitting SARS-CoV-2 (Q1), asymptomatic patients transmitting SARS-CoV-2 (Q2), as well as whether the modification of scientific ideas can be considered as an exception or norm in science and what this implies for NOS (Q3). The content of the three sessions is summarized in Table 1.

TABLE 1

The overview of the sessions

Sessions	Target NOS aspects	Text content
1	Socio-cultural embeddedness of science	Researchers around the world have set their research interest on COVID-19. COVID-19 has changed the way science is carried out, especially regarding the communication of the results.
2	Creativity in doing science	Scientists examined possible treatments of COVID-19 by repurposing drugs developed for other diseases. Many research projects with unique features run for the development of a vaccine against SARS-CoV-2.
3	Tentativeness of scientific knowledge	Scientists' ideas about children's role in the transmission of COVID-19 changed as new data about the disease accumulated. Scientists' ideas about transmitting SARS-CoV-2 before developing symptoms changed as new data about the disease accumulated.

FINDINGS

Social-embeddedness of science

Students' responses showed that most of them (5/8 pairs) were able to use text information as building blocks for a reasoning strand that leads to the desired conclusion about the socio-cultural embeddedness of science. More specifically, they recognized that science is influenced by society, referring, e.g., to scientists working together instead of working in secret, as well as to scientists shifting their research focus because of societal challenges. In students' own words:

– *'Society directly affects science, and this is evident in the case of the pandemic. In order for humanity to be saved, the way that scientists were usually working has changed, and more collaboration is taking place among governments and scientists and within the scientific community itself'.*

– *"It seems that science is influenced by the society. As we have seen in the texts, many scientific studies about several things have been discontinued and the scientists' focus has been set on understanding the virus and fighting the pandemic'.*

– *'Science aims to improve people's lives. Scientific research appears to follow the needs of society (when, for instance, there is a specific situation to deal with).*

In the whole class discussion that followed the pair-work, students shared their ideas about how urgent social needs can re-shape the research agenda of the scientists and the strategies of knowledge dissemination used within the scientific community, whereas they were further supported in reaching explicitly the conclusion that science is a socially-embedded endeavor. Moreover, they were prompted to explore another, less positive aspect of science's socio-cultural embeddedness by drawing on cases from the history of science in which society held science back rather than boosting it.

Creativity in science

Students' responses showed that all of them (6/6 pairs) were able to recognize that scientists' creativity is crucial for their work, by drawing on text information. In students' own words:

- 'Scientists' creativity and their constant search for knowledge in various inventive ways is a key element of science'.
- 'Scientists needed to activate their creativity to envision the use of such drugs in the treatment of COVID-19. Being creative helps scientists doing science'.
- 'Science in general is based on empirical data but also requires the imagination and creativity of scientists'.

In the whole-class discussion, students shared their ideas about creativity in science and stressed its importance for articulating solutions to complex scientific problems and for developing new drugs or technologies. Moreover, they compared scientists to artists and concluded that being creative applies equally to both.

Tentativeness in science

Students' responses showed that all of them (3/3 pairs) were able to reach the conclusion that scientific knowledge is subject to change when new research data emerge, by drawing on text information. In students' own words:

- 'Scientists initially believed that SARS-CoV-2 could only be transmitted by people showing obvious symptoms. Research has shown that the virus may also be transmitted by asymptomatic people one or two days before they become ill. This assumption explained the rapid spread of the virus, both within a particular country and around the world. Scientific knowledge being subject to change seems to be the norm in science, as new research data are constantly emerging'.
- 'The reason why scientists modified their original ideas for the transmission of the corona-virus by asymptomatic patients is the new data that emerged. The modification of scientific knowledge is the rule as the conclusions of scientists are constantly changing'.
- 'Scientists revised their original ideas about the transmission of SARS-CoV-2

by asymptomatic patients because they were able to discover new features of the process of the virus transmission and think differently. The modification of scientific knowledge seems to be a norm as scientific conclusions may change over time'.

In the whole-class discussion, students shared their ideas about the tentativeness of scientific knowledge due to the emergence of new data and were prompted to explore the idea that tentativeness may also arise when known data are interpreted in new ways.

Discussion

As already mentioned in the introduction of the paper, since the appearance of SARS-CoV-2 there have been published several papers about COVID-19 in science teaching and learning, with few of them addressing the teaching and learning of NOS in particular. For instance, García-Carmona (2021) offered examples about how to use news articles as a context for addressing NOS aspects like the tentativeness of scientific knowledge, the role of error in science, the role of modelling in science and the ethical aspects of doing science. In fact, he suggested that a relevant teaching intervention could have specific phases like (a) the phase of group-work in which students are engaged in reading news articles and collaborating in groups in order to give answers to relevant questions, (b) the phase of whole class discussion in which they share and further elaborate their initial answers, and (c) the phase of conclusions. However, the work of García-Carmona (2021) was theoretical, thus not grounded on empirical data.

Demirdöğen & Aydın-Günbatar (2021) introduced a guide of how one may select and use science news on COVID-19 pandemic in order to teach about NOS in high school (K9-K12). More specifically, they made suggestions about how media articles should look like in order to be suitable for educational use. For instance, they suggested that media articles as teaching tools should not be too long and detailed, should not include unfamiliar terms, should be reliable etc. Moreover, these researchers provided examples with specific NOS aspects like the tentativeness of scientific knowledge and the role of evidence, inference and collaboration in science, and reported on the results of a pilot study with four pre-service, high-school science teachers.

The suggestions of García-Carmona (2021) about structuring a news articles-based teaching intervention about NOS in specific phases were taken into account when designing our own learning environment. The same is valid for the suggestions of Demirdöğen & Aydın-Günbatar (2021) about the features of the news articles should have in order to be used in educational settings. Moreover, it should be noted that, in fact, the study we report here *added* to these studies in two ways: first, we provided data about whether our learning environment can work, by piloting it with university

students of educational sciences; and second our learning environment concerns the teaching and learning of NOS aspects, like science's social embeddedness and creative character, that did not concern the previous studies.

The results from the data we obtained during the implementation of the learning environment, suggest that the texts we created from science-related news articles about COVID-19 *did* offer students a good opportunity to explore quite well our target NOS aspects while interacting with each other. However, what should be investigated more rigorously is the actual impact of such a learning environment on students' initial understanding about NOS. This requires a pre/post research design, whereas it also requires dealing with the limitation of time. Important educational goals are likely to be achieved through systematic, *long-term* instruction (García-Carmona & Acevedo Díaz, 2016). It seems difficult for such goals to be attained through short teaching interventions, especially when they concern the NOS concept which is complex and probably not so familiar to education students. On the other hand though, when one aims to incorporate NOS teaching in a course within a program of educational studies, they need to adapt the teaching intervention and its duration to the syllabus at hand.

So, as a future step, we plan to perform our main study by (a) involving significantly more students, (b) attempting to increase the duration of the learning environment if possible, and (c) evaluating the effectiveness of the learning environment with typical pre/post comparisons. Having experienced, in this pilot study, students' interest in reading and discussing about the science behind the pandemic through texts based on news articles, we have further enhanced our initial judgment about the pedagogical value of these texts in exploring NOS aspects.

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