Science & Education (2021) 30:441–444
https://doi.org/10.1007/s11191-021-00245-8

EDITORIAL

Respect for Evidence: Can Science Education Deliver It?

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Accepted: 7 May 2021 / Published online: 21 May 2021

In the short span of a year, numerous vaccines have been developed by various scientific research teams across the world. We cannot acknowledge enough the countless scientists who have been working tirelessly to develop drugs as well as vaccines to combat COVID-19. If it wasn't for these scientists' respect for evidence, regardless of whose evidence and from where, it is difficult to imagine how the world would have coped with no reliable vaccines a year after the emergence of the pandemic. Even though the pandemic context has put the interplay of science with economics and politics on display, illustrating the tensions in how scientific knowledge may be interpreted in and for public consumption, it is important to highlight that "science" can still serve humanity at a time of public health crisis thanks to the great value it places in generating, evaluating, and using evidence. Scientific evidence rests on objectivity, as contested a definition this concept may invite (Longino, 1990; Needham, 2020). Imagine what vaccine research would look like if it were guided by accounts of subjective experiences of scientists of different backgrounds and identities establishing their own idiosyncratic mechanisms of COVID-19 immunity without a sense of collective critique and robust validation, where findings and conclusions are divergent on empirical adequacy and accuracy, where the language and representations are localized to the point of obscurity, and only intelligible to those who utter them. It would indeed, most likely, lead to a public health disaster.

Respect for evidence is an important social value in science, relevant to the contemporary context of anti-science sentiment displayed through issues such as climate change denial but how does science education deal with such values and indeed, does and can science education actually instill respect for evidence? There is research in science education on student engagement with scientific evidence (McNeill & Berland, 2016) as well as accounts that indicate the possibility of belief revision in light of data (Masnick et al., 2017). However, engagement with and understanding of evidence does not necessarily guarantee respect for evidence. Respect for evidence can apply to different senses of "science education." One sense is about teaching in formal and informal contexts such as schools, museums, and other learning environments. Another sense is about science education as a domain of educational research carried out by academics, researchers, as well as teachers in different organizational settings. The question of respect for evidence can be raised in both senses. The current issue of *Science & Education* includes a set of papers that explicitly or implicitly embrace respect for evidence, whether this is embedded

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in how “science” is depicted in teaching, learning, textbooks, and the like, or however it infiltrates the analytical approaches of research, be them empirical, historical, or theoretical in nature.

Following an overview of the papers in this issue of *Science & Education*, I will return to the notion of respect for evidence. The papers cover a range of themes such as the teaching of contextualized nature of science (NOS), the use of history of science in formal and informal learning environments, multidisciplinarity at the interface of science and art, as well as the juxtaposition of politics and public health. Analytical approaches represented in the papers include epistemic network analysis and conceptual tools from sociology and philosophy of education. Collectively, the papers illustrate the various facets of how science education can be enhanced through reflections on the history, philosophy, and sociology of science not only through theoretical arguments but also through empirical evidence and practical resources.

Fackler argues that epistemic understanding of knowledge production in science with a focus on avoiding the backfire effect may potentially facilitate students’ attitudes toward science. “Backfire effect” refers to how efforts to correct individuals’ false beliefs may not result in removing those beliefs. The author suggests that more emphasis could be placed on expanding ways of knowing and marking the boundary between the scientific way of knowing and other ways of knowing. The theme of knowledge production is picked up in the paper by Hopkins where neuroscience is presented as a contemporary example of “science-in-the-making,” providing a contemporary science domain for contextualized NOS instruction. Through a range of analytical approaches, the author investigates pre-service teachers’ understanding of NOS. Broader notions of NOS are raised in the subsequent two papers. Moura, Nascimento, and Lima situate politics as a constituent feature of science, not playing a subsidiary role in science. They draw on arguments from science studies and exemplary cases from history of science and analyze public controversies surrounding COVID-19 in the context of Brazil. The broader conceptualization of science is also evident in Mulvey and colleagues’ paper where the discussion of NOS moves beyond knowledge of discrete NOS aspects to consider connections among NOS aspects. The authors present a study involving three teacher cases to explore the potential of an innovative analytic approach that focuses on “epistemic network analysis.”

It has long been argued that a major goal of science education is to develop scientific literacy. Valladares provides a systematic theoretical analysis of the main visions of the concept of “scientific literacy” developed in the last 20 years, including a transmissive educational vision of scientific literacy and a transformative vision with a stronger engagement with social participation and emancipation. Using conceptual tools from sociology and the philosophy of education, the notions of science participation and emancipation associated with the transformative vision of scientific literacy are articulated. Ke and colleagues, on the other hand, draw on literature from science education and philosophy of science to illustrate that students should engage in both scientific and socio-scientific models as they explore complex societal issues. The authors argue that developing and using multiple models can equip students with the appropriate knowledge and skills needed to deal with complex issues.

The next two articles focus on historical approaches in science education. Jardim, Guerra, and Schiffer investigate how understanding of scientific practices can be developed through classroom discussions focusing on historical cases as well as students’ own social contexts. The historical episode selected for inclusion in physics lessons was the development of the Leiden jar in Europe, in the eighteenth century illustrating the construction and use of this artifact. The use of history of science is reiterated by Wei and Chen who examine the quality of lesson plans based on a five-dimensional framework composed of conceptual, procedural, epistemological, affectional, and social dimensions. The findings indicate that the conceptual, procedural, and affectional dimensions are more prevalent as compared to the epistemological and social dimensions. Furthermore, some differences between three science subjects (biology, chemistry, and physics) and between the junior and senior secondary schools were identified.

Dai and colleagues present a study focusing on whether narratives based on the history of research on the structure of DNA shared using an explicit and reflective approach would affect students' understandings of NOS. A mixed method approach was used to assess students' NOS understanding in two different versions of a biology course, with or without the use of historical narratives. Results indicate that most of the participants in the intervention treatment made significant changes from pre- to post-assessment with respect to their understanding of aspects of NOS. Historical narratives are further explored at the interface of science and art by Dutta who uses the example of Leonardo da Vinci's Mona Lisa to show why and how the painting can be considered as a prototype for multidisciplinary science education. The analysis of the inner details together with Leonardo's scientific epistemology advocates the importance of putting into practice repeated experiments and observations.

The last two articles focus on the design of learning environments to facilitate understanding of science. Samon and Levy examine the contribution of laboratory experiments and computer model explorations to the learning of chemistry through a complex-systems approach. One hundred and fifty-nine seventh-grade students participated in a non-randomized four-group comparison quasi-experimental pre-test-intervention-post-test design. By contrast, Bernarduzzi and colleagues illustrate one case of an informal science learning environment, the Pavia University History Museum which houses historic items from physics and medicine. The authors describe the development of an innovative technological tool, an augmented reality application, made available to visitors to facilitate interpretation of historical-scientific artifacts.

The manuscripts in this issue have thus scrutinized a range of theoretical frameworks, methodological approaches, and practical tools to generate evidence that can help improve understanding of how science education can be supported through insights from history, philosophy, and sociology of science. Just as scientists have been striving to establish evidence in order to produce understanding of COVID-19 as well as the practical know-how for solving a public health crisis, the authors have placed value in respecting evidence whether as part of research methodology and as part of the characterization of science in their studies. If science education — whether in the sense of teaching or a research domain — does not respect evidence, including its objectivity, then it risks being paradoxical, perpetuating a self-destructive, anti-science stance itself. Anti-science science education will do no service to science nor to public empowerment, particularly at a time of global health emergency when scientific progress and scientific literacy are sorely needed.

Declarations

Conflict of interest The author declares no conflict of interest.

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