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Editorial

Breaking Free from Laplace's Chains: Reimagining Science Education Beyond Determinism

Olivia Levrini, Mauricio Pietrocola, Sibel Erduran

Throughout history, human development has continuously transformed the planet Earth. One of the consequences of the human impact on the planet is the climate crisis, leading to environmental and social changes and influencing every aspect of our lives, spanning from economic, political, social, and cultural elements to the deepest realms of our most intimate personal, emotional, and affective experiences. These changes reflect not only planetary and societal realities but also affect the content of our research aspirations in science education and science studies, since they touch on the heart of the relationships between science, technology, nature, and human beings. The emerging landscape of research necessitates that we question the traditional epistemological foundations of scientific thought on which the project of modernity was grounded since the Enlightenment in the 18th century. Modernity presupposed the belief in the power of science to build a progress-oriented societal order. Newtonian determinism, expressed in the metaphor of Laplace and his demon (Laplace, 1825), led to the appreciation of a special type of knowledge where causal laws reduced the future to the present. Such an account of determinism predicated that if someone (the demon in the metaphor) knows the exact location and momentum of every atom in the universe, the past and future characteristics of the atom can be specified through the laws of classical mechanics.

The hidden corollary of modernity is that more science in the future leads to more technology, which in turn leads to greater welfare for all. In other words, it was conceived that science and technology have the power to drive us towards a brighter and more equitable future. However, the legendary figures like the Golem, or the science fiction character of Frankenstein, together with, for example, the novel *The Man That Was Used Up* by Edgar Allan Poe, written a century and a half ago (Poe, 1939), had systematically called attention to the ambiguous role of science and technology, as a type of knowledge that may construct, but also destroy to reconstruct again in a different way, thus changing our humanity. The limits of the naïve positivistic picture of science have been well known in the philosophical debates on the nature of science, and problematized within contemporary science where, in particular, the concepts of uncertainty, non-linearity, complexity deeply question the “monuments” of the naïve positivistic view of science, revealing their historical character but also the capacity of science to be refounded on different values.

Against a backdrop of the modernity project in science studies and science education, more recent developments demonstrate that we are living in a *Risk Society* (Beck, 1992), where advancements in science and technology not only provide solutions but also introduce new uncertainties and threats to society (Pietrocola et al., 2021). Values such as commitment to certainty, faith in linear and unlimited progress, belief in positive impact of technologies as well as ideologies of ethical and gender neutrality currently reflect idealistic aspirations with intrinsic limitations. Increasingly, the dream of modernity to control nature clashes with the emerging evidence that solutions offered by science and technology are only partially attainable. On the other hand, a relatively new feature of the science and technology nexus involves the advancements in artificial intelligence (AI). AI is reshaping our relationship with technology, blurring boundaries between human and machine. AI, in its pursuit of efficiency and innovation, questions norms and confronts us with the ethical commitments of our systems of knowledge production and consumption. With respect to science education, AI destabilises not only teachers' roles in managing the content of science lessons, but also the very nature of science itself (Erduran, 2023; Erduran & Levrini, 2024). AI is now enabling scientists to generate new hypotheses (Hutson, 2023) and to design investigations in ways that were not previously possible (Wang et al., 2023), raising questions about *how* science is done and *who* does science.

In contrast, within science education the naive form of positivism still persists, with another hidden corollary: securing people that the brighter future, instead of educating them to think “probabilistically” (Rosenberg, Kubsch, Wagenmakers, et al, 2022) and to imagine what futures are possible and which ones can be desirable. In post-modernity, scientific knowledge would rather provide ways to make sense of social issues and make decisions about balancing positive and negative aspects of each choice. Within the context of educational institutions, determinism can be recognized in the spacetime rituals of schooling and in the linear and external conception of clock-time that they incorporate. Education rituals are mainly based on standardized measurements of learning units, progress and achievement, applied to guarantee the values of efficiency and optimization of learning and teaching. School time is almost always conceived to mark – and value – regular, ordered and continuous progression toward an ideally perfect control of what can happen. Such conception of time is revealing serious concerns. First, societies across the world caught in a fast paced era are encountering the dominant narrative of “*We no longer have 'time to take our time'*” (Benasayag, 2022; p.10). Furthermore, there is a wide and deep sense of “alienation from time” where people are pursuing objectives and practices that no external agent or factor oblige them to do when they do not feel like doing them (Rosa, 2010). The increasing phenomena of *burning out, quite quitting, identity fragmentation, declination in motivation* (Han, 2015) are worrying signals that alienation from time deeply implies a sense of alienation from the self and alienation from the others. Our identity and sense of ourselves derive from our actions, experiences and relations, and from how we situate them and ourselves in the social and material world as well as in the space-time fabric. These new forms of anxiety that emerge in students’ school experiences are at the core of some research agendas and actions that take care of these anxieties as psychological or mental health problems (e.g. Walburg, 2014).

The implication is that science educators need to revisit how scientific literacy is conceptualised, and what should be included in science teaching and learning. As well as guiding the students in their formative path within and through science, an increasing attention is paid to the goal of preparing the young to grapple with the risks and uncertainties brought about by the complex interaction between science, society, technology, and the environment (Clucas & Sjöström, 2024). Kamporurakis & McCain, 2020; Fazio, 2022,2023; Sjöström, Frerichs, Zuin & Eilks, 2017). As difficult a balance such emerging complex dynamics might be for students to manage, science education cannot escape from the responsibility to help students in dealing with the implications, including managing anxiety and disorientation instigated by a fast changing landscape of society.

For over four years, we as the editors of *Science & Education*, observed the impacts of the deep transformations of our societies on science education research. We noticed that the scope and accelerated rate of these transformations have influenced the journal and the articles that have been submitted for publication. We observed a renewed need to frame the debate on science education research from wider sociological, economic, and political points of view (Moura, Nascimento & Lima, 2021; Lopez & Mattos, 2024) and to diversify the perspectives from which HPS can be related to science education (Erduran, 2024; Moura, Guerra, Heering, 2024; Reiss, 2020). We observed the community stressing the need to investigate the sense of trust in science as represented in issues 5 and 6 of Volume 31 of the journal in 2022; problematize the apparent neutrality and dogmatism of scientific discourse in public debates (Mattos, Lopez, Ortega, et al, 2020); discuss the axiological and ethics dimensions (Koster & de Regt, 2020); explore complexity and uncertainty (Chen, 2020; Covitt, Anderson, 2022; Pereira, Silva, & dos Santos, 2022; Rosenberg, Kubsch, Wagenmakers, et al, 2022); and, of course, to deepen the debate on the impact of AI on science and science education. A special issue on epistemic insight and artificial intelligence is currently underway and some of the articles have already appeared online (Barelli et al., 2024; Oh & Lee, 2024).

Despite a growing interest in the HPS community in challenging the core of modernity and addressing the emerging societal challenges in novel ways within science education, it is difficult to shift the educational landscape in practice given how radically embedded the values of modernity are within our university and school systems. For example, the values of modernity are tightly linked to problem solving practices, assessment cultures and educational rituals. It is structurally embedded in the curriculum, pedagogy, and assessment practices that remain static, rigid and seem to continue to follow the impulse of preserving the modern tradition of guaranteeing what Giddens calls “ontological security” (Giddens, 1991). Our educational systems are functional to the technocratic society that induces us to drink in deterministic theories and stories and to desire to have total control of what 'is to happen'. Determinism is not only embedded in the contents that are taught. It is in the type of problems that are present in the textbooks and in the language that is used, implicitly conveying the message that science can provide the right solutions. In school practices, we still tend to carry the main message, foundational for the Enlightenment, that humankind sought to be emancipated through the creation of a new society based on the extensive and powerful use of science. Education was fundamental to the successful dissemination of such messages because it required people's compliance. Antony Giddens emphasizes this point, stating that “what is conveyed to the child in the teaching of science is not just the content of technical findings but, more importantly for general social attitudes, an aura of respect for technical knowledge of all kinds” (Giddens, 1991). Such observations lead the conclusion that as science educators, we need to reconstruct the ontological, epistemological, axiological tools of science contextualised within our society, and explore new ways of situating them in science education. Otherwise we run the risk of preparing the students for a world that no longer exists, a world of the past that has a fundamental dissonance with the present not to mention the future.

Our reflection here aims to show that they can be interpreted also as a signal of an epistemological crisis of our school disciplines that still conveys the illusion that science can guarantee ontological security. The epistemic, ontological, axiological, social and spacetime structure of our schooling seems to prepare students for a world that no longer exists and, maybe also for this reason, school science is no longer perceived as relevant from a personal, social and vocational point of view (Stuckey, Hofstein, Mamlok-Naaman, & Eilks, 2013). Furthermore, our

These reflections are presenting us, the science education researchers with a major challenge. How can we contribute to the regeneration of science teaching to help the young to inhabit, navigate and transform the fast-changing society? How can we break free from Laplace's chains? Where is the deterministic, linear, rigidly binary thinking hidden in current science education practices in schools and how can they be transformed to accommodate the needs of society? What new visions can be developed for science education and its role within society? Some of these questions have been addressed empirically through research projects where a range of stakeholders including students, teachers, curriculum developers, teacher educators and informal learning experts have engaged in articulating new visions for science education that go beyond the legacy of determinism.

Among them, some projects explicitly start from a regeneration of the scientific contents by questioning their epistemological, ontological and axiological foundations. For example, the 3-year EU-funded FEDORA project (<https://www.fedora-project.eu>) engaged with 6 partner institutions from 5 European countries exploring the regeneration of the ecosystem of science learning, by developing a future-oriented model to enable creative thinking, foresight and active hope, as skills needed in formal and informal science education (Levrini et al). The regeneration agenda for the science education eco-system in the project produced and applied conceptual tools such as “sense-making and strange-making” , “boundary making-unmaking”, “order and chaos” and “imagining the future-acting in the present” resulting in the reappropriation of teaching and learning practices in distinctively different forms as compared to the status quo. A cautionary stance was taken to ensure that the classical features of science, such as the potential of science to contribute to objective knowledge, are retained without destroying the whole of science while navigating uncertainties and disorder. Further theoretical and empirical investigations are needed to produce more examples of

new visions of science education and how science education can be better aligned with accommodating the contemporary demands of society.

With this editorial, we are approaching the conclusion of our mandate as editors of the journal at the end of the year. We wish to advocate the continuation of research to deconstruct the epistemological fossils and stereotypes that are reifying our educational systems and to make them less and less relevant. Our engagement with the journal has been a very professionally enriching experience, given *Science & Education* has a privileged position from which we can observe, through research reported in the journal, the developing complex social phenomena and associated educational imperatives including in the pandemic context. For interested scholars, we will continue our reflections in a new Special Interest Group of ESERA that we are establishing, where we discuss how and to what extent FUTURES-oriented science education can challenge and inform the epistemic foundations of science.

References

- Allan Poe, E. (1939). The Man Was Used Up - A Tale of the Late Bugaboo and Kickapoo Campaign. First published in August 1839 in *Burton's Gentleman's Magazine*
- Barelli, E., Lodi, M., Branchetti, L. *et al.* (2024). Epistemic Insights as Design Principles for a Teaching-Learning Module on Artificial Intelligence. *Sci & Educ*. <https://doi.org/10.1007/s11191-024-00504-4>
- Beck, U. (1992). *Risk society: towards a new modernity*. London: Sage.
- Benasayag, M. (2018). *Fonctionner ou exister? Le Pommier/Humensis*, Paris (Italian Edition: *Funzionare o esistere?*, Vita e Pensiero, 2019).
- Chen, YC. (2020). Dialogic Pathways to Manage Uncertainty for Productive Engagement in Scientific Argumentation. *Sci & Educ* 29, 331–375.
- Clucas, P., Sjöström, J. (2024). Traces of Bildung in Upper Secondary Science Education: A Critical Investigation of Chemistry Teachers' Orientation Towards Promoting Bildung in Chemistry Education. *Sci & Educ*. <https://doi.org/10.1007/s11191-024-00510-6>
- Covitt, B.A., Anderson, C.W. (2022). Untangling Trustworthiness and Uncertainty in Science. *Sci & Educ* 31, 1155–1180. <https://doi.org/10.1007/s11191-022-00322-6>
- Erduran, S. (2024). HPS for All in Journal's Metrics. *Sci & Educ* 33, 1–4. <https://doi.org/10.1007/s11191-023-00491-y>
- Erduran, S. (2023). AI is transforming how science is done. Science education must reflect this change. *Science*, 382, eadm9788. DOI:10.1126/science.adm9788
- Erduran, S., & Levrini, O. (2024). The impact of artificial intelligence on scientific practices: an emergent area of research for science education. *International Journal of Science Education*, 1–8. <https://doi.org/10.1080/09500693.2024.2306604>
- Fazio, X. (2022). *Science curriculum for the Anthropocene, Volume 1: Complexity, systems, and sustainability perspectives*. Springer Nature.
- Fazio, X. (ed.) (2023). *Science Curriculum for the Anthropocene, Volume 2*. Palgrave Macmillan, Cham. https://doi.org/10.1007/978-3-031-37391-6_5
- Giddens, A. (1991). *Modernity and self-identity: self and society in the Late Modern Age*. Cambridge: Polity Press.
- Han, B. C. (2015). *The burnout society*. Stanford University Press.
- Hutson, M. (2023). Hypotheses devised by AI could find 'blind spots' in research: Artificial intelligence is asking questions that humans hope to answer. *Nature*. <https://doi.org/10.1038/d41586-023-03596-0>
- Kampourakis, K., & McCain, K. (2019). *Uncertainty: How it makes science advance*. Oxford University Press.

- Koster, E., de Regt, H.W. (2020). Science and Values in Undergraduate Education. *Sci & Educ* 29, 123–143. <https://doi.org/10.1007/s11191-019-00093-7>
- Laplace, P.-S. (1825). *Essai philosophiques sur les probabilités*, Courcier.
- Lopez, F.S., de Mattos, C.R. (2024). Science Education in the USA During the Cold War. *Sci & Educ*. <https://doi.org/10.1007/s11191-024-00502-6>
- Mattos, C., Lopez, F.S., Ortega, J.L. *et al.* (2022). The Public Discussion on Flat Earth Movement. *Sci & Educ* 31, 1339–1361. <https://doi.org/10.1007/s11191-022-00321-7>
- Moura, C.B., Nascimento, M.M. & Lima, N.W. (2021). Epistemic and Political Confrontations Around the Public Policies to Fight COVID-19 Pandemic. *Sci & Educ* 30, 501–525. <https://doi.org/10.1007/s11191-021-00193-3>
- Oh, P.S., & Lee, G. G. (2024). Confronting Imminent Challenges in Humane Epistemic Agency in Science Education: An Interview with ChatGPT. *Sci & Educ*. <https://doi.org/10.1007/s11191-024-00515-1>
- Pereira, B.B., Silva, L.F. & dos Santos, J.R. (2022). Environmental Education and Complexity. *Sci & Educ* 31, 1–20. <https://doi.org/10.1007/s11191-021-00228-9>
- Pietrocola, M., Rodrigues, E., Bercot, F. *et al.* Risk Society and Science Education. *Sci & Educ* 30, 209–233 (2021). <https://doi.org/10.1007/s11191-020-00176-w>
- Reiss, M.J. (2020). Science Education in the Light of COVID-19. *Sci & Educ* 29, 1079–1092. <https://doi.org/10.1007/s11191-020-00143-5>.
- Rosa H. (2013). *Beschleunigung und Entfremdung - Entwurf einer kritischen Theorie spätmoderner Zeitlichkeit*, Suhrkamp (Eng. Trans: *Acceleration and Alienation - Towards a Critical Theory of Late-Modern Temporality*, 2015).
- Rosenberg, J.M., Kubsch, M., Wagenmakers, E.J. *et al.* (2022). Making Sense of Uncertainty in the Science Classroom. *Sci & Educ* 31, 1239–1262. <https://doi.org/10.1007/s11191-022-00341-3>
- Sjöström, J., Frerichs, N., Zuin, V. and Eilks, I. (2017), Use of the concept of Bildung in the international science education literature, its potential, and implications for teaching and learning, *Studies in Science Education*, 53(2), 165-192.
- Sun, F., Ye, R. (2023). Moral Considerations of Artificial Intelligence. *Sci & Educ* 32, 1–17. <https://doi.org/10.1007/s11191-021-00282-3>
- Walburg, V. (2014). Burnout among high school students: A literature review. *Children and Youth Services Review*, 42, 28-33. <https://doi.org/10.1016/j.childyouth.2014.03.020>.
- Wang, H., Fu, T., Du, Y., Gao, W., Huang, K., Liu, Z., Chandak, P., Liu, S., Van Katwyk, P., Deac, A., Anandkumar, A., Bergen, K., Gomes, C. P., Ho, S., Kohli, P., Lasenby, J., Leskovec, J., Liu, T.-Y., Manrai, A., ... Zitnik, M. (2023). Scientific discovery in the age of artificial intelligence. *Nature*, 620(7972), 47–60. <https://doi.org/10.1038/s41586-023-06221-2>