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Commentary

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Meaning and Truth in Science Education

Abstract

Education informed by scientifically meaningful ideas is insufficient, unless the proposed scientific meaning is committed to a comprehensive web of well-evidenced, coherent, and truth-conducive explanations. Meaning without truth is potently misleading; of course, there is no simplistic way to ascertain truth, but there must be principled routes within science education to commit meaning to reality.

Keywords: Truth, meaning, science, education

"Misrepresentation—a token of a structure with a false content… Meaning without truth"

Fred I. Dretske, quoted in Fodor (1992, p. 62)

Human life is meaningful. Indeed, we humans create meaning in our lives. When we bow to someone, we mean prayer, gratitude, or honour to the person: "For a kindly greeting, bow thou down with zeal" (Gandhi, 1970, p. 34). Our thoughts and actions, our beliefs and ideas create meaning. We confer meaning to our acts and beliefs by committing ourselves to certain values. For instance, reverence creates meaning to a ritual for a believer. Likewise, fasting as a mode of protest is meaningful to a person committed to the value of non-violence. Similarly, for a scientist, unification (understanding natural phenomena in terms of a small number of hypotheses) is one of the values that regulates her beliefs about which theory is more acceptable. For example, the epistemic value of unification (descent with adaptive divergence) of the unimaginably diverse species into a single "tree of life" informed Charles Darwin's crucial step towards developing the idea of natural selection (White, Hodge, & Radick, 2021).

Beliefs, values, and meanings are distinct but deeply intertwined. Our values, individual and collective, are a response to human experience. Meanings embody values. However, meaning is not the only constituent of good human lives. Truth is equally necessary. Science is not only a search for meaning but also for truth. Scientists aim not only at meaningful and coherent

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explanations, but also at true explanations. For example, Darwin was (also) motivated by the value of *vera causa* (true, real, existing cause) (Hodge, 1999).

The social institutions of science and science education have an obligation to learn to seek and communicate scientific truth.

Communicating truth requires communicating beliefs and communicating beliefs presupposes a common language. All this opens a Pandora's box of questions, such as what determines the content of our beliefs, what is truth, meaning, reality, and how do all these relate to language, intentionality, desire, etc. I cannot compress this in the space of a paragraph. My purpose at hand is limited: to reflect on certain pressing contemporary concerns that are misleadingly labelled as "too philosophical" to worry about, and thereby, are relegated to the margins of science education.

In the contemporary scenario, are the social institutions of science and education meeting their obligations to communicate the scientific truth? To know the truth-value of a hypothesis is to learn what it refers to and to ascertain the aspect of reality it represents. We presume that words refer to something in the world. The web of words carries meanings, and at the same time, refers to objects in the world. The question is, do they represent reality? For example, messages going viral on social media are certainly meaningful to users, but do they have anything to do with truth? For example, do various meanings associated with the word "omicron" or "FLiRT" represent the same thing as the SARS-CoV-2 virus variants, omicron or FLiRT? Moreover, what is the role of science education and science communication in all this? "Omicron" may carry multiple associations—restrictions on personal freedom for some, money for some, trauma from loss of employment for some, social stigma for some, virtual schooling for some, death for some, and breakthrough infections, immune escape, or vaccine resistance for some. But what is the biological reality that "omicron" refers to (and how does what it refers to compare with the known lessons from the science of evolution and ecology of host-virus interactions)?

Science is a source of meaning, particularly of entities beyond the grasp of sense-experience: antibodies, mutant variants, receptor proteins, genes, cytokines, and so on. Their meanings are often conveyed by phrases such as "waning antibodies," "cytokine storm," "target genes,"

"variant of concern," "immune escape," and so on. To what extent do these phrases reflect scientific reality?

As stressed earlier, science discourse must convey scientific truths—antibodies are but a part of the complex immune system. Mutation, variation, change, and adaptive continuity are biological evolutionary norms since antiquity; cytokines are necessary for cell-to-cell communication; variation does not automatically amount to virulence, and so forth.

Who gets to decide what meaning is attached to particular scientific descriptions, and on what grounds? A set of genes coding for a particular protein has many mutations, and in biology, mutations mean something. In science, descriptions are placed within explanatory frameworks and scientific meaning is fixed by scientific explanations. For example, the meaning of mutation of a virus in biology depends on the explanatory frameworks in microbial evolution, structure–function relationships, immunological and epidemiological perspectives on host-pathogen interactions, and so on. Scientists may be adept at making sense of scientific phenomena from the perspectives of multiple explanatory domains, but what about the old man in the sea of social media (Thorp, 2021)? To navigate through the jungle of meanings, one must locate a common referent: first, the scientific description and then its scientific explanation. Social media tends to reduce truth to (trivial, if not false) meanings. Look for the scientific reality represented by "viral" statements such as, "Oh! So many mutations in the spike protein!"

Cumulative pictures of scientific reality are slow to emerge, arising as they do through several piecemeal developments. Science tracks truth but there is no fast food on the menu. Many viral variants exist on the horizon, but it takes time to evaluate scientific descriptions and explanations of their evolution and their entailing implications for the host's immune system and biology. Science is not a mere dispenser of meanings ready for mass dissemination and concerted consumption. In the ethical and epistemic land of virtues in science, it takes a while before one can weigh in on a public policy to be put to practise with a sense of immediacy authorised by statistical precision. It takes a while, as it should, to mark the evidential pebbles on the path of truth. The gap between posting a preprint on social media to enacting a principled scientific policy is considerable, and therefore, it must take time and patience to traverse.

The development of science—and its attendant beneficial consequences for human welfare—is premised on the social institutions of science being a torchbearer of scientific truths. Science

presupposes and relates to scientific objects, i.e., things with objective properties. Galileo Galilei reminded us that "names and attributes must be accommodated to the essence of things, and not the essence to the names, since things come first and names afterwords" (Shapin, 2018, p. 18). In science, naming should reflect necessity. Names—"beta," "delta," "omicron"—go viral on social media (particularly when variants get categorised a certain way). However, what meaning runs through these names? Moreover, does the meaning in vogue commit to the truth about the virus (Frankfurt, 2009)? If not, these viral meanings pose a challenge (of trust) to the scientifically tempered community of scientists, science educators, and communicators (O'Neil, 2002).

Education, including science education, is expected to establish a necessary link between meaning and truth. To teach science is to teach the principles of science in the interest of truth; to follow science is to follow the norms of science. Science teaches us to value truth. Let the meaning of a variant be determined by the scientific reality of the virus. Education is obliged to the epistemic and ethical health of society, but particularly so when social media tramples on textbook distinctions between infection and disease; innate and acquired immunity; specificity and diversity of antigen-antibody complexes; adaptive inheritance and adaptive change. Science should certainly make sense to the student, but for it to be scientific, it cannot be emptied of truth.

What constitutes truth and what constitutes the scientific search for truth are heavy and complex questions, and this commentary is not a place to address them. However, I will mention some pointers for science education that could help us achieve the expectations set in the preceding paragraphs.

The question for science educators is: what virtues must education cultivate among students, so that they learn to value truth-seeking and truth-telling, so that meaning-making in science education is not empty of accurate representations of the aspects of nature under study?

In his book *Truth and Truthfulness*, Bernard Williams (2025) has persuasively argued that both seeking and asserting truth require the virtues of accuracy and sincerity. To bring this to bear on science and education is to assert that to be a person of science is to learn to have "a will to truth"; to learn to distinguish between one's false and true beliefs, between fantasy and reality; to learn that truth is not subject to the "assertion of power" (p. 148). Every science educator

and teacher must reflect on the question that Williams poses: “What responsibilities does one take on by telling a tale in… the mode of truth rather than in the mode of myth?” (p. 164).

Williams argues that the responsibility lies in a categorical, not conditional, commitment to truth. “The unconditional will to truth” means that “we want to understand who we are, to correct error, to avoid deceiving ourselves, to get beyond conformable falsehood” (2025, p. 15). Science students must learn to demarcate between wishful thought and scientific thought. To learn this demarcation is to learn to value accuracy and sincerity. Science students must learn to accurately represent the world they study and sincerely evaluate and report these representations (cf. John, 2021). To learn to do science is to learn to protect truth and truth-telling from the shadows of common human vices. For,

> Everywhere, there are wishes, and, among them, unfulfilled wishes; it is the pathos of the unfulfilled wish, in fact, that makes wishes obvious, and it registers the gap between wishes and truth. Just because the gap can be so painful, true belief… has to be protected against subversion by the wish, and this is why both the virtues of truth typically include defences against the pleasure principle, whether it is a matter of finding out the truth, and the protection is against such things as laziness and self-deception, or one is concerned… with the announcement or rehearsal of the truth, and the defences must be against such things as cowardice, ambition, and the desire to be loved. (Williams, 2025, pp. 165–66)

Science education must, of course, be meaningful, but that is not enough, for scientific descriptions often have multiple meanings and associations. Authentic science education must not fall short of protecting truth and truthfulness. In science education, meaning without truth is meaningless.

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