

Investigating the Nature of Science with Zeno's paradox

Pasquale ONORATO, Marco DI MAURO

Department of Physics, University of Trento, Via Sommarive 14, 38123, Trento, Italy

Abstract. This study presents a sequence of activities aligned with Nature of Science (NoS) principles to engage students in scientific knowledge-building, emphasizing the empirical nature of science. Designed for an experimental physics course for future teachers, the activities explore Zeno's paradox of Achilles and the tortoise. They include experimental and theoretical analyses of phenomena like the bouncing marble, aided by infinite series. Debates on whether Zeno was a scientist prompt discussions on science as a doctrine versus a process. These perspectives are further elucidated through discussions on a reconstructed Achilles' Paradox quote from Aristotle and an excerpt from Somerville's "Umbrellaology" (1941).

Introduction

Most Science Education Researchers stress that teaching scientific content alone is insufficient. It is vital to foster students' understanding of scientific knowledge construction, practical applications, scientific interactions, and societal influences. This encompasses Nature of Science (NoS), which delves into philosophical, epistemological, ontological, and sociological aspects. Despite the recent flourishing of NoS research, some facets like societal influences on scientists remain overlooked in physics lectures. NoS is integral to scientific literacy, essential for informed decision-making. Understanding how science works is pivotal both for personal and societal matters. NoS explores three main conceptions of science [1], usually juxtaposed: as doctrine, process, and social institution. The first defines sciences by subject matter; the second defines it by its methods; the third sees science as a human endeavour, shaped by society.

In this work we suggest a series of activities aimed at involving students in the creation of scientific knowledge, while fostering an appreciation for its empirical basis. An additional aim is to prompt a dialogue regarding what science is. The original approach of this proposal is to incorporate conceptual aspects, beginning with the challenges students face in integrating mathematics and physics, along with experimental and historical aspects to introduce some themes of NoS.

The activities

The activity is integrated into an experimental physics course designed for future high school teachers. These tasks focus on examining Zeno's paradox of Achilles and the tortoise as reported for example in ref. [2].

Before conducting the laboratory experiments, the students were presented with a multiple-choice question regarding the issue of a bouncing ball: "A ball is thrown upwards from the ground at a speed of v_0 . Every time it reaches the ground the ball bounces and its vertical velocity (as well as obviously undergoing a change of direction) varies by a fraction of $1/2$. Let us suppose that air friction is negligible. (A) How many bounces will the ball do before it stops? (B) How long does it take before it stops?" After discussing the answers with the students, highlighting on the one hand their misconceptions and on the other hand the equivalence of this problem with that of Zeno's famous paradox, the students carry out the experiment and analyze it with Tracker [2].

At this point, the students, having read Aristotle's reconstruction of the paradox, are asked to answer the question of whether Zeno was a scientist and why. The answer is negative, and in the reasons given by the students, there emerges the prevalence of an idea of science as a process, i.e. characterized by method, schematized also somewhat naively as a recipe. This conception is

sometimes accompanied by an empiricist-falsificationist view, which focuses on the contradiction between prediction and observation. Following a cultural approach, we focused with the students on how in ancient Greek thought the problem of demarcation arose as the problem of distinguishing true knowledge (ἐπιστήμη, which indicated knowledge established on a firm foundation and derived from the use of reason, λόγος) from mere opinion (δόξα) and technology (τέχνη). Reversing the logic of modern empiricism, the Eleatic philosophers and their successors did not base knowledge on sensible, deceptive data, but on reasoning and logical argumentation.

To challenge students' conception of science, we suggest presenting an excerpt from the 1941 article titled "Umbrellaology, or, Methodology in Social Science" by John Somerville [3]. This prompts the question: "What arguments can be made against the assertion that umbrellaology qualifies as a science?" Through student discussions, a perspective emerges regarding science as a doctrine, suggesting that the distinction between science and non-science lies in the subject matter it explores, or its content.

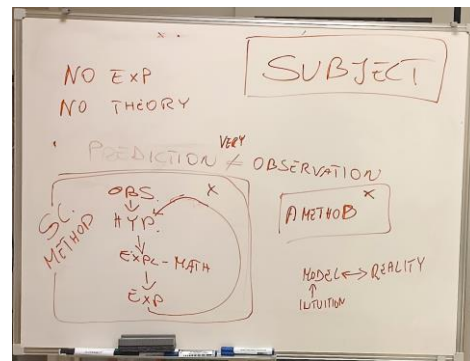
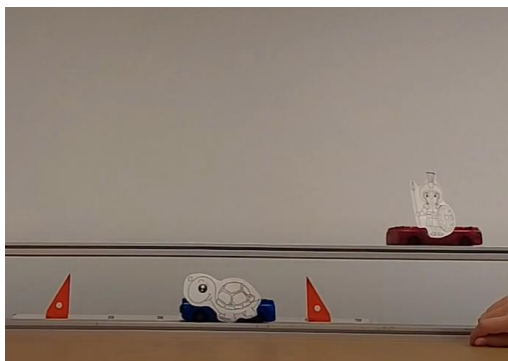


Figure. (Left) The depictions of Achilles and the turtle are affixed to two carts in motion. Initially, the cart carrying the turtle moves slowly, followed a second later by the cart carrying Achilles, which moves at a faster pace. (Right) The whiteboard which summarized the students' ideas as they emerged during the class discussion.

In conclusion, the array of arguments presented, both in favor of and against the scientific classification of "Zeno's paradox" and "umbrellaology," facilitated an examination of science as a doctrine, process, and institution. Our objective is not to reach a definitive conclusion regarding the status of Zeno's philosophy or "umbrellaology" as sciences, but rather to engender discussion among students and foster critical thinking regarding the nature of science. Further elaboration on students' perspectives regarding the teaching opportunities related to NoS, the efficacy of our approach, and the overall integration of historical and philosophical elements into scientific curricula will be presented during the conference.

References

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