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What is science and what is it not? Current overview of the problem of the demarcation of science

¿Qué es ciencia y qué no lo es? Panorama actual del problema de la demarcación científica

Vizioli, Nicolás Alejandro

https://orcid.org/0000-0002-6113-6847

Master's Degree in Psychodiagnostics and Psychological Assessment from the University of Buenos Aires (UBA). Undergraduate degree in Psychology from UBA. Associate Professor of Introduction to Scientific Thought at UBA XXI. Assistant Professor of Professional Practice 852: Community Approach in Vulnerable Neighborhoods. Senior Assistant in Theory and Techniques of Psychological Exploration and Diagnosis Module I: Psychometric Techniques at the Faculty of Psychology of UBA. Postgraduate Researcher at UBACyT. Undersecretary of Student Welfare at the Faculty of Psychology of UBA.

Milicich, Federico

https://orcid.org/0009-0006-4513-4282

Professor of Secondary and Higher Education in Philosophy from UBA. Senior Assistant in Introduction to Scientific Thought at UBA XXI. Assistant Professor of Ethics in Public Service at the Associate Degree in University Administration and Management (TAGU) at UBA. Member of the pedagogical coordination team of UBA's Remote Learning program in Secondary Education.

Rozas, Lara Lucila

https://orcid.org/0009-0001-4643-5881

Master's student in Cognitive Psychology at UBA. Undergraduate Degree in Psychology from UBA. Senior teaching assistant in Practical Assignments in Community Approach in Vulnerable Neighborhoods, Public Health and Mental Health, and General Psychology at UBA. Senior Counselor at UBA.

Núñez D´agostino, Fernando Adrián

https://orcid.org/0000-0002-7008-5869

Undergraduate Degree in Psychology. Master's student in Educational Policy. Head of Practical Assignments in Introduction to Scientific Thought at UBAXXI. Junior Assistant in Introduction to Scientific Thought at CBC UBA. Undersecretary of Innovation and Academic Quality at UBA.

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Abstract

Science is a practice that allows the production of epistemically warranted knowledge about topics of interest to human beings. However, there has yet to be a consensus about the criteria to determine what science is and what it is not. Therefore, this manuscript aims to a) explore the essential current proposals for the demarcation of science (DoS), and b) explain the characteristics of scientific knowledge and those of pseudoscience. The most relevant monocriterion and multicriteria DoS proposals during the 20th century, by Popper, Lakatos, Hempel, Kuhn and Bunge, are described. Scientific knowledge is characterized according to the contributions of Bunge and the contributions of Bunge and Lilienfeld to recognize pseudoscience and differentiate it from science. It is concluded that, although the DoS proposals are valuable, it is also necessary to know the characteristics of scientific knowledge and those of pseudoscience in order to have more tools for their recognition. The differentiation between science and pseudoscience is a matter of degrees rather than types.

Keywords: demarcation of science, scientific demarcation, science, pseudoscience, scientific knowledge, epistemology.

Resumen

La ciencia es una práctica que permite producir conocimientos garantizados epistémicamente acerca de temas de interés para los seres humanos. Sin embargo, no existe un consenso acerca de los criterios para determinar lo que es ciencia y lo que no. Por ello, el presente manuscrito pretende a) explorar las propuestas actuales más importantes de demarcación científica (DC) y b) explicitar las características del conocimiento científico y las de la pseudociencia. Se describen las propuestas de DC monocriterio y multicriterio de mayor relevancia surgidas durante el siglo XX, de Popper, Lakatos, Hempel, Kuhn y Bunge. Se caracteriza el conocimiento científico de acuerdo a los aportes de Bunge, y las contribuciones de Bunge y Lilienfeld para reconocer a la pseudociencia y diferenciarla de la ciencia. Se concluye que, aunque las propuestas de DC resultan valiosas, también es preciso conocer las características del conocimiento científico y las de la pseudociencia, a fin de tener más herramientas para su reconocimiento. Posiblemente la diferenciación entre la ciencia y la pseudociencia sea una cuestión de grados más que de tipos.

Palabras clave: demarcación científica, ciencia, pseudociencia, conocimiento científico, epistemología.

Introduction

Science is a social activity that aims to improve the natural and artificial environment of human beings (Bunge, 2018). It can be defined as the means of producing knowledge (Hansson & Aven, 2014). More specifically, science is the practice that provides the most epistemically warranted statements that can be made, at a given time, about topics covered by the community of the disciplines of knowledge. These topics address the nature of human beings, societies, physical constructs and constructs of thought (Hansson, 2013). Having said that, this practice is characterized by a set of rules and values that constitute its ethics and distinguish it from others (Bunge, 2007). One of the pioneers in the development of these rules was Merton (1942, 1973), who established that science is characterized by an ethos or spirit consisting of four sets of imperatives: universalism, epistemic communalism, disinterestedness and organized skepticism. Universalism implies that truth claims should be subjected to pre-established, impersonal criteria, so that the acceptance or rejection of the claims does not depend on the identity of their authors. Epistemic communalism assumes that scientific findings are the products of social collaboration; therefore, they belong to the entire community. Disinterestedness aims to implement institutional controls to prevent the influence of the personal or ideological bias that individual scientists may have. Organized skepticism allows science to impartially scrutinize beliefs or propositions that may hold significant value for other institutions. Merton's norms can be understood as a guide for conducting scientific research, emphasizing that specific values such as religious, political or social convictions should have the least possible influence on the judgment of scientists (Hansson & Aven, 2014).

In summary, science could be described as a practice that allows the production of epistemically warranted knowledge on topics of human interest. This practice is characterized by specific rules and values. However, there is no consensus on the criteria used to differentiate scientific from non-scientific knowledge. Therefore, this article aims to: a) explore the most important current DoS proposals, and b) specify the characteristics of scientific knowledge and those of pseudoscience.

The problem of demarcation

DoS consists in establishing a criterion that allows researchers to determine whether a discipline or a proposition is scientific or not (Hermida, 2020). Distinguishing science from non-science also involves differentiating science from pseudoscience (Pigliucci & Boudry, 2013). Establishing demarcation criteria requires determining what science is. According to Laudan (1983), an effective criterion must 1) provide a clear distinction between what science is and what it is not, 2) include a set of necessary and sufficient premises enabling demarcation, and 3) consider the practical consequences of demarcation.

In recent years, a series of events has brought attention to the demarcation of what can be considered science and what cannot across different disciplines. For example, the phenomenon of science denial has become an increasingly discussed topic in the last decade. Various authors have commented on the

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similarities between non-scientific rejections of climate science and similar reactions to other scientific areas such as evolution, vaccination and smoking (Hansson, 2017). Likewise, the social implications of pseudoscience are also a strong reason to develop a demarcation criterion, given their high prevalence and detrimental impact in clinical and educational contexts (Lilienfeld et al., 2001). Therefore, DoS has significant consequences for society. Although there is no universally agreed solution to the problem of DoS (Lilienfeld et al., 2014), various proposals have been developed.

DoS proposals in the 20th century

The problem of DoS was a significant issue during the 20th century. During this period, various proposals were developed, which can be classified as monocriterion and multicriteria. The most important proposals according to Fernández Beanato (2020) are described below.

1. Monocriterion proposals

Although DoS has its origins in Aristotelian writings (Laudan, 1983), it was not until the 20th century that it became a part of the Philosophy of Science with Karl Popper's work "The Two Fundamental Problems of the Theory of Knowledge". This book was published in 1979, but it started circulating as an essay in the 1930s (Fernández Beanato, 2020). In this study, Popper proposes falsification as a tool for DoS (Hernández González & Pedro da Fonseca, 2020; Popper, 1952/2002). Falsification can be defined as the philosophy that knowledge advances through a process of exposing false hypotheses (Kluge, 2001). According to Popper, scientific theories start as generalizations in our minds, the validity of which is tested by the scientific method until they are falsified (Maboloc, 2018; Parvin, 2010). In other words, theories are tested to determine if they are incorrect, in order to be replaced with better theories (Holtz & Monnerjahn, 2017). Therefore, the more efforts are made to falsify a conjecture, the more corroborated it arguably becomes. However, this corroboration would also be uncertain and could not be quantified in probabilities (Gardner, 2001). Popper's proposal also presents some difficulties. For example, the fact that any falsified theory could be considered scientific; that, when a theory is tested, falsifiable assumptions that do not belong to that theory are also tested; and that this proposal excludes scientific activities that do not involve testing theoretical constructs (Bunge, 1983; Hansson, 2013; Fernández Beanato, 2020).

In 1970, Lakatos reformulated the concept of demarcation from the perspective of scientific research programs. These programs refer to theories that are developed successively and share a hard core of conventionally accepted postulates. When a theory needs to be modified to resist the attack of other theories on its hard core, auxiliary hypotheses are created, leading to the development of new theories (Páez Coello & Samaniego Garrido, 2021). According to Lakatos (1970), scientific research programs should be both theoretically and empirically progressive. The theoretical progressiveness of a scientific research program stems entirely from the occurrence of a change, whereby each new theory in the program surpasses the content of its predecessor, even introducing novel predictions (Fernández Beanato, 2020).

Therefore, the emphasis would be placed on the development of knowledge, specifically the progressive increase in descriptions of the world through successive additions and challenges (Borge, 2022). On the one hand, a program progresses theoretically if the new theory resolves the anomaly faced by the previous one, is independently testable and makes new predictions. On the other hand, a program progresses empirically if at least one of these new predictions is confirmed (Musgrave & Pigden, 2023). In this sense, theory appraisal is a fundamental part of what Lakatos (1970, 1978) considers to be a progressive research program. In this iterative process, reviews are explicitly acknowledged, explained and justified so that they can be critically evaluated by other scientists. When theory reviews are not performed transparently, a theory can be endlessly adjusted and readjusted to keep it alive, causing the research program to shift from being progressive to degenerative (Hambrick et al., 2020). From the point of view of demarcation, Lakatos' proposal makes it possible to distinguish between progressive (or good) programs and degenerative (or bad) ones (Fletcher, 2021). Furthermore, Lakatos contributes another criterion for the demarcation between science and pseudoscience (Fernández Beanato, 2020): changes are accepted as scientific only if they are at least theoretically progressive; otherwise, they are rejected as pseudoscientific (Lakatos, 1970; Lilienfeld et al., 2014). Lakatos' proposal is not without criticism. For example, Newton-Smith (2002) argues that Lakatos' proposal is insufficient to address the conceptual aspects of science, such as the possibility of avoiding conceptual difficulties.

2. Multicriteria proposals

Hempel (1951) proposed a series of criteria to evaluate the levels of significance of theoretical systems, understanding such systems as sets of hypotheses, definitions and auxiliary statements (Fetzer, 2022). Hempel's criteria for evaluating theoretical systems included: the clarity and accuracy in their formulation, including explicit connections with observational language; the systematic, explanatory and predictive power of the system in relation to observable phenomena; the formal simplicity of the systems, which achieves a certain degree of systematic power; and the extent to which these systems have been confirmed by empirical evidence. In order to achieve demarcation, all these aspects must be considered as part of a list of the properties that are typical of science (Fernández Beanato, 2020).

Kuhn (1977) proposed a list of epistemic values that characterize science and are considered essential when choosing a theory: accuracy (the deducible consequences of a theory must be in demonstrable agreement with the results of existing experiments and observations); consistency (both internal and with other accepted theories); scope (its consequences must extend beyond the data to be explained); simplicity (to organize phenomena that would otherwise be confusing and isolated); and fruitfulness (for future research). Although Kuhn considers these to be constitutive values of science, Bird (2022) argues that these values cannot determine scientific choice. In this sense, Bird identifies three difficulties: the distinction of which characteristics of a theory meet these criteria; the inaccuracy of the criteria, which leads to disagreements about the extent to which they are fulfilled; and the way values are pondered against each other. It should be noted that Kuhn (1977) himself highlighted some difficulties in using these values to make decisions regarding demarcation. Bunge (1982, 1983, 1984, 1991) proposed a DoS based on the detailed characterization of an epistemic field. An epistemic field is a group of individuals, including their theories and practices, which aims to obtain some kind of knowledge (Mahner, 2021). According to Bunge, epistemic fields (E) are organized sets, where E = <C, S, D, G, F, B, P, K, A, M>, with C representing the research community; S, the host society of C; D, the domain or universe of discourse of the members of C; G, the philosophical background consisting of metaphysics, epistemology and methodology; F, the formal background, if any; B, the elements of knowledge taken from other fields; P, the difficulties or set of problems that affect the members of D or other components of E; K, the knowledge previously obtained by the members of C; A, the objectives of the members of C; and M, the methods and techniques used by the members of C in their study of the members of D. Following Mahner (2021), an epistemic field is considered scientific if and only if, for example, C is a research community (rather than a community of beliefs); S allows free research; D deals only with concrete or material entities; G consists of realistic and naturalistic metaphysics as well as a realistic epistemology and methodology that comprise a set of logical values; K is a set of elements that is always growing rather than a stagnant one; and B is not empty, i.e., a scientific field connects with others. According to Bunge (1982), DoS had to comply with a list of criteria that are individually necessary and collectively sufficient. However, various authors consider this proposal to be too strict (Fernández-Beanato 2020; Mahner, 2021).

Science in the 21st century: characteristics of scientific knowledge

According to Hansson & Aven (2014), scientific knowledge is concerned with data and information derived from the analysis of evidence about a particular phenomenon. These data and information contribute to the formation of a body of knowledge that experts and scientists use as a basis for future research in their field (Hansson & Aven, 2014).

Bunge (2018) provided greater specificity by classifying sciences into formal and factual. Formal sciences are systematic, rational and verifiable; however, they are not objective and do not deal with the facts of reality (such as logic or mathematics). Factual sciences, according to Bunge (2018), are sciences of facts. For these sciences, it is not enough to be rational or verifiable; they require empirical data to determine whether their statements are probably true. From the perspective of the characteristics of factual sciences, Bunge (2018) proposes a series of characteristics of scientific knowledge, which are described below.

1. Scientific knowledge is factual. It starts from facts and aims to describe them as they are. Factual statements, known as empirical data, are the basis for theory elaboration.

2. Scientific knowledge transcends facts. It discards them to produce and explain new ones. Scientific research is not limited to observed facts; it fully exploits reality in order

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to go beyond appearances, discarding the greater part of perceived facts and selecting those deemed relevant. Facts can be controlled and reproduced.

3. Science is analytical. Scientific research tackles specific problems individually, aiming to break them down into their elements. It addresses partial problems and solutions.

4. Scientific research is specialized as a result of addressing partial problems and solutions.

5. Scientific knowledge is clear and accurate. Its problems are distinct and its results are unambiguous. Achieving clarity involves formulating problems in a precise manner, starting with simple notions and progressively making them more complex, defining concepts, using symbols, and measuring and recording phenomena.

6. Scientific knowledge is communicable and public. Effective communication enhances education and enables verification or refutation.

7. Scientific knowledge is verifiable. It must explain a set of phenomena based on assumptions that must pass empirical tests.

8. Scientific research is methodical and planned. Researchers know what to look for and how to find it. All research is based on previous knowledge, particularly on the best-confirmed conjectures. Hypotheses must be empirically tested.

9. Scientific knowledge is systematic. It consists of a system of logically connected ideas.

10. Scientific knowledge is general. It places specific facts within broader principles.

11. Scientific knowledge is based on laws. It seeks these laws and applies them.

12. Science is explanatory. It seeks to explain facts through laws and laws through principles. More than describing reality, it must question it to reveal its causes.

13. Scientific knowledge is predictive. It transcends the facts of experience in an attempt to explain future scenarios and modify the course of events.

14. Science is open. It recognizes no barriers to accessing knowledge. If knowledge is not initially refutable, then it is not scientific.

15. Science is useful. It seeks truth and aims to provide tools. It has practical purposes for the benefit of humanity.

In conclusion, according to Bunge, scientific knowledge is distinguished from other forms of knowledge by the characteristics described above.

What is pseudoscience and how to recognize it?

In principle, the criteria that establish what constitutes science would also enable the differentiation from what does not, including pseudoscience. Although it is argued that there is no clear line between what is science and what is pseudoscience (Pigliucci & Boudry, 2013), Bunge (1984) suggests that pseudoscience can be characterized by the following indicators:

1. The components of epistemic fields (E) change very little over time. When changes do occur, they are often due to controversies or external pressures rather than to scientific research.

2. The community (C) is made up of believers who call themselves scientists, even though they do not engage in scientific research.

3. Society (S) supports the community (C) for practical reasons.

4. The domain (D) consists of elements whose veracity cannot be verified, such as astral influences or immaterial thoughts.

5. The philosophical background (G) includes an ontology of immaterial processes, an epistemology of fallacies of authority or modes of thought only accessible to those well acquainted with the subject, a value system that does not prioritize clarity, accuracy, depth, consistency or truth, and an ethos oriented toward the defense of dogma.

6. The formal backgrounds (F) do not adhere to logic or mathematics and often include models that are empirically unverifiable or outright false.

7. Knowledge taken from other disciplines (B) is scarce. Pseudoscience learns little or nothing from other cognitive fields and contributes little or nothing to their development.

8. The problem (P) mainly includes practical issues related to human life, such as how to feel better or how to influence others, rather than cognitive issues.

9. Prior knowledge (K) consists of hypotheses that are either untestable or clash with scientifically confirmed hypotheses.

10. The objectives (A) of the community (C) are practical rather than cognitive issues. Therefore, they do not seek the usual scientific goals, such as formulating laws or predicting facts.

11. The methodology (M) includes procedures that are neither verifiable by alternative methods nor justifiable by well- confirmed theories. Criticism is not well received by pseudoscientists.

12. Only other pseudosciences can enrich the epistemic field (E); no other fields of knowledge can do so.

Lilienfeld et al. (2014) developed a series of indicators to characterize pseudosciences:

1. Excessive use of ad hoc hypotheses: Ad hoc hypotheses are overused to create virtually impermeable barriers against falsification.

2. Absence of self-correction: While incorrect statements in science are corrected, pseudoscientific hypotheses tend to persist even when proven wrong.

3. Active stance against peer review: Pseudoscientists often avoid peer review, which is essential for identifying errors in authors' reasoning, methodology and analysis.

4. Emphasis placed on confirmation rather than refutation: Ideally, scientists subject their claims to the risk of refutation, while pseudoscientists tend to seek confirmation.

5. Shifting the burden of proof: In science, the burden of proof generally falls on those presenting a claim, not on their critics. However, in pseudoscience, skeptics are often urged to prove, beyond reasonable doubt, that a claim is false.

6. Lack of interconnectedness: Unlike scientific research programs, pseudoscientific research programs often lack links with other scientific disciplines. Pseudosciences aim

to create new paradigms from scratch rather than building on existing, well-supported ideas.

7. Excessive reliance on anecdotal evidence: Anecdotal evidence can be useful in the early stages of scientific research, particularly for exploration or hypothesis generation. However, pseudoscientific claims often use specific case reports as a means of providing evidence.

8. Use of obscure language: Several advocates of pseudoscience attempt to introduce superficial components into their disciplines, such as specific languages or jargon. This language can appear persuasive to those unfamiliar with the scientific fundamentals of the claims, leading to the endorsement of claims that are not scientifically justified.

9. Absence of boundary conditions: Most well-supported scientific theories have boundary conditions under which hypothetical phenomena must and must not occur. In contrast, pseudoscientific phenomena operate across a very wide range of conditions and individuals.

10. The mantra of holism: Supporters of pseudoscience often argue that claims must be understood within the framework of larger assumptions and cannot be discussed individually.

Conclusion

The issue of DoS has historically been one of the most interesting debate topics in the Philosophy of Science and has significant practical implications (Lilienfeld et al., 2014) in areas such as education and health (Hansson, 2017; Lilienfeld et al., 2001). Among the DoS proposals, the monocriterion put forward by Popper (1952/2002) and Lakatos (1970) as well as the multicriteria suggested by Hempel (1951), Kuhn (1977) or Bunge (1982, 1983, 1984, 1991) can be highlighted. Although the monocriterion proposals made significant contributions to DoS, it was not possible to find a single accurate criterion that would allow for clear demarcation (Fernández Beanato, 2020). Multicriteria models emerged to overcome this issue, so that DoS would depend on several indicators, though they are still subject to criticism (Bird, 2022; Fernández- Beanato 2020; Mahner, 2021). In this sense, it is also important to understand the characteristics of scientific knowledge and those of pseudoscience, in order to have more tools for their recognition. The difference between science and pseudoscience may be more a matter of degrees than of types (Lilienfeld et al., 2014). In any case, it is necessary to consider that scientific thinking is not something natural; it requires setting aside one's own biases to focus on solid data (Lilienfeld, 2010).

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