1. Defining Science: A Comparative Study of Demarcation Theories in Science and Society

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Science is the systematic process that combines the structure and behavior of nature through experimentation and observation. It generally consists of forming hypotheses, conducting experiments, analyzing data, and making conclusions to understand how things work. Firstly, observation should be done based on science's processes, like collecting facts. Also, facts should be based on observation and experiments because they are theory-dependent for being appropriate to science. For a theory to be accepted, it can be confirmed by facts about the world. For example, the scientific concept of gravity is generally accepted. The most famous experiment may come to mind when considering the collection of facts. Galileo's famous experiment demonstrated that he dropped two balls of different weights from the Leaning Tower of Pisa. This experiment yielded Newton's laws of motion and Einstein's general theory of relativity, which improved our understanding of gravity. A basic illustration of how science works is the process of observing a phenomenon (objects falling), developing a hypothesis (mass affects the falling speed), testing it (dropping the balls), and drawing conclusions (gravity acts equally on all masses).

On the other hand, pseudoscience refers to beliefs claimed to be scientific without enough evidence or methodology. It tries to define genuine science because it generally relies on anecdotal evidence without testing or tries to ignore contradictory data. Unlike science, pseudoscience does not follow the scientific method. It often can't be tested or falsified. For instance, Astrology claims that the positions of the stars and planets affect our lives and personalities. On the other hand, astrology can make some matches-of course, with your life and some concepts. However, it is not empirical. There is currently no known mechanism joining planetary placements with human activity. Several scientific studies have shown that astrological forecasts are no more accurate than chance. Although it is popular, astrology does not fall into the category of the study of science thus it is said to be pseudoscientific.

After considering what science and pseudo-science are, we must consider the philosophical problem of demarcation. The philosophical problem of demarcation between science and pseudo-science is closely related to the issues of scientific methods and scientific progress. There are some reasons for this problem. The first one is the scientific method. The scientific method is a set of procedures used to get knowledge. It is widely used to distinguish science and pseudo-science. This method typically involves basic science steps like observation, hypothesis formation, experimentation, data analysis, and conclusion drawing, as I mentioned before.

The second one is scientific progress. The demarcation problem is also related to the concept of progress in science. Many scientists believe science is a progressive discipline where knowledge is continually enhanced. The scientific method systematically evaluates hypotheses and increases understanding. It makes this growth feasible. However, pseudo-science may not

improve science since it often relies on subjective interpretations, anecdotal evidence, or untestable claims.
In short, for the related issue to be considered a part of science, it must undergo specific procedures and be presented verifiable. It must also be falsifiable rather than assumed always to be correct. This is because science is a field that develops via the accumulation of knowledge throughout time. However, pseudo-science does not require evidence. It could represent topics, and some people might have these opinions. However, it is science if there is proof because falsifiability and observation have been achieved. It must also be shown that the number of people who believe in something does not prove its truth. On the other hand, the number of believers doesn't show that the ideas are valid and testable. For instance, sheep follow each other, but unfortunately, not everything they do is correct. Before believing in something, testing it and reviewing the results is essential. What the majority believes in is not always necessarily true, as sheep do.

There are some different solutions to this problem. We can describe all of them by giving an example in detail.

1.1 Inductivism

Inductivism is derived from the process of science, which involves accumulating observations, generalizing, and proposing theories. Inductivism suggests that theories can be gathered and used to construct theories and hypotheses without prejudice, such as using sensory organs. It generally consists of accurate and valid information [1]. Regarding the confirmation problem, the only thing that matters is the logical relationship between theory and evidence. It makes no difference what historical setting the evidence was obtained in.

1.1.1 Merits

It indicates that empirical evidence and observation are essential in scientific methods. They guarantee that scientific hypotheses are founded on observable, repeatable occurrences and are thus anchored. These processes help to improve theories. Being based on observations makes the hypothesis valid according to inductivism.

1.1.2 Limitations

As David Hume famously indicated, inductivism struggles with the difficulty of induction and deduction. For instance, observing white swans does not prove that all are white. It doesn't guarantee that generalizations based on specific observations are always accurate. It also disregards scientific theoretical developments that aren't solely supported by empirical data. For example, the development of atomic theory is a decent example of inductivism. John Dalton and other early scientists gathered empirical data on gas behavior and chemical reactions. After conducting several experiments and noticing trends in how components combined ratios, they concluded that matter is composed of indivisible atoms. Dalton's atomic theory benefited from observing and generalizing that substances combine in specific quantities. This empirical data allowed scientists to build an initial model of matter that could be assessed and refined.

However, other findings, such as the presence of neutrons, protons, and electrons, called into question the notion that atoms are indivisible. These discoveries showed the limitations of inductivism. When the discoveries were insufficient to explain phenomena like electron behavior, theoretical developments like quantum mechanics demonstrate how inductivism might not be able to predict the more intricate complexity of nature, necessitating the development of original hypotheses with empirical evidence.

1.2 Falsificationism (Karl Popper)

Popper's falsificationism suggests that scientific theories cannot be entirely accurate. According to Popper, a theory should be scientific if it is testable and falsifiable. If it survives many attempts at falsification, it stays provisionally accepted but never fully confirmed. A theory gains more credibility if it produces positive evidence when a fresh prediction is tested. The difficulty of confirmation depends critically on the historical setting in which the evidence is obtained.

1.2.1 Merits

Falsificationism offers several criteria for distinguishing science from pseudo-science, namely, eliminating false theories and hypotheses rather than focusing exclusively on confirmed ones. So, it is considered that research is self-corrective. It is said that more limitations on hypotheses and facts are followed because of such approaches. This is consistent with the pursuit of scientific development rather than a fact-finding endeavor. Induction is not applied; instead, one deduces to test whether the hypotheses or theories under consideration are false.

1.2.2 Limitations

Even if many scientific ideas, like Darwinian evolution, are difficult to disprove, they improve explanatory capacity. Furthermore, anomalies frequently put aside rather than instantly disproving a theory are complicated for falsificationism.

One example of falsificationism in neuroscience is the study of the localization of brain functions. Early neuroscientists like Franz Gall proposed the phrenological hypothesis, which maintained that some brain functions were limited to specific bumps on the skull. This theory makes testable assertions linking behaviors to brain areas. Neuroscientific research later questioned phrenology's predictions after finding that its claims lacked empirical support. For instance, imaging tools such as fMRI showed that brain functions are not restricted as phrenology indicated. This falsification led to the rejection of phrenology, demonstrating that, by Popper's principles, science is self-correcting.

However, falsificationism also encounters limitations in more complex areas of neuroscience, such as the study of consciousness. Consciousness is difficult to test and falsify, as everyone knows, because the subjective nature of experience doesn’t always lend itself to precise, falsifiable predictions. Concepts about consciousness, like the global workspace theory or integrated information theory, progress by refining explanations rather than being conclusively falsified. This highlights a limitation of falsificationism. Some aspects of neuroscience may not be easily testable in the short term, but they still contribute to scientific progress through gradual refinement and increased explanatory power.

1.3 Thomas Kuhn’s Paradigm Shifts

Kuhn’s approach is based on the structure of scientific revolutions, handled with inductivism and falsification. He suggested that science operates within paradigms. Scientific progress and methods occur through falsification and gradual accumulation via paradigms where the existing framework can no longer explain anomalies. This sometimes leads to the adoption of a new paradigm.

He indicates that "science" experiences recurring revolutions known as paradigm shifts rather than developing as an accumulation of new information. A paradigm is a particular theoretical approach reflecting a specific scientific community at a given time. It is founded on an individual research technique. The research questions developed from within that theoretical perspective are directed by a paradigm, which also serves as the foundation for assessing the research's output. The problems of what should be seen and how to interpret the data are given by a paradigm. [2]

Also, Kuhn says that converging paradigms are incommensurable since one is not to be understood through the vocabulary and conceptual frameworks of another. The paradigm is what we must see through to determine reality so that the community, the scientific. It will take a crisis to give us a paradigm shift. Instead, science and its discoveries are characterized by revolutionary shifts in puzzle games rather than a continuously unbreaking and stable path in evolutionary terms.

One of the most crucial figures is Thomas Kuhn, who claims that science has recurring periods in the book The Structure of Scientific Revolutions. What is interesting in this book, among other things, is that the long-term strategy for problem-solving can lead to sudden revolutionary transformations.

1.3.1 Merits

Kuhn’s model captures the historical reality of how science often advances through revolutions. It recognizes the social and institutional aspects of scientific progress, highlighting that scientists work within accepted frameworks until those frameworks break down.

1.3.2 Limitations

One problem with Kuhn's theory is its relativism. Scientific progress is ambiguous if paradigms are incommensurable, meaning they cannot be directly assessed. It's difficult to determine whether more recent paradigms are objectively superior. Kuhn's emphasis on non-rational components in paradigm changes also raises concerns with scientific advancement.

This kind of development from the typical programming paradigms, such as procedural programming, into model-oriented programming can also illustrate Kuhn's theorem on paradigm shifts, especially in computer science. For many years, this central paradigm in computer science has been procedural programming where one creates several functions to deal with data. This was demonstrated by the method in C, where programming steps were followed. Yet this paradigm failed to address issues concerning code reusability, scalability, and maintainability, especially after the emergence of sophisticated software systems. Then came a drastically different paradigm with object-oriented programming with languages like Java. OOP allows users to define the world's objects in terms of enclosed data and activities, thereby improving module independence, reuse, and code structure standards. That is how procedural programming meant all this transformation, evidently creating OOP as the new paradigm in software development.

Kuhn's theory could also highlight the disadvantages of this shift despite its advantages. OOP may not be the best solution for every problem, even if it has been the most often used paradigm. Some developers still choose procedural programming because of its convenience in scenarios like smaller projects. Several programming paradigms demonstrate how Kuhn's theory could not capture the complexity of computer science's development, as different paradigms may be used simultaneously based on specific needs.

1.4 Imre Lakatos' Research Programs

To solve such problems, Imre Lakatos combined concepts from Popper and Kuhn and developed a hybrid strategy. According to Lakatos' methodology, scientific revolutions occur when one research program surpasses another in advancement. The most remarkable scientific successes are research programs that may be assessed regarding progressive issues. This approach provides a logical reconstruction of science. The easiest way to explain it is to compare it to conventionalism and falsificationism, from which it takes critical components. He practically applies Popper's falsifiability at the level of scientific theories, and his research programs are somewhat comparable to Kuhn's scientific revolutions [3].

Popper's criteria are modified by Lakatos, who refers to them as sophisticated methodological falsificationism. According to this idea, the restriction criterion must be applied to a whole research program rather than just a single hypothesis or theory. Therefore, sophisticated falsificationism shifts the focus from how to assess the theories to how to evaluate the set of theories. It is only a collection of hypotheses that may be categorized as scientific or non-scientific rather than a single theory.

In summary, he maintained that although science functions inside theoretical frameworks. These frameworks contain supplementary hypotheses that may be modified in response to anomalies and unfalsifiable assumptions. Unlike degenerative research programs, which only adapt to explain anomalies without generating new findings, progressive research programs generate unique, testable hypotheses, which is how progress is created.

1.4.1 Merits

Lakatos avoids Kuhn's paradigm shifts while providing a more adaptable strategy than Popper. It considers how scientific hypotheses are modified over time rather than being rejected at the first hint of a problem.

1.4.2 Limitations

Lakatos' method has been criticized for lacking a clear, immediate criterion for deciding when a research project should be abandoned. Despite having little empirical backing, specific areas like string theory in physics continue to exist, and it's not always clear whether they're progressive.

For instance, Lakatos' concept of biological research programs is exemplified by the evolution of the theory of evolution itself, particularly the debates between Darwinian evolution and neo-Darwinism. Darwin's original theory of evolution by natural selection laid a solid basis for basic concepts, such as variety, competition, and differential survival. As more information from genetics and molecular biology became accessible over time, the protective belt of supplemental hypotheses expanded. The combination of Darwinian evolution with Mendelian genetics led to the development of neo-Darwinism, encompassing concepts such as genetic drift and gene flow. This change allowed the theory to include new research and offer testable hypotheses about genetic mechanisms based on evolutionary processes.

However, other problems with evolution show Lakatos' model's weaknesses. Some critics say that the theory of punctuated equilibrium, proposed by Stephen Jay Gould and Niles Eldredge, is not entirely considered by neo-Darwinism, even though it explains many biological events well. Punctuated equilibrium challenges the slow, gradual change Darwinism suggests by arguing that evolution happens in quick bursts, with long periods of little to no change. This leads to debates about whether the current neo-Darwinist theory can adapt to these ideas.

In conclusion, Lakatos's idea of research programs is best shown by the development of the theory of evolution in biology. It highlights the difficulty of identifying whether a theory is progressive and shows how scientific concepts may evolve.

1.5 Paul Feyerabend's Epistemological Anarchism

Epistemological anarchism is an epistemological theory developed by Paul Feyerabend. It argues that no valuable and methodological rules govern science's progress. The theory indicates that the idea of science functioning with fixed, universal rules is unrealistic and harmful.

The term anarchism in epistemological anarchism reflected the theory's formula of methodological pluralism since pioneering scientific methods did not have a monopoly on beneficial results. Feyerabend thought that science began as a liberating movement. It became increasingly dogmatic and rigid. Therefore, it gradually became an ideology. Despite its achievements, science acquired some oppressive features, and there was no solution to separate science from religion, magic, or mythology. He thought the privileged domination of science to guide society was authoritarian [4].

1.5.1 Merits

For Feyerabend, pluralism includes the consideration that innovation may sometimes be hindered by dogmatism and considers various scientific practices and methodologies. He also emphasizes social and political dimensions of research that tend to be ignored in more rigid schemes.

1.5.2 Limitations

Feyerabend's rejection of all methodological norms may result in severe relativism. If all methods are equally trustworthy, it is impossible to distinguish between science and pseudo-science, which might damage the legitimacy of scientific research. Arguments concerning the legality of non-Euclidean geometry illustrate Feyerabend's epistemological anarchism in mathematics.

In the early days, Euclidean geometry was the dominant framework, and many believed it to be the only proper form of geometry. When non-Euclidean frameworks were proposed in the 19th century, they met with resistance because they challenged the fundamental assumptions of Euclidean geometry. Feyerabend would contend that these alternative frameworks deviate from conventional presumptions and shouldn't be disregarded.

Meanwhile, Feyerabend's "anything goes" philosophy may also provide mathematical difficulties. There might not be any precise standards for identifying which mathematical systems are practical to actual occurrences if all methods are used without distinction. For example, not all alternative mathematical frameworks necessarily offer significant discoveries, even though non-Euclidean geometry has proven helpful for disciplines like physics. Without some standard, the "anything goes" approach risks blurring the line between rigorous, practical mathematics and unsupported speculative ideas. In this example, Feyerabend's openness to diverse approaches has pushed mathematics forward by allowing new systems. Still, it also highlights the potential downsides when no guiding framework separates productive theories from less meaningful ones.

In summary, falsificationism and inductivism attempt to put the scientific process in a logical framework, but they are not enough. Although Kuhn used a historical method, he did not provide a realistic standard for evaluating ideas. Lakatos offered a rational standard for contrasting ideas but could not adequately explain it. On the other hand, Paul Feyerabend attacked all these methods and proposed an anarchist explanation of science.

1.6 My Preferred View

1.6.1 Vaccine Development and Safety with Inductivism

Vaccine science evolution can be inducted. Inductivism holds that repeat observations and empirical data build scientific knowledge through generalizations. In the case of vaccines, many experiments are conducted for the researchers to watch how the vaccine affects and safely what it does. Data from the clinical trials justify the vaccines' efficacy. All these observations accumulate until overall safety and efficacy approval is reached. This in turn improves or develops credible results for a broader applicability of the vaccines. The citizens gain faith in society through this significant public health step of the data-driven process. Yet, Inductivism alone can be rigid about problems where an anomaly is experienced. For example, some individuals experience rare side effects. An inductivist approach may have difficulty addressing such exceptions because it focuses on the general trends in large sample groups.

1.6.2 Kuhn's Paradigm Shifts and Inductivism with Vaccine Opposition and Acceptance

Thomas Kuhn's paradigms can explain how society's perception of vaccines has changed. Initially, the importance and safety of vaccines may not be widely accepted. However, when there is broad acceptance within the scientific community and among the public that vaccines are effective, this can be described as a period of science. However, when trust problems occur due to side effects of vaccines or incorrect information, a crisis period may appear in society. These crises may lead some people to question the idea that “vaccines are safe and beneficial,” which is the current paradigm. According to Kuhn, these crises can cause a paradigm shift or lead society to strengthen the existing paradigm by accepting new evidence. Kuhn's model explains the dynamic nature of society's perception of vaccines. Crises around vaccines can be understood through new scientific evidence and social changes. However, this model can legitimize the unscientific views advocated by vaccine opponents as an “alternative paradigm,” whereas these views do not have scientific validity. The knowledge that inductivism offers will push people to get vaccinated. The data obtained with this knowledge will provide more confidence. Thus, people will not be against such vaccination campaigns. In cases of opposition, the Kuhn paradigm rather than inductivism comes into play. It offers an algorithm that will prepare the ground for the change of insufficient information that has taken place in people's minds by taking jumps here.

By replacing the information obtained after these jumps with a new one, people's views on these campaigns can be changed for the better, and such applications can be prevented from slowing down or stopping. By combining Kuhn's paradigm shifts approach with inductivism, we can offer a comprehensive perspective on vaccine science and community perception. Inductivism's data-based method provides a reliable vaccine development framework. At the same time, Kuhn's approach can explain how society perceives vaccines, how crises of trust arise, and how society accepts scientific evidence. For example, while the development of COVID-19 vaccines shows the importance of inductivism, the crises of confidence and social debates experienced during this rapid development of vaccines are also good examples of Kuhn's paradigm shifts. This dual approach can be used to fully address how vaccine science is progressing and how society is accepting these advances.

As can be seen, different solutions to the demarcation problem can be the result. Of course, they all have good and bad sides, and they have the structure to support each other when used together. Different combinations will be more beneficial depending on the areas used. After the differences between science and pseudo-science were mentioned, studying other ideas has provided a better basis for this. I try to explain each idea by giving examples from different fields so that the ideas can be better understood after a detailed explanation. The last part aims to combine two different ideas and complete each other's shortcomings. If it is necessary to add one last thing, it is needed to support the ideas that come true, not the majority’s ideas, but these ideas with evidence so that the truth can be visible to everyone one day.

The scientific theorist is not to be envied. Nature, or experiment, is an exorable and not very friendly judge of his work. It never says "yes" to a theory. In the most favorable cases, it says "Maybe," and in most cases, simply "No." If an experiment agrees with a theory, it means "Maybe," if it does not agree, it means "No." Probably every theory will someday experience its "No" - most theories, soon after conception [5].

Albert Einstein

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