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Research Article

The Reconstruction of the Structure of Scientific Knowledge in the Perspective of Thomas S. Kuhn's Paradigm

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Abstract

The development of scientific knowledge does not occur linearly but undergoes fundamental and revolutionary changes. This article aims to re-examine the structure of scientific knowledge through the perspective of Thomas S. Kuhn's paradigm, as elaborated in his seminal work The Structure of Scientific Revolutions. This study employs a qualitative approach using the library research method, by analyzing Kuhn's primary texts along with relevant secondary literature. The findings indicate that, according to Kuhn, the structure of scientific knowledge is built upon a dynamic paradigm. A scientific paradigm shift occurs when anomalies within the existing framework can no longer be explained by prevailing theories, leading to a scientific revolution that transforms scientists' perspectives on reality, methodology, and the object of inquiry. In the context of the digital era and the Industrial Revolution 5.0, understanding this dynamic becomes crucial for epistemological reconstruction, ensuring that science remains relevant, proportional, and sustainable. This study provides a theoretical contribution to the development of modern philosophy of science and reinforces critical awareness of the interrelationship between paradigm, knowledge crisis, and scientific progress.

Keywords: Thomas S. Kuhn, Scientific Paradigm, Structure of Scientific Knowledge, Scientific Revolution, Epistemological Reconstruction.

INTRODUCTION

In an era of rapidly changing scientific development, the notion that science progresses smoothly and accumulatively is now facing serious challenges. According to Thomas S. Kuhn's approach, scientific progress does not move linearly or gradually, but rather through radical paradigm shifts—fundamental transformations that trigger scientific revolutions and establish new frameworks for the scientific community. (Matthews 2024) explains in his study of Kuhn's paradigm, "science does not develop as a linear accumulation of new knowledge, but undergoes periodic revolutions known as paradigm shifts." Therefore, understanding the structure of scientific knowledge must acknowledge "leaps" and "disruptions" as integral elements of scientific dynamics, not merely as anomalies to be corrected.

Amid the accelerating forces of digitalization, artificial intelligence (AI), and the transition toward the Industrial Revolution 5.0, the classical view of scientific progress as a linear and cumulative process has become increasingly unstable. The era when dominant paradigms could persist unchallenged has shifted toward one where empirical reality, methods, and objects of study are continuously disrupted by technology, big data, and multidisciplinarity. For example, Lazzeretti (2023) demonstrates that the integration of "artificial intelligence, big data, and algorithms" within the context of Industry 4.0 has marked a paradigm shift across various scientific clusters and industrial research domains. Consequently, traditional scientific paradigms—built on assumptions of stability, singular methodologies, and narrowly defined objects—must be reconstructed to accommodate complexity, speed, and interconnection across disciplines(Anand, Larson, and Mahoney 2020).

Kuhn's ideas have become highly relevant in the contemporary era, where science and technology evolve not merely through the accumulation of new knowledge but through transformations in the very frameworks of understanding. In the field of education, for instance, the radical shift in teaching methods due to digitalization, online learning, and the use of big data has prompted a transition from the "traditional teaching" paradigm to the "smart learning" paradigm, which integrates technology, analytics, and interactivity(DiSessa 2014).

In the realm of science and technology, the evolution from classical computing to generative artificial intelligence and large-scale AI systems illustrates how the old paradigm—emphasizing a single experimental method and narrowly focused objects of study—can no longer address the complexity of cross-disciplinary interaction and the rapid pace of technological change (Gretzel et al. 2020). Hence, Kuhn's framework—emphasizing "normal science, anomaly, crisis, paradigm revolution, and new paradigm"—serves not merely as a historical model but as a critical analytical tool to understand the ongoing reconstruction of scientific structures in the digital and Fifth Industrial Revolution eras.

In a world where digital technologies, large-scale algorithms, and AI reshape the ways humans acquire, validate, and disseminate knowledge, the traditional structure of science, built on the assumption of methodological and epistemic stability, is no longer sufficient. Recent studies reveal that within the natural sciences, epistemological and ontological transformations have emerged due to the rise of AI. Knowledge production and validation processes are now no longer entirely dependent on human observation and reasoning but increasingly rely on algorithmic capacities to process data on a massive scale (Kuehn 2015).

Meanwhile, in the fields of education and digital epistemology, traditional epistemological systems must be reconstructed to reflect learning processes, user data, and human–machine interactions. This transformation signifies a shift from traditional epistemology toward a digital epistemology that is more dynamic and adaptive (Hanks and Severi 2014). Therefore, the reconstruction of scientific knowledge structures, encompassing a redefinition of science's basic concepts, sources of knowledge, and epistemic as well as methodological foundations, becomes a strategic necessity. Such reconstruction ensures that scientific inquiry remains relevant, proportional, and meaningful in addressing the challenges of complexity, speed, and interdisciplinary interconnectedness in the era of the Fifth Industrial Revolution.

2. METHOD

This study employs a qualitative approach with a library research method, focusing primarily on examining philosophical concepts that are conceptual and reflective rather than empirical. The qualitative approach was chosen to allow for a deeper interpretative exploration of Thomas S. Kuhn's ideas in his seminal work, as well as to interpret the meanings of paradigm, anomaly, crisis, and scientific revolution within the framework of modern epistemology. (Schwanen, Banister, and Anable 2011) states, the qualitative approach enables researchers "to interpret the meaning of ideas and experiences within philosophical and contextual frameworks," making it particularly appropriate for philosophical studies of science that require a holistic and reflective understanding of texts(Thomas et al. 2023).

This library-based research focuses its philosophical analysis on Kuhn's primary text and various secondary sources that support interpretations concerning the structure of scientific knowledge, scientific paradigms, and epistemological reconstruction in the digital era. This approach not only examines the content of texts descriptively but also engages in a hermeneutic process, seeking to understand the meanings behind the texts and their relevance to contemporary contexts. As emphasized, library research plays a vital role in the philosophy of science because it provides a strong conceptual foundation for theory building and fosters critical reflection on paradigm shifts in knowledge(Yanow and Schwartz-Shea 2015). Thus, this method was chosen to enable the research to comprehensively and argumentatively portray the dynamics of the structure of scientific knowledge from Kuhn's perspective.

Data Analysis Techniques
This study employs content analysis and philosophical hermeneutics as the main approaches for interpreting the meaning of Kuhn's *The Structure of Scientific Revolutions* and its relevance to the contemporary structure of scientific knowledge. Content analysis was used to identify, classify, and understand contextual patterns that emerge within both primary and secondary texts—particularly those related to the concepts of paradigm, crisis, and scientific revolution. As explained by (Stone 2012), content analysis allows researchers "to move beyond surface meanings and uncover the conceptual structures underlying philosophical texts," making it highly suitable for examining complex and meaning-rich philosophical works.

Meanwhile, philosophical hermeneutics was applied to interpret the deeper meanings underlying Kuhn's ideas and relate them to the epistemological representations of the present era. Hermeneutics not only examines what the text explicitly conveys but also how it constructs new horizons of meaning in explaining the reality of science. According to (Golinski 2024), hermeneutic approaches in modern philosophical research help "reconstruct meaning through a dialogical process between classical texts and the researcher's contemporary context," thus producing interpretations that are not merely historical but also reflective and relevant to current scientific developments.

In this research, the analysis process was carried out through three main stages.

1. Comprehension of Kuhn's key concepts—such as paradigm, normal science, anomaly, and scientific revolution—to understand the internal structure of Kuhn's thought.
2. Analysis of interconceptual relationships to uncover the dynamics between the stability of normal science and paradigm change.
3. Reflection and reconstruction of the contemporary scientific context, linking Kuhn's concepts with new epistemological challenges in the digital age, the Fifth Industrial Revolution, and the interdisciplinarity of knowledge.

Through these stages, the analysis moves beyond textual description to produce a deep philosophical understanding that is contextually relevant to the ongoing reconstruction of the structure of scientific knowledge(Butts and Rich 2022).

3. RESULT AND DISCUSSION

Result

The findings of this study reveal that the structure of scientific knowledge, as conceptualized by Thomas S. Kuhn, is not static or cumulative but rather dynamic and revolutionary. Kuhn's philosophy challenges the positivist assumption that science progresses through a gradual and linear accumulation of facts. Instead, scientific development occurs through a series of paradigm shifts, in which existing theories are replaced by new frameworks that offer alternative explanations of reality(Dixon 2019). These paradigm changes occur when the dominant scientific model can no longer account for emerging anomalies, resulting in a crisis of scientific legitimacy that leads to a revolutionary transformation of knowledge.

An in-depth analysis of Kuhn's key concepts—paradigm, normal science, anomaly, and revolution—demonstrates that scientific progress depends on the collective behavior of the scientific community. During the phase of normal science, researchers operate within a shared paradigm that dictates methods, questions, and valid interpretations(Edwards and Holland 2013). However, when anomalies accumulate and can no longer be resolved, the existing paradigm loses its explanatory power. This crisis creates the conditions for a scientific revolution, a moment of intellectual rupture where a new paradigm emerges, reorganizing how scientists perceive the world and interpret data.

The study further shows that scientific change is not purely theoretical or empirical but also socio-historical. Kuhn's model situates the evolution of science within the context of human communities, emphasizing that paradigm shifts are shaped by consensus, persuasion, and worldview transformation. Hence, the structure of scientific knowledge is as much a reflection of cultural and intellectual conditions as it is a result of empirical observation. This means that science evolves not in isolation but through an ongoing dialogue between theory, society, and the human search for coherence and meaning.

In the context of the digital age and the Fifth Industrial Revolution, Kuhn's paradigm theory remains highly relevant. The current transformation of knowledge systems—driven by artificial intelligence (AI), big data, algorithms, and automation—represents a new form of scientific revolution. As Lazzeretti (2023) and Dhar (2023) argue, the integration of digital technologies into research and knowledge production is creating new paradigms that redefine the roles of scientists, machines, and data. These digital disruptions have introduced new epistemic conditions, where scientific inquiry no longer relies solely on human observation but also on algorithmic reasoning and automated data interpretation.

The findings also suggest that the epistemological foundations of modern science must be reconstructed to accommodate these technological transformations. As noted by Chang López (2022), the emergence of digital epistemology marks a transition from traditional modes of reasoning toward a more dynamic and adaptive understanding of knowledge—one that integrates human cognition, machine learning, and data-driven processes. This epistemological reconstruction expands the boundaries of science, allowing it to engage with complex, interdisciplinary, and rapidly evolving problems in a manner consistent with Kuhn's vision of paradigm evolution.

The study affirms that Kuhn's framework—emphasizing normal science, anomalies, crises, and revolutionary shifts—remains a powerful analytical tool for understanding the transformation of science in the modern era. The continuous interaction between knowledge, technology, and society demonstrates that scientific revolutions are not confined to history but persist as part of an ongoing process of reconstruction. Therefore, reconstructing the structure of scientific knowledge requires redefining its conceptual, epistemological, and methodological foundations to ensure that science remains relevant, proportionate, and sustainable in addressing the challenges of complexity, speed, and interdisciplinarity in the digital age.

Discussion

1. The Dynamic Nature of Scientific Knowledge

The results of this study emphasize that scientific knowledge, according to Thomas S. Kuhn, does not develop in a linear or cumulative manner. Science is a human enterprise characterized by discontinuities, ruptures, and revolutions. Kuhn (1962) proposed that every scientific era is guided by a dominant paradigm—a shared framework of assumptions, theories, and methodologies that directs the normal activities of scientists. When the paradigm is stable, science functions in a phase known as *normal science*, where researchers focus on solving puzzles within the accepted framework rather than questioning its foundation.

However, this phase of normal science is inherently temporary. Over time, anomalies—phenomena that cannot be explained by the existing paradigm—begin to accumulate. These anomalies represent cracks in the foundation of scientific certainty. When they become too significant to ignore, they trigger a crisis, prompting scientists to search for alternative frameworks. This process marks the beginning of a scientific revolution, where a new paradigm replaces the old, transforming the fundamental concepts, methods, and goals of science itself.

This dynamic view of scientific progress challenges the traditional positivist belief that science evolves merely by adding new facts to old theories. Instead, Kuhn views scientific development as a cyclical and revolutionary process, marked by intellectual discontinuity and radical reinterpretation. The implication is profound: the history of science is not a smooth ascent toward truth but a series of paradigm-dependent reconstructions of what counts as "truth," "evidence," and "reality."

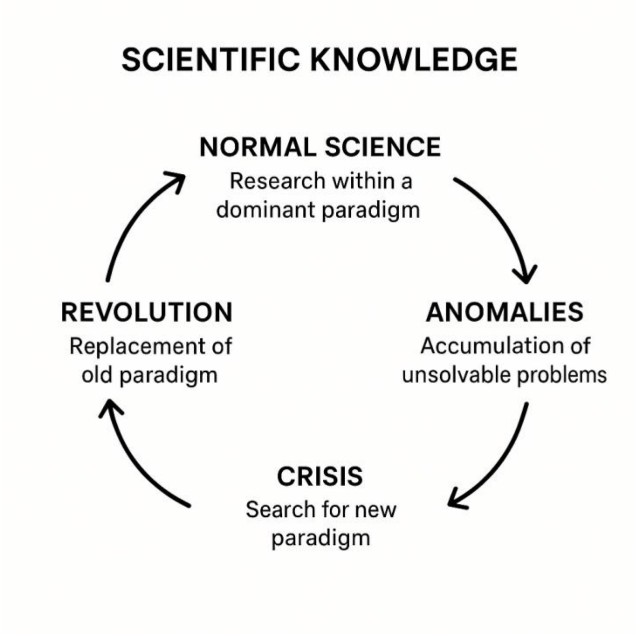

Image 1, Scientific Knowledge

The illustration above depicts Thomas S. Kuhn's cyclical model of scientific development, emphasizing that the evolution of scientific knowledge does not follow a linear trajectory but occurs through a dynamic process of continuity, disruption, and transformation. The diagram begins with the phase of Normal Science, where a dominant paradigm governs research activities, providing stability and guiding scientists in solving problems within accepted frameworks. Over time, however, Anomalies—observations or phenomena that cannot be explained by the prevailing paradigm—start to accumulate. As these anomalies increase, they create tension within the scientific community, leading to a Crisis Phase where the validity of the existing paradigm is questioned(Lundeto 2023).

This crisis fosters the search for alternative explanations, giving rise to the Scientific Revolution, a transformative period in which an entirely new paradigm replaces the old one. The transition signifies a fundamental redefinition of theories, methods, and scientific values. Once the new paradigm is established, a new cycle of normal science begins, continuing the process of knowledge reconstruction. The circular structure of the diagram reflects Kuhn's view that scientific progress is revolutionary and cyclical, marked by intellectual discontinuity and paradigm-dependent shifts in the understanding of truth, evidence, and reality. This visualization challenges the traditional positivist notion of linear scientific accumulation, illustrating instead that science evolves through successive revolutions that reshape the foundations of knowledge itself.

2. Paradigm Shifts and the Logic of Scientific Revolutions

Kuhn's concept of the paradigm shift provides a philosophical explanation of how scientific revolutions occur and why they are necessary. A paradigm serves as the intellectual matrix that determines what scientists see, how they interpret data, and which questions are considered legitimate. During normal science, the paradigm offers stability and direction. But when the paradigm fails to account for growing anomalies, confidence in it begins to waver. This tension leads to what Kuhn called a crisis of faith in the existing scientific order.

The crisis phase represents a period of intellectual uncertainty, where alternative theories begin to emerge. Competing paradigms coexist, leading to incommensurability, or the inability to fully compare one paradigm with another due to their differing conceptual languages. The acceptance of a new paradigm, therefore, is not purely logical or empirical; it also involves a transformation of worldview, social negotiation, and sometimes generational change within the scientific community. This process redefines not only theories but also the methods and epistemic values that guide scientific reasoning.

Ultimately, the scientific revolution marks a new beginning. The new paradigm reorganizes the field of knowledge, redefining what constitutes valid evidence, legitimate inquiry, and acceptable explanation. In this way, Kuhn's theory introduces a historical and sociological dimension to the philosophy of science, showing that progress in science is not a straightforward accumulation of facts but a reconstruction of the very structure of knowledge itself.

3. Paradigm Transformation in the Digital and Industrial Revolution 5.0 Era

The relevance of Kuhn's ideas extends to the digital era and the Fifth Industrial Revolution, where the nature of science itself is being transformed by technology. Today's knowledge systems are shaped by artificial intelligence (AI), big data, machine learning, and algorithmic reasoning, which redefine how data are collected, analyzed, and interpreted, this technological disruption represents a form of contemporary paradigm shift—one that alters not only scientific methods but also the epistemological foundations of inquiry.

In this context, the scientific community is experiencing a transition from traditional human-centered inquiry to data-driven and machine-assisted epistemology. Algorithms now play a crucial role in pattern recognition, hypothesis generation, and predictive modeling—functions once exclusive to human reasoning. This shift challenges Kuhn's earlier notion of paradigms as strictly human constructs by extending epistemic agency to non-human systems. The integration of AI into scientific practice blurs the line between "observer" and "instrument," giving rise to what scholars call digital epistemology—a new paradigm of knowing.

Moreover, this technological revolution has led to the emergence of interdisciplinary knowledge ecosystems, where natural sciences, social sciences, and computational fields converge. Such complexity requires a redefinition of Kuhn's model to account for multi-paradigmatic and hybrid knowledge structures. Thus, the digital revolution can be viewed as an ongoing meta-paradigm shift, reshaping the very conditions under which knowledge is produced, validated, and transmitted.

4. Epistemological Reconstruction and the Future of Scientific Knowledge

The study's findings suggest that in the age of digital transformation, the reconstruction of epistemology has become both necessary and inevitable. Traditional epistemological models—based on stability, singular methods, and human observation—are no longer sufficient to explain the complexity of modern science. Scholars such emphasize that the rise of digital epistemology requires rethinking how knowledge is structured, validated, and disseminated across interconnected systems of humans and machines.

Kuhn's framework offers valuable insight into this process. His cyclical model of scientific change—*normal science, anomaly, crisis, and revolution*—provides a philosophical foundation for understanding how knowledge adapts in response to technological and societal transformation. By viewing digital transformation as a form of "epistemic anomaly," we can interpret the ongoing evolution of AI-based science as a revolution that expands the boundaries of human cognition and methodology. This reinforces Kuhn's claim that science evolves through disruption and reorganization rather than through linear accumulation.

Looking forward, the reconstruction of the structure of scientific knowledge demands a balance between continuity and transformation. It involves redefining key concepts such as truth, objectivity, and rationality in light of technological mediation and interdisciplinary integration. In this sense, Kuhn's paradigm theory serves not only as a historical explanation but as a living framework for understanding how science continues to reinvent itself in the era of artificial intelligence and the Fifth Industrial Revolution.

Table 1. Reconstruction of Epistemology in the Era of Digital Transformation

Aspect	Traditional Epistemology	Digital Epistemology (Contemporary Reconstruction)	Relevance of Kuhn's Paradigm Theory
Epistemic Foundation	Based on stability, fixed methods, and human-centered observation.	Dynamic, data-driven, integrating human cognition and machine processing.	Reflects *normal science* transitioning to *anomaly* as traditional frameworks fail to

			explain digital complexity.
Methodological Orientation	Singular and discipline-specific methods dominate scientific inquiry.	Multi-method, interdisciplinary, and algorithmic approaches combining AI, big data, and human interpretation.	Represents a *paradigm shift* where new tools redefine the process of scientific reasoning.
Knowledge Validation	Validation through empirical observation, peer review, and reproducibility.	Validation includes algorithmic verification, computational modeling, and networked collaboration.	Mirrors Kuhn's *crisis phase*, where old validation systems lose adequacy and new norms emerge.
Structure of Knowledge	Linear, cumulative development of knowledge.	Non-linear, adaptive, and constantly evolving networks of knowledge production.	Demonstrates Kuhn's idea that science progresses through *revolutionary reorganization* rather than accumulation.
Role of Technology	Technology serves as a passive instrument for observation and measurement.	Technology (AI, algorithms) becomes an active epistemic agent that co-generates knowledge.	Expands Kuhn's model to include non-human epistemic actors in shaping paradigms.
Concepts of Truth and Objectivity	Truth viewed as correspondence between theory and empirical reality.	Truth becomes contextual, relational, and mediated by human–machine interactions.	Reinforces Kuhn's argument that objectivity is paradigm-dependent and historically situated.
Epistemological Goal	To discover universal and timeless scientific laws.	To construct flexible, adaptive systems of understanding suitable for complex realities.	Reflects *scientific revolution*—a redefinition of what counts as valid knowledge.
Outcome	Stable but limited understanding of knowledge and method.	Continuous epistemic reconstruction and redefinition of rationality in the	Shows Kuhn's paradigm theory as a living framework for explaining

	digital era.	modern epistemic evolution.

4. CONCLUSION

This study concludes that the development of scientific knowledge is not linear or accumulative but occurs through a dynamic and revolutionary process marked by paradigm shifts. Thomas S. Kuhn's theory demonstrates that scientific progress depends on the cyclical transition from normal science to anomaly, crisis, and scientific revolution, which collectively reshape the fundamental assumptions, methods, and objectives of science. In the digital era and the context of the Fifth Industrial Revolution, these paradigm transformations have expanded to include the influence of artificial intelligence, big data, and interdisciplinary collaboration, which redefine the structure of knowledge and the processes of validation and discovery. Therefore, epistemological reconstruction becomes a necessity to ensure that science remains relevant, proportional, and sustainable in addressing contemporary complexities. Kuhn's paradigm framework thus continues to serve as a vital philosophical foundation for understanding the continuous reconstruction of knowledge in the age of technological disruption and digital transformation.

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