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Introducing Robotic Scientists: Explorations into New Dimensions of Scientific Objectivity and Creativity

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Abstract

This study investigates the epistemological and sociological implications of robotic scientists—autonomous systems capable of hypothesis generation, experimentation, and inferences are examined in terms of objectivity in the context of contemporary science. However, scholars such as S. Harding, and H. Douglas have shown that science is inherently value laden. The emergence of robotic scientists further complicates the epistemological and sociological dimensions of this debate: although designed to minimize human biases, they reintroduce values via algorithmic design and data selection. The study uses examples like "Adam" and the Liverpool-based robotic chemist to highlight the ability of these systems to execute large-scale scientific procedures autonomously and with consistent outcomes. Their ability to generate and test hypotheses reconfigures how scientific agency and authorship are understood, demanding a redefinition of objectivity as both an epistemic and procedural standard. Additionally, it addresses the question of robotic creativity, using Boden's framework to suggest that such systems already demonstrate exploratory creativity. Supported by international initiatives like the OECD's "Nobel-Turing Challenge" the potential for robots to play more innovative scientific roles is becoming more tangible. Sociologically, robotic scientists challenge established institutional norms. Drawing on Latour's Actor-Network Theory and Lamola's concept of the "robosphere," the paper argues that these machines are not just tools but participants in socio-technical networks. They provoke reevaluation of concepts like expertise, community, and legitimacy. Robotic scientists do not merely enhance traditional research—they reshape the norms, values, and boundaries of science itself. Their emergence calls for interdisciplinary inquiry to address the ethical, philosophical, and institutional frameworks that must guide this transformation.

Keywords: Robotic Scientists, Scientific Objectivity, Human-Machine Interaction..

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Robotik Bilimcilerle Tanışma: Bilimsel Nesnellik ve Yaratıcılıkta Yeni Arayışlar

Öz

Bu çalışmada hipotez üretme, deney yürütme ve bilimsel çıkarım yapma kapasitesine sahip otonom sistemler olan robotik bilimcilerin, çağdaş bilim bağlamında epistemolojik ve sosyolojik etkileri nesnellik açından incelenmektedir. Ancak S. Harding ve H. Douglas gibi araştırmacılar, bilimin doğası gereği değer yüklü olduğunu ortaya koymuştur. Robot bilim insanlarının ortaya çıkışı, bu tartışmanın epistemolojik ve sosyolojik boyutlarını daha da karmaşık hale getirmektedir: İnsan önyargılarını azaltmak üzere tasarlansalar da, algoritmik tasarım ve veri seçimi yoluyla yeni değer katmanlarını sisteme dahil ederler. "Adam" adlı Robot Bilimci ve Liverpool Üniversitesi'nde geliştirilen kimyager otonom robot ve benzeri örnekler, bu sistemlerin büyük ölçekli deneyleri bağımsız ve tutarlı biçimde gerçekleştirebildiğini göstermektedir. Hipotez üretme ve test etme becerileri, bilimsel öznellik ve yazarlık gibi kavramların yeniden tanımlanmasını gerektirebilir. Bu durum, nesnelliğin yalnızca epistemik değil aynı zamanda işlemsel bir standart olarak yeniden düşünülmesine yol açabilir. Ayrıca, Boden'in çerçevesi doğrultusunda robotik yaratıcılık meselesini ve bu sistemlerin halihazırda keşfedici düzeyde yaratıcı işlevler gösterdiği görüşüne makalede yer verilmiştir. OECD'nin "Nobel-Turing Meydan Okuması" gibi uluslararası girişimleri de robotların bilimsel yenilik süreçlerine aktif biçimde katılabileceklerini göstermektedir. Sosyolojik olarak, robotik bilimciler bilimsel kurumların yerleşik normlarını zorlamayabilir. Latour'un Aktör-Ağ Kuramı ve Lamola'nın "robosfer" kavramı aracılığıyla, bu makinelerin yalnızca araç değil, sosyo-teknik ağlarda etkin aktörler olduğu öne sürülmektedir. Robotik bilimciler yalnızca bilimsel araştırmayı geliştirmekle kalmaz, bilimin normlarını, değerlerini ve sınırlarını da yeniden şekillendirebilir. Bu dönüşümün etik, felsefi ve kurumsal temellerle uyumlu biçimde ilerleyebilmesi için disiplinler arası bir çabaya ihtiyaç duyulmaktadır. Bu makalede bu çabanın genel çerçevesi çizilmeye çalışılacaktır.

Anahtar Kelimeler: Robotik Bilimciler, Bilimsel Nesnellik, İnsan-Makine Etkileşimi.

Introduction

Throughout the history of science, the notion of objectivity has occupied a central position, shaping scientific methodologies and epistemological frameworks. The pursuit of objectivity—conceived as the systematic elimination or reduction of subjective biases and personal values from scientific inquiry—has consistently shaped the development of scientific methodology. However, despite rigorous methodologies, achieving complete objectivity remains a challenge due to inherent psychological biases and sociocultural values influencing researchers. Recent advancements in artificial intelligence and robotics have opened new possibilities, suggesting the emergence of robotic scientists—autonomous systems capable of conducting independent research activities, from hypothesis generation to experimental verification (King et al., 2009, p. 86). These robotic systems promise an unprecedented level of consistency, precision, and detachment from human-specific biases, thereby reviving and reshaping the discussion around scientific objectivity. Nonetheless, such developments remain subject to considerable debate and contention. Critics of technological determinism caution against overly optimistic assumptions regarding the epistemic neutrality or superiority of machines. Scholars argue that robotic systems, like any human-made artifact, are embedded with assumptions, priorities, and blind spots inherited from their creators (Winner, 1980, p. 128). Accordingly, an uncritical embrace of robotic scientists may obscure the socio-technical dynamics that shape knowledge production.

This article critically examines the implications of integrating robotic scientists into research processes, particularly focusing on their potential to enhance scientific objectivity. It also explores associated philosophical and sociological dimensions. While robotic scientists may indeed offer significant epistemic advantages, they simultaneously provoke ongoing debates regarding the nature of scientific knowledge production and the possibility—or impossibility—of truly value-free science (Douglas, 2009, p. 86; Harding, 1991, p. 113). Additionally, the paper briefly touches upon broader epistemological transformations and shifts within scientific communities resulting from the presence of these autonomous research agents. By navigating these interrelated aspects, the article aims to clarify the transformative potential of robotic scientists within contemporary science, framing this development as a critical juncture in the ongoing history of scientific thought and practice.

Moreover, Carl G. Hempel's deductive-nomological (D-N) model provides a structured foundation for assessing objectivity in scientific explanation. Hempel argued that scientific objectivity rests on the logical derivation of empirical statements from universal laws and initial conditions (Hempel & Oppenheim, 1948, p. 139). However, this model presupposes a high degree of transparency and linguistic clarity that may not align with the probabilistic or opaque inferences of AI-driven research systems. Particularly in robotic science, the covering-law model struggles to account for the epistemic processes of non-human agents whose inferential steps may be inaccessible or non-intentional in nature (Hempel, 2001, pp. 69–87). Thus, while Hempel's model offers a formal standard for objectivity, its applicability to robotic science remains contested.

1. Scientific Objectivity: A Historical and Philosophical Overview

Scientific objectivity is widely regarded as an essential goal within the scientific enterprise, shaping the practices and methodologies scientists adopt. Historically, objectivity emerged as a significant epistemological ideal in the nineteenth century, reflecting a shift away from subjective interpretations toward standardized methods aimed at eliminating personal biases (Daston & Galison, 2010). Early scientific practices relied heavily on personal skill, judgment, and interpretation, but as science evolved, efforts increased to establish methodologies designed explicitly to minimize individual subjectivity. Philosophically, the concept of objectivity has been deeply intertwined with the debate over value-free science—the idea that scientific inquiry should be entirely independent of social, cultural, and personal values. Prominent philosophers such as Longino (2020), Harding (1991), and Douglas (2009) have critically explored this notion, highlighting inherent challenges in separating knowledge production from values and social contexts. According to Longino, scientific objectivity is achievable not through the absence of values but through critical discourse among diverse scientific communities. Harding, similarly, argued that complete neutrality is unattainable, advocating instead for explicit acknowledgment of the social dimensions of scientific knowledge. The psychological and sociological dimensions introduce additional layers of complexity to the pursuit of scientific objectivity. Researchers inevitably bring cognitive biases, emotional predispositions, and culturally influenced perceptions to their scientific endeavors. These influences can subtly shape hypotheses, methods, and interpretations of data, thus challenging the purity of scientific objectivity. The introduction of robotic scientists offers a novel possibility of addressing these biases, potentially leading to a new chapter in the pursuit of objective knowledge.

Recent policy-driven analyses, such as the OECD's 2023 report on artificial intelligence in science, further support this by suggesting that objectivity must also be understood in terms of increasing research efficiency and accelerating discovery. According to the report, AI systems—including robotic researchers—can augment the scientific process not only by minimizing bias but also by substantially raising productivity across disciplines (OECD, 2023, pp. 10–13). This reconceptualization reframes objectivity as both an epistemic and operational value, with robotic systems serving as mediators of both accuracy and scalability.

2. Robotic Scientists and the Pursuit of Objectivity

Robotic scientists, defined as automated systems capable of independently performing tasks traditionally reserved for human researchers, represent a significant innovation in contemporary scientific practices. These systems possess the potential to enhance scientific objectivity by systematically reducing human cognitive biases and errors (King et al., 2009, p. 86). The utilization of robotic scientists spans various disciplines, from pharmaceuticals and biotechnology to chemical synthesis, demonstrating their broad applicability and transformative potential.

A prominent example is the robotic chemist developed at the University of Liverpool, which autonomously conducted 688 experiments over eight days during the COVID-19 pandemic lockdown, operating 21.5 hours a day and making experimental decisions based on previous outcomes (World Economic Forum, 2020). Such systems can plan and execute entire experimental workflows, including weighing reagents, initiating reactions, and quantifying outputs, while navigating laboratory environments without human intervention. These capabilities position robotic scientists not merely as tools, but as autonomous research agents with epistemic relevance. Additionally, the Robot Scientist "Adam", developed to investigate yeast metabolism, exemplifies the capacity of robotic systems to autonomously generate hypotheses and verify them through formal experimentation. According to King et al. (2009), Adam was able to identify previously unknown gene functions and outperform average human researchers in experimental efficiency. This underscores the claim that robotic scientists, while engineered by humans, can exceed human performance in narrowly defined epistemic tasks. Robotic systems' capacity to consistently replicate experimental conditions with high precision significantly enhances reliability and reproducibility—key aspects of objective scientific inquiry (King et al., 2009, p. 87). Unlike human researchers, robots are not susceptible to emotional fatigue, cognitive biases, or lapses in attention, thereby providing an epistemic advantage in certain contexts. Nevertheless, robotic researchers are not entirely immune to bias, as their programming inevitably reflects human-designed algorithms and objectives.

Yet the autonomy of robotic scientists demands not only technical reliability but also ethical governance. As Steve Fuller (2007, pp. 6–9) notes, the scientific enterprise is inseparable from political and moral accountability. Robotic systems, by being perceived as epistemic agents, must also be evaluated through the lens of social responsibility—particularly regarding the goals their creators encode and the broader consequences of their outputs. If left unregulated, robotic epistemic agency risks perpetuating biases and assumptions under the guise of objective neutrality (Fuller, 2007, p. 172). This raises profound questions: To whom are robotic scientists accountable? What happens when their knowledge exceeds human interpretability but lacks moral comprehension?

Furthermore, fictional formulations such as Asimov's *Three Laws of Robotics* have historically served as speculative but instructive principles for conceptualizing machine behavior. Although originally literary constructs, these laws continue to influence ethical programming and human expectations surrounding autonomous systems. Contemporary ethical frameworks—such as IEEE's Ethically Aligned Design—reflect foundational concerns first explored in speculative fiction, including the prioritization of human safety, accountability, and adherence to moral constraints (Floridi et al., 2018, p. 698). Accordingly, objectivity in robotic science is not solely defined by technical precision, but also by predictable and ethically consistent behavior. From an epistemological standpoint, the integration of robots into research practices compels a reconsideration of the traditionally human-centric paradigm of knowledge production. Collins (2010, p. 125) argues that human knowledge inherently involves tacit dimensions—subtle, implicit understandings gained through experience—which robots may struggle to replicate fully. While robotic scientists promise enhanced objectivity, their contributions to scientific knowledge also necessitate critical evaluation of the limits and scope of robotic epistemology.

While robotic scientists are frequently praised for their capacity to perform predefined tasks with objectivity and precision, a more fundamental question emerges: can such systems also engage creatively in the process of scientific discovery? Margaret Boden (2004, pp. 3–4) identifies three forms of creativity—combinational, exploratory, and transformational—that may serve as a useful framework for assessing the creative potential of robotic systems. Current robotic scientists primarily demonstrate exploratory creativity, systematically navigating problem spaces and generating novel hypotheses from large datasets, as exemplified by the Robot Scientist Adam in biological research (King et al., 2009, p. 88). These advancements demonstrate that robotic systems are increasingly capable not only of testing hypotheses but also of autonomously generating them through inductive reasoning and algorithmic pattern detection. Such capacities challenge the conventional view that scientific creativity is an inherently human attribute, shaped by intuition, context, and lived experience. Yet, although robotic agents may replicate certain dimensions of creative scientific practice, it remains debatable whether these processes reflect genuine innovation or merely the computational imitation of frameworks predefined by human designers.

The epistemological implications of these developments are profound. As robotic systems increasingly participate in the production of scientific knowledge, the classical epistemic dichotomy between subject (the scientist) and object (nature) becomes unsettled. In its place, human–robot interaction may foster a hybrid epistemology in which knowledge emerges through the collaborative agency of both human and machine actors. This perspective calls for a reconfiguration of existing theories of knowledge and suggests that scientific inquiry is entering a phase where agency, intentionality, and creativity are no longer solely human attributes (Collins, 2010, pp. 130–132). Recent advances in deep learning and embodied cognition suggest that machines are increasingly operating beyond explicit instruction, acquiring procedural and implicit knowledge through adaptive algorithms. These developments raise the possibility of machine-native epistemologies—distinct forms of knowing grounded in computational architectures rather than human experience (Besold et al., 2017, p. 1; Burrell, 2016, p. 3). Within this framework, robots are not only simulating knowledge production but are actively generating novel patterns, insights, and predictive models, often in ways opaque to human understanding.

Beyond explanation, the increasing autonomy of machine learning systems raises the spectre of ethical disengagement. As Fuller (2007) argues, the integration of intelligent systems into epistemic communities must not obscure their entanglement with socio-political agendas. Robotic systems reflect the design assumptions and data biases of their creators—even when such systems are presumed "neutral" (pp. 6–9). This introduces a moral hazard: when a machine's recommendation causes harm, responsibility is often diffused across opaque networks of developers, institutions, and algorithms. Fuller therefore insists that the epistemic agency granted to machines must be mirrored by corresponding forms of social accountability, including regulatory scrutiny and transparent auditability (Fuller, 2007, p. 207).

Another challenge concerns the potential emergence of artificial epistemic agency. Some scholars propose that advanced robotic scientists may soon exhibit what could be termed "functional intentionality"—the capacity to generate and revise hypotheses based on goals inferred from contextual learning rather than direct human programming. This blurs the line between mere instrumentality and autonomous reasoning. Yet, as Fuller (2005) notes, agency in science has never been a purely technical designation; it also entails moral and discursive legitimacy within a community of knowers (pp. 133–135). Therefore, even as robotic systems expand their creative and inferential capacities, their integration into scientific epistemology must remain conditional upon their adherence to norms of intelligibility, explainability, and normative deliberation.

In this light, the future of robotic science cannot be envisioned as a mere substitution of human labour with automated precision. Rather, it necessitates a reconfiguration of how scientific institutions define knowledge, responsibility, and participation. This implies the co-development of governance frameworks—such as ethical AI oversight bodies and dynamic regulatory schemas—that can evolve alongside robotic scientists. Such mechanisms would ensure that the epistemic power granted to machines does not outpace our collective ability to oversee and interrogate it.

This opacity challenges classical norms of scientific explanation. This lack of transparency challenges traditional standards of scientific explanation. As Lipton (2018, p. 32) notes, certain AI-generated results may meet criteria for scientific validity while remaining epistemologically opaque to the very humans who designed them. Consequently, robotic creativity entails not just generating new knowledge but doing so in a form that forces us to reassess what counts as intelligible or legitimate within scientific epistemology.

In this context, robotic principles—conceived as a speculative yet increasingly necessary normative framework—can be interpreted as a call to develop meta-principles that mediate between human and machine cognition. Instead of imposing anthropocentric frameworks on machines, a pluralistic epistemology may offer a more inclusive approach—one that recognizes and accommodates the diverse modalities through which intelligent agents acquire knowledge, construct interpretations, and act upon the world.

3. Robotic Scientists within Scientific Communities

The integration of robotic scientists into research environments also necessitates a sociological analysis of their role within scientific communities. From the perspective of Actor-Network Theory (ANT), as articulated by Bruno Latour (1987, pp. 70–72), scientific knowledge is not solely produced by individuals but emerges through dynamic interactions among human and non-human actors, including instruments, institutions, and now, robotic agents. In this framework, robotic scientists are not merely passive tools but active participants that reshape the structure and flow of scientific practice. Robotic agents introduce new forms of interaction within research networks, prompting reevaluation of agency and authorship in scientific output. For instance, if a robotic system autonomously generates a hypothesis and tests it successfully, to what extent can—or should—authorship be attributed to the machine? These questions resonate with broader sociological concerns about labor division, accountability, and legitimacy within evolving scientific institutions (Knorr Cetina, 1999, pp. 183–185). Furthermore, the increasing presence of robotic scientists may alter the institutional and cultural organization of science. As automation becomes embedded in laboratory routines, the roles of human researchers may shift toward supervisory, interpretative, or integrative functions. This transition may challenge traditional academic hierarchies and redefine expertise. Sociological analysis thus reveals that the adoption of robotic scientists does not merely change research methods—it transforms the social fabric of scientific communities.

Philosophical perspectives on robot sociality provide additional insight into the evolving dynamics of human–machine interaction. Lamola (2022) proposes that robots may progressively occupy meaningful positions within what he designates as the robosphere—a cyber-physical social realm in which intelligent artefacts are recognized as active participants in relational networks of meaning-making. In this context, the sociotechnical agency of robots transcends functionality, implicating them in processes of social ontology. These developments require science studies scholars to address how notions of epistemic agency, community boundaries, and even legitimacy are redefined in this expanding cognitive ecosystem.

The framing of robots as epistemic agents also intersects with concerns of epistemic justice. As Fricker (2007, p. 1) defines, epistemic injustice occurs when individuals or groups are wrongfully denied credibility as knowers. Extending this framework to human-machine systems raises the question: if machines can generate knowledge, do they warrant recognition as participants in epistemic practices? And if so, how do we ensure that such recognition does not undermine human accountability or reinforce asymmetric power structures embedded in algorithmic systems? From a historical-philosophical perspective, Hilary Putnam's early reflections on the possibility of robot consciousness and moral agency already hinted at these debates. In his 1964 paper, Putnam questioned whether machines that simulate human behavior could ever be considered morally or socially responsible agents, pointing toward foundational tensions in how machines are integrated into systems of scientific meaning and responsibility (Putnam, 1964, pp. 668–670). The potential for robotic consciousness or quasi-agency also introduces metaphysical concerns. While Hempel was skeptical about bridging mental phenomena with physical laws, acknowledging the limits of scientific explanation in such domains (Hempel, 2001, p. 238), contemporary AI research faces similar dilemmas. Can embodied cognition in robots, trained through reinforcement and adaptive algorithms, qualify as epistemically intentional? Fuller (Fuller, 2006, pp. 133–141) provocatively argues that if machines simulate moral reasoning or autonomy, they may be said to inhabit a rudimentary form of agency—one that necessitates recognition within our sociotechnical frameworks, even if this agency is devoid of consciousness in the human sense. Such philosophical ambiguity only intensifies the need for institutional mechanisms of accountability and inclusion.

Taken together, these considerations suggest that the integration of robotic scientists not only reshapes how knowledge is produced but also how scientific communities define agency, responsibility, and legitimacy. The rise of robotic epistemic actors thus demands a reflexive reevaluation of the norms governing scientific authorship and sociotechnical citizenship in the age of intelligent machines.

Conclusion

The emergence of robotic scientists represents a significant epistemological and institutional turning point in the history of science. As this paper has demonstrated, robotic systems offer clear advantages in consistency, reproducibility, and the mitigation of human cognitive bias—qualities that resonate with classical ideals of scientific objectivity. Yet, as scholars such as Douglas (2009, pp. 86–89) and Harding (1991, pp. 112–115) have emphasized, the notion of a fully value-free science remains deeply contested. Robotic scientists are not exempt from this epistemic debate; rather, they reconfigure the locus of value-leadenness, embedding it within algorithmic architectures and data infrastructures.

Moreover, these robotic systems are not merely epistemic tools. As shown by the case of Adam and the Liverpool robot chemist, they can autonomously generate hypotheses, perform experiments, and propose efficient strategies for inquiry. Their operational autonomy forces a reassessment of traditional boundaries between instrument and agent, scientist and tool. Robotic scientists thus challenge the human exclusivity of scientific creativity, participating—albeit within structured limits—in the generative processes of discovery (King et al., 2009; OECD, 2023). As the discussion of epistemic machines and deep learning has shown, the very concept of knowledge is undergoing redefinition. Robotic systems capable of generating non-symbolic, procedural, and statistically inferred knowledge demand that epistemology move beyond anthropocentric paradigms. If knowledge production becomes increasingly distributed between human and non-human agents, scientific communities must embrace pluralistic, hybrid epistemologies that acknowledge machine-native forms of understanding.

Sociologically, the rise of robotic scientists reconfigures scientific communities. Drawing on Latour's Actor-Network Theory, Lamola's robosphere concept, and Fricker's notion of epistemic injustice, it becomes evident that these systems require new forms of epistemic recognition and social accountability. Robotic agents challenge the norms of authorship, responsibility, and legitimacy, demanding that scientific institutions reflect on their structural inclusion and moral positioning. Furthermore, the epistemic opacity of robotic systems undermines traditional norms of scientific explainability. Classical models, such as Hempel's D-N structure, emphasized logical transparency and verifiability. In contrast, robotic inferences—especially those from deep learning models—often resist interpretability, challenging our capacity to verify conclusions or attribute responsibility. As Fuller warns, delegating epistemic authority to inscrutable systems can erode public trust and limit participatory governance. Thus, any framework for integrating robotic scientists must also embed mechanisms for ethical scrutiny, interpretability, and civic oversight.

In conclusion, robotic scientists do not merely enhance traditional research—they reshape the norms, values, and boundaries of science itself. Their emergence calls for interdisciplinary engagement to address the ethical, philosophical, and institutional frameworks that must accompany this transformation. Rather than resolving long-standing tensions in science, robotic scientists amplify them—ushering in a posthuman moment in which humans and machines co-construct knowledge and ethical responsibility. Future research should pursue the development of adaptive and inclusive frameworks—such as Principia Robotica—that integrate ethical foresight, epistemic pluralism, and participatory governance into the design and deployment of autonomous systems. Only through such reflection can we ensure that the future of science remains intelligible, equitable, and responsible in a world shaped by artificial agency.

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