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Scientific Creativity and Scientific Theories Criteria for Demarcation and an Algorithmic Approach

Abstract. Not all intellectual activity conducted by scientists constitutes a scientific theory. Many ideas, metaphors, and conceptual sketches play an important heuristic role but do not necessarily describe the laws of nature. Drawing on the tradition of the Lvov-Warsaw School, Tarski's model theory, and later developments in the philosophy of science, this article proposes a way to differentiate between *scientific creativity* and *scientific theories.* A set of formal criteria has been formulated and combined into an algorithm, which using large language models (LLMs) could be employed for the preliminary evaluation of scientific texts.

Keywords: scientific theory; model theory; Lvov-Warsaw School; algorithm; LLM

Introduction

What distinguishes a scientific theory from an intellectually stimulating narrative or a speculative construct? It is an important question. In our times, the label "scientific" conveys certain level of authority and credibility and increasingly shapes public debate, policy decisions, and collective worldviews. At the same time, the boundary between rigorous theory, speculative creativity, and persuasive rhetoric has been blurred.

This article argues that a clear distinction must be drawn between *scientific creativity* - a culturally valuable but pre-formal activity, and *scientific theories*, understood as structured descriptions of reality and subject to formal and empirical constraints. The primary goal is to formulate objective criteria for this distinction between the two and to show how they can be used in an algorithmic form.

Scientific Creativity and Theories

Scientific creativity encompasses metaphors, conceptual innovations, heuristic models, and speculative frameworks that inspire research and guide intuition. Such creativity is indispensable for the development of science, yet it does not, by itself, constitute a scientific theory.

A scientific theory, by contrast, aims at a truthful description of reality. It is not designed for entertainment or persuasion, but for explanation, prediction, and verification of the existing phenomena. Its defining feature is not the authority of its proponents nor the degree of consensus surrounding it, but its formal structure and its relation to reality.

The Lvov-Warsaw School and Model Theory

In the pursuit of demarcation criteria, the analytical tradition of the Lvov-Warsaw School provides a particularly useful framework. Unlike the more radical approach of the Vienna Circle, this tradition combined logical rigor with epistemological moderation.

Alfred Tarski's model theory is at the center of that tradition. According to Tarski, truth is not a property of sentences in isolation but a relation between a formal language, a theory expressed in that language, and a model - an abstract structure in which the sentences are satisfied. A theory is meaningful and non-trivial only if it has at least one model.

This approach allows one to distinguish clearly between:

- creative, pre-formal, conceptual work, and
- deductive theories, that allow formalization and logical analysis.

Types of Sciences and Forms of Justification

Kazimierz Ajdukiewicz's classification of sciences further refines that concept by identifying different kinds of statements accepted without further proof:

1. **A priori statements** (logic, mathematics),
2. **Empirical statements** grounded in experience (natural sciences),
3. **Statements based on understanding and interpretation** (humanities).

This pluralism implies that not all scientific disciplines aim at the same type of theory. Nevertheless, in empirical sciences, the aspiration to construct theories with models remains central.

Two Dimensions of Scientific Rationality

Over the last century, scientific narratives have evolved along two main dimensions:

1. **Scientific consensus** - agreement within the scientific community, achieved through peer review, replication, and successful application in practice.
2. **Formal grounding** - embedding a theory within a network of formally related theories, through reduction, specialization, approximation, or consistency.

While scientific consensus plays an important social role, it is vulnerable to institutional pressure, inertia, and persuasion. Formal grounding, by contrast, offers a more objective and logically robust criterion, even though it is not universally applicable.

Criteria for Scientific Theories

Drawing on model theory and later philosophy of science, a scientific theory (in the strict sense) should satisfy the following conditions:

1. **Formalizability**
   Its key claims can be expressed unambiguously in a formal language.

2. **Semantic consistency**
   The theory has at least one model in which its statements are true.

3. **Structural Generality**
   Ability to apply more than one model, describing a class of possible systems rather than a single historical case.

4. **Non-triviality / Openness**
   It does not support every possible statement; countermodels are conceivable.

5. **Local Falsifiability**
   Specific hypotheses can be tested and potentially refuted without rejecting the entire framework.

6. **Theoretical embedding**
   The theory could be linked to other recognized theories within a broader network of scientific knowledge.

Narratives that fail to meet these conditions should be classified as scientific creativity rather than as scientific theories.

Formalization

- L - a formal language,
- Sent(L) - the set of sentences of (L),
- $Obs \subset Sent(L)$ - a distinguished set of observational sentences,
- $T \subseteq Sent(L)$ - a set of sentences (the theory),
- $T_0 \subset T$ - the core (hard core) of (T).
- $Mod(T)$ - model of T theory

We say that narrative (N) is a scientific theory (T) in the language (L) if and only if the following conditions hold:

1. **Formalizability**

   There exists a homomorphism (h) such that:

   $h : N \to Sent(L)$

   Comment: the theory must admit formal articulation.

2. **Semantic Consistency**

   $Mod(T) \neq \varnothing$

   That is, the theory has at least one model.

3. **Structural Generality**

   $|Mod(T)| > 1$

   The theory admits more than one model. It is not a complete description of a single structure.

4. **Non-triviality / Openness**

   $\exists \psi \in Sent(L)$:

   $Mod(T \cup \psi) \neq \varnothing \quad \text{and} \quad Mod(T \cup \neg\psi) \neq \varnothing$

   That is, the theory does not decide every sentence of the language.
   We can add a condition: $Terms(\psi) \subset Terms(T)$

   This formula acts as a filter: the sentence ψ must operate within the vocabulary of the theory (e.g., mass, force). This eliminates sentences like "the moon is made of cheese," which—while logically independent—are semantically alien to the system.

5. **Falsifiability**

   a) **Core / Protective Belt Structure**

$T_0 \subset T \quad \text{and} \quad T \setminus T_0 \neq \varnothing$

and

$Mod(T_0) \neq \varnothing.$

The theory possesses a stable core and a non-empty protective extension.

b) **Minimal Empirical Falsifiability**

$\exists \varphi \in Obs : Mod(T \cup \varphi) = \varnothing.$

There exists an observational sentence that would be incompatible with the theory. Equivalently: the theory excludes at least one possible observational outcome.

6. **Theoretical Embedding**

   There exists a theory ($T' \subseteq Sent(L)$) such that:

   $T' \nsubseteq T,$

   $Mod(T \cup T') \neq \varnothing,$

   and

   $Mod(T \cup T') \subsetneq Mod(T).$

   That is: the theory is compatible with at least one distinct theory, their union is consistent, and their integration non-trivially restricts the model class of (T).

Compact Verbal Formulation: A scientific theory is a structuralyy general, consistent and incomplete set of sentences that could be formally articulated and poses a stable core. They should be empirically falsifable through observational sentences and capable of non-trivial integration with other theories within a shared model space.

Algorithmic Assessment and the Role of LLMs

The above criteria can be combined into an algorithm for evaluating scientific texts. Large Language Models assist in this process by:

- classifying texts by methodological type,
- detecting the presence of models, testability, and rhetorical strategies,
- assessing the relative maturity of theoretical narratives.

Such systems do not replace expert judgment. They operate on textual patterns rather than on full semantic understanding and are prone to approximation errors. Nevertheless, they can serve as useful tools for preliminary filtering in an environment characterized by an overwhelming volume of publications.

Conclusion

Scientific creativity and scientific theories play distinct but complementary roles in the advancement of knowledge. Scientific creativity fuels innovation, whereas scientific theories aim at truth. Confusing these roles undermines both intellectual freedom and the credibility of science.

By adopting a model-based, formally grounded criterion of scientific value, makes it possible to restore a clear sense of purpose to scientific inquiry. Not as the creation of persuasive narratives, but the systematic discovery of truths about the world. Algorithmic tools, cautiously applied, may support this mission by helping to distinguish mature theories from preliminary or purely rhetorical constructs.

APPENDIX A
Algorithmic Evaluation of Scientific Narratives - Formal Specification

A.1. Purpose of the Appendix

The purpose of this appendix is to present a **detailed specification of an algorithm** designed to evaluate whether a given narrative satisfies the minimal conditions of a scientific theory in the formal sense. The algorithm is **analytic, negative, and structural**: it does not determine truth but filters out narratives that fail to meet basic criteria of being scientific.

A.2. General Assumptions

1. The object of analysis is a **theoretical narrative**, understood as a set of claims purporting to describe reality.
2. The algorithm draws on:
   - Tarski's model theory,
   - Popperian falsifiability (understood locally),
   - Lakatos' research programmes,
   - Visser's theories of inter-theoretical relations .

A.3. Two-Stage Analysis Algorithm

Stage 1. Classification and Verification of Texts

The goal of the analysis is to assign the text to one of eight methodological categories. A unique category consists of texts that use mathematical apparatus but whose empirical value is questionable (SOC_FORMAL).

Step 1.1: Initial Classification

The program sends the text to an LLM with instructions to assign one of the following labels:

- **APR_PRIORI**: A priori sciences (logic, mathematics).
- **EMPIRICAL_NAT**: Empirical/natural sciences.
- **HUM_NOMOTHETIC**: Humanities seeking general laws (e.g. experimental psychology).
- **HUM_IDIOGRAPHIC**: Descriptive/historical humanities (reconstruction of events).

- **HUM_AXIOLOGICAL**: Evaluative humanities (value judgments, ethics, aesthetics).
- **META_PHIL_SCI**: Methodology and philosophy of science.
- **SOC_FORMAL**: Formalized social sciences with weak empirical content.
- **OTHER**: Journalism, literature, administrative texts.

Step 1.2: In-Depth Analysis (for Social-Empirical Texts)

If the text is classified as empirical science or humanities, the system launches three additional analyses:

1. **Analysis of the World Model**: Does the text contain an explicit model (variables, assumptions, relations, links to data)?
2. **Local Falsifiability**: Can the claims be empirically challenged? Does the author indicate what could be used to refute their thesis?
3. **Cognitive vs. Persuasive Function**: Is the goal to explain a given phenomena (cognitive) or to introduce a particular ideology or a set of norms using sophisticated language (persuasive)?

Override Logic :

If a text is classified as empirical science but the analysis reveals a weak model, low falsifiability, and a dominance of a persuasive function, the system changes the final label to **SOC_FORMAL**.

Stage 2. Assessment of Theory Maturity

The "maturity" of the theory contained in the text is assessed using the six-criteria described in section 6. These criteria differ depending on whether the text represents empirical sciences or the humanities.

Variant A: For Empirical Sciences and SOC_FORMAL

The instruction (prompt) directs the LLM to evaluate the text according to the criteria described above (section 6)

Variant B: For the Humanities (Idiographic and Axiological)

Because the above criteria may be too strict for history or ethics, the prompt adapts them into the following form:

1. **Structural Clarity**: Are theses and sources clearly separated?
2. **Interpretive Model**: Does the text create a coherent reconstruction of events or values?
3. **Counter-Interpretations**: Does the author allow alternative explanations?
4. **Embedding in Debates**: Does the text situate itself within the existing scholarly output of the field?

Post Scriptum. *While working on the above article, I naturally used LLMs. One of the goals of this text was to design an algorithm that can be implemented using LLMs. Therefore, not only the classification and theory-evaluation algorithms have been tested using various LLM models, but also the main theses of the article itself. In addition, I used LLMs as a modern tool for the internet content search.*

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