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Escaping the rabbit hole: turning information overload into cumulative knowledge again

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Chemical Engineering is increasingly distinguished by its breadth: catalysis, separations, electrochemistry, materials processing, bioprocesses, digitalization, and sustainability are now tightly intertwined. For researchers entering any of these areas, the abundance of papers can be both inspiring and cognitively exhausting. In principle, review articles should reduce this burden by transforming dispersed findings into understanding. In practice, however, many reviews have drifted toward being catalogues of results - useful as bibliographies, but weak as learning tools - because they often under-explain *why* trends occur, *which mechanisms* are supported, and *what questions* remain unanswered. This Perspective argues that the erosion of explanatory synthesis is not merely a stylistic problem; it is a symptom of incentive structures, delegated authorship practices, and a "publish-or-perish" culture that rewards output volume over durable understanding. Keeping in mind the common and fundamental questions typical of chemical engineering, we try to explore the current literature, and we suggest some recommendations to avoid losing oneself in the rabbit hole of data.

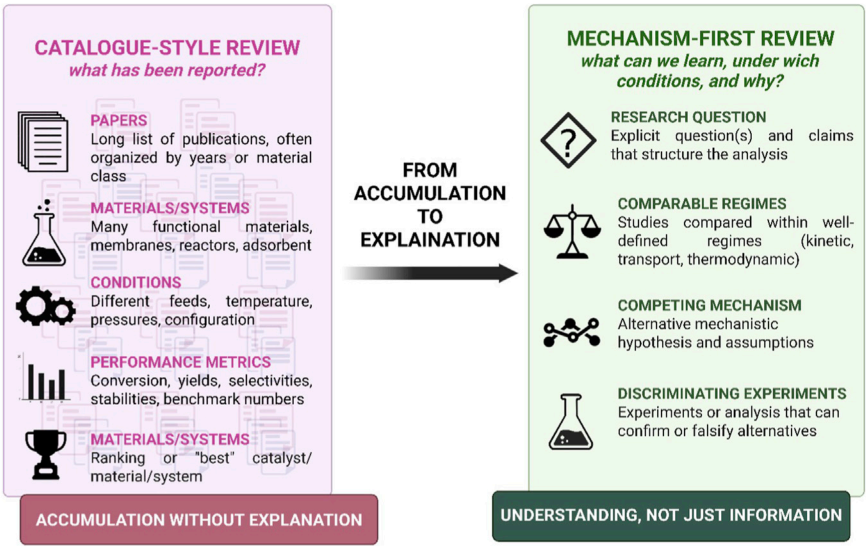
KEYWORDS
chemical engineering, early-career researchers, mechanistic understanding, pedagogy, publication bias, research review, review articles, scholarly incentives

1 Introduction: the paradox of abundance

Chemical engineering has always been multidisciplinary, but the scale and pace of cross-fertilization have accelerated. The same workstream may require fluency in transport phenomena, reaction networks, surface science, data-driven modelling, and life-cycle constraints. For early-stage researchers, this landscape is intellectually exciting yet emotionally taxing, because the "entry cost" is no longer a handful of foundational papers but a moving target of hundreds.

In this scenario, review articles are not peripheral: they are *infrastructure*. They are meant to provide orientation, compress complexity, and transmit the tacit logic that experts use to judge claims. In catalysis, for instance, two papers may report opposite selectivity trends for the same nominal material, not because one is wrong and the other is right, but because they operate under different conversion levels, transport regimes, catalyst histories, or analytical protocols. Analogously, two similar CO_2-capture sorbents reported in different papers may exhibit significantly different adsorption capacities because of the distinct pre-conditioning parameters (e.g., outgassing temperature and duration) used to prepare the samples for the adsorption test. A catalogue-style review can place these papers side by side; a mechanism-first review asks whether they are even comparable. Reviews should not merely summarize the literature, but should provide a balanced perspective and address controversies, gaps, and future directions (Editorial, 2024).

The aspiration is clear, execution is the challenge.



GRAPHICAL ABSTRACT

The flood of publications, driven by a publish-or-perish culture (Teixeira da Silva and Nazarovets, 2026), creates the illusion of rapid progress, but this is often disconnected from meaningful breakthroughs or genuine understanding (Grant and Booth, 2009; Messeri and Crockett, 2024; Shiffrin et al., 2018). In this context, early-career researchers are particularly vulnerable to this trend. The pressure to publish and career uncertainty, which typifies young researchers, may push them toward output-oriented strategies, losing sight of academic significance, precisely at the critical moment when it is necessary to build up expertise.

2 Why catalogue-style reviews do not fit chemical engineering

Many researchers recognize a common pattern: a review that reads like an inventory. The narrative is dominated by "who did what, with which catalyst/membrane/reactor, at what performance," with limited space for mechanistic interpretation. The result is paradoxical: the review contains *more papers than ever* but provides *less understanding than expected*.

This shift has a huge impact, in particular in chemical engineering, because mechanistic reasoning is not an aesthetic preference: it is the backbone of translation from lab observations to models, allowing scale-up, design, and appropriate control. Lists of performance metrics rarely clarify which step is rate-limiting (transport vs. kinetics vs. phase behaviours), and whether the evidence supports one mechanism or another (Flaherty and Bhan, 2024; Gray, 2021). Moreover, reviews often fail to state the assumptions needed to interpret discrepancies across studies and fail to suggest which experiments would discriminate competing explanations.

A review that does not articulate these points forces newcomers to reconstruct the logic by looking for the primary papers, often through endless citation chains that point back to other reviews. The readers do not only fail to find answers, but sometimes, fail to find the *question* that should be asked.

The absence of explicit research questions is a shortcoming of contemporary research practice. Instead of starting with questions such as "What controls selectivity?", "Which transport regime applies?", the review starts with "Recent progress in X," then proceeds chronologically or by material class.

When research questions remain implicit, papers that address different regimes are easily compared as if they tested the same claim. This produces conceptual drift: differences in feed composition, hydrodynamics, reactor geometry, catalyst pretreatment, or measurement protocol are treated as secondary details rather than as possible causes of disagreement. The consequence is a literature that appears cumulative in terms of citations but remains fragmented in terms of explanation.

Another shortcoming is the adoption of misleading narratives: conclusions become only descriptive ("A improves B") rather than explanatory ("A improves B because it shifts the dominant pathway from X to Y under regime R"). This weakens the explanatory depth of the literature. Finally, a phenomenon of citation recursion is observed: reviews cite reviews and key claims become "known" without a clear trail to decisive evidence.

This is not a condemnation of review writing, but it is a predictable consequence of compressing a fast-growing literature under tight time and career constraints.

3 Structural drivers of shallow reviews

To tackle the problem of the impoverishment of reviews, it is first necessary to identify its possible roots. From our perspective, these can be grouped into four categories (Hicks et al., 2015).

First, the erosion of mechanism in reviews reflects a broader shift in research behaviour. When careers are evaluated by short-term bibliometric indicators, researchers optimize their work to achieve rapid, positive and incremental results (Fanelli, 2010; Johann et al., 2024).

This phenomenon is amplified for young researchers (González Flores, 2025) who, in parallel to professional growth, deal with personal paths that may be particularly demanding. Young researchers live a period of their life that can be characterised by major life events, such as a child's birth (Mason, 2022), that require time and (mental) resources. From this point of view, parental leaves generally induce stops in the career path and in the research production which are difficult to catch up with (the so-called "parental wall" (Mason, 2022; Simms, 2025). In the worst case, this induces researchers to resign; indeed, after maternity leave almost 1 out of 3 women in science leave their job (Torres, 2020). When researchers are expected to compensate for career interruptions or periods of reduced productivity by rapidly rebuilding their publication record, catalogue-style reviews may become an attractive option. They can be compiled relatively quickly, generate visible output, and require less additional experimental/interpretative effort than mechanism-first reviews. This is not a failure of individual researchers, but a consequence of an incentive system that often rewards rapid productivity more than slow, cumulative understanding.

Another structural factor is how review writing tasks are assigned. Reviews can be excellent training projects for young researchers, but only when they are supervised as exercises in critical synthesis rather than delegated as literature compilation. Early-career authors often know the newest papers better than anyone else in the group; what they may still be developing is the field-specific judgement needed to decide which comparisons are valid, which mechanisms are underdetermined, and which claims require stronger evidence. This makes mentorship central to review quality. Without strong mentorship, the safest path becomes compilation: summarizing is less risky than evaluating mechanisms, because mechanistic claims invite disagreement.

Publication bias also matters because the visible literature is not a neutral sample of all attempted experiments. If positive or high-performance outcomes are preferentially submitted (Ramos, 2026), accepted, and cited, a catalogue-style review may transform selective visibility into apparent consensus (Ioannidis, 2005; Smaldino and McElreath, 2016). A mechanism-first review should, instead, treat missing negative results, failed replications, and contradictory observations as mechanistic constraints (Dalton et al., 2016; Gray, 2021). A "try something, publish the best version, tweak, publish again" loop is not always bad; optimization is part of engineering. The problem arises when optimization displaces understanding: when we improve a metric without learning which lever mattered, and whether it will generalize beyond the narrow test case (Heesen and Bright, 2025).

Finally, in recent years, Large Language Model (LLM)-based tools may exacerbate this depletion of meaningfulness in reviews (Ciaccio, 2023; Kacena et al., 2024). Indeed, LLM-based tools can accelerate literature screening and first-pass summarization, but they also make it easier to produce catalogues of papers without verifying whether the compared studies address the same mechanistic question. Their main risk in review writing is not only factual hallucination (Walters and Wilder, 2023), but explanatory shallowness: the production of coherent text that does not distinguish observation, inference, regime, and evidence (Haider et al., 2024).

4 A mechanism-first template for reviews

The remedy is not "longer reviews" or "more references." It is a change in *organizing principle*: from topic-first to question-first, and from results-first to mechanism-first (Snyder, 2019).

Below is a practical template that, we hope, can be applied to reviews to overcome the merely summarized work.

4.1 Start with testable mechanistic questions

A strong synopsis begins by listing 3-6 research questions as verifiable statements, for example:

- "Under operating regime R, selectivity is controlled primarily by surface coverage rather than mass transfer."
- "Reported stability differences are dominated by test protocol, not intrinsic material durability."
- "Scale-up failures arise from a shift in hydrodynamic regime, not catalyst deactivation."

Each claim should then be evaluated against evidence. In such a way, results taken from the literature and reported in the review are not simply listed but rather compared and discussed. This process generates knowledge both in the writer and in the reader creating a virtuous cycle. For example, in catalysis, this approach can be summarized by the following questions:

- Is selectivity controlled by intrinsic active-site structure, surface coverage or residence time?
- Is catalyst deactivation caused by leaching, oxidation-state changes or mass-transfer-induced hot spots?
- Are reported activity differences intrinsic, or do they arise from catalyst mass, particle size or heat/mass transfer?

4.2 Separate observations from explanations

For each trend, explicitly separate observations, explanations, and discriminating evidence. For identifying observations, answer to the question "what is observed?" and check whether this is robust across different laboratories. Then look for an answer to the query "what is inferred?". This will provide a mechanistic interpretation of the observed data, based on the principles typical of the discipline (Hoque and Guzman, 2018) (i.e., laws, models…). Finally, try to understand "what would disprove it?", suggesting critical experiments/measurements that could prove wrong or confirm the inferred interpretations (Flaherty and Bhan, 2024). Such an approach prevents a common trap: treating an interpretation as if it were a measurement and giving only descriptions rather than explanations. Table 1 illustrates some examples of the proposed strategy.

TABLE 1 Observation, inference, assumptions, and discriminating tests: examples from chemical engineering.

Observation →	Inference →	Assumptions →	Discriminating test
Photocatalyst A produces more H_2 than photocatalyst B under simulated solar light	A promotes more efficient charge separation and electron transfer to protons	Same absorbed photon flux, catalyst loading, illuminated area, sacrificial agent concentration, pH, stirring, reactor geometry, and stability	UV–Vis absorption, PL/TRPL, transient photocurrent, EIS, H_2 normalized by absorbed photons, post-reaction characterization
Sorbent A adsorbs more CO_2 than sorbent B (adsorbed quantity normalised by specific surface area)	A may expose a higher density of accessible adsorption sites or stronger CO_2-binding sites	Same pre-treatment/outgassing, pressure, temperature, gas composition, humidity, equilibration time, and normalization procedure	*In situ/operando* IR spectroscopy to identify adsorbed species; CO_2 isotherms and heats of adsorption; XPS, solid-state NMR or titration methods to quantify surface functional groups/active sites

4.3 Compare studies within compatible regimes

In chemical engineering, comparability is not guaranteed by studying the same material or reporting the same metric. Comparability requires compatible regimes, protocols, and boundary conditions.

Where possible, synthesize results into regime-aware comparisons. For this purpose, exploit dimensionless groups (e.g., Péclet, Damköhler, Reynolds, Sherwood), check whether transport or kinetics controls the observed performance (Mears, 1971), try to identify phase constraints, look for measurement artifacts and protocol dependence (Zhang et al., 2019). All this information will help in identifying the mechanism and regime underlying the observed data.

In chemical engineering, performance is rarely an intrinsic material property. It is a system response emerging from kinetics, transport, thermodynamics, hydrodynamics, phase behaviour, and protocol (Weisz and Prater, 1954). For this reason, review tables that rank catalysts, membranes, or reactors by a single metric can be misleading unless the operating regime is explicit. A mechanism-first review should therefore ask whether studies are compared within the same kinetic regime, conversion window, reactor configuration, residence time distribution, and measurement protocol (Flaherty and Bhan, 2024).

Even a qualitative regime map can be more informative than a leaderboard table.

4.4 Treat contradictions as mechanistic information

Contradictory results are not inconveniences to smooth over. Some contradictions arise from true mechanistic multiplicity; others from different regimes, normalization choices, catalyst histories, or analytical artefacts. A review that simply averages them loses information. A review that explains why they diverge produces knowledge.

4.5 Convert uncertainty into a roadmap

Finally, when some questions remain open or with uncertain answers, a good review should not simply state that “more studies are needed”. It should transform uncertainty into a roadmap for future research and exploit unresolved questions to define what the field still needs to learn, and which evidence would be most useful to collect next.

Future directions should therefore be formulated as targeted questions and discriminating tests. If two or more mechanisms remain plausible, the review should indicate which experiment, measurement, model, or reporting standard could help distinguish between them. For instance, if a difference in catalytic activity may arise either from intrinsic active-site density or from mass-transfer limitations, the review should suggest the kinetic tests, transport criteria, normalization procedures, or *operando* measurements needed to identify the dominant explanation under specific conditions.

This is particularly important in chemical engineering, where uncertainty often arises from the coupling of kinetics, transport, thermodynamics, hydrodynamics, material properties, and protocol. Different mechanisms may dominate in different regimes, so the goal is not always to provide a single universal answer. Rather, a useful review should clarify which explanation is supported, under which boundary conditions it holds, and what evidence would be required to revise it (Matera et al., 2015).

In this way, a review becomes more than a summary of published studies. It becomes a decision-making tool for the field, guiding researchers toward experiments that reduce uncertainty and build cumulative knowledge.

The major tips provided in the precedent paragraphs are reported in Table 2; this can be used as a starting roadmap when writing a review on chemical engineering.

Finally, as explained in the introduction, apart from issues strictly connected to the writing style of reviews, there are also environmental boundaries affecting young researchers’ approach, such as evaluation criteria based on bibliometric indicators and personal constraints (i.e., temporary leaves…). The analysis of these conditions does not allow the definition of a unique solution: it is beyond the scope (and of the possibilities) of this perspective to provide solutions to them. Nevertheless, it is worth mentioning these problems to raise awareness and encourage further discussion within the academic community.

5 Who can change what?

A mechanism-first approach requires coordinated changes from all the actors of the publishing chain. The principal stakeholders

TABLE 2 Mechanism-first checklist for chemical engineering review writing.

Component	Catalogue-style minimum	Mechanism-first upgrade
Research questions	Topic scope stated	3–6 testable mechanistic questions
Comparability	Papers grouped by topic/material	Studies compared within compatible regimes and protocols
Evidence	Results treated similarly	Evidence graded by controls, replication, uncertainty, and assumptions
Mechanisms	Mentioned qualitatively	Competing mechanisms and discriminating experiments stated
Contradictions	Smoothed over or minimized	Used to identify hidden variables and boundary conditions
Future directions	Generic calls for more studies	Prioritized roadmap of experiments that would reduce uncertainty

involved in this process are authors, supervisors, editors and reviewers.

Authors should choose fewer questions and answer them more deeply. The unit of writing should not be the paper, but the mechanism: instead of moving from study to study, a review should move from observation to explanation, from explanation to evidence, and from evidence to uncertainty.

Authors should also use AI-assisted tools critically. LLM-based tools can support literature screening and first-pass summarization, but they should not replace mechanistic judgement (Kacena et al., 2024; Walters and Wilder, 2023). Their use should be guided by explicit questions: Are the compared studies operating in the same regime? Are observations being separated from interpretations? Are mechanistic claims supported by discriminating evidence? Without this guidance, AI tools may accelerate the production of fluent but shallow catalogues.

If reviews are used as training projects, **supervisors** should exploit them as training in judgement, not only as exercises in literature collection. Senior co-authors are responsible for helping young authors identify invalid comparisons, hidden assumptions, unsupported mechanistic claims, and overgeneralized conclusions. This role is especially important in chemical engineering, where differences in reactor configuration, operating regime, catalyst history, transport limitations, or analytical protocol can make two apparently similar studies difficult to compare.

Supervisors should guide early-career researchers in moving from “paper paragraphs” to “mechanism paragraphs”. This means encouraging them to ask not only what each study reported, but also what was demonstrated, under which assumptions, and what evidence would be needed to challenge the proposed explanation. In practice, mentorship can include co-developing the key research questions of the review, checking whether studies are grouped within comparable regimes, discussing contradictory results as mechanistic clues, and explicitly evaluating the strength of evidence behind major claims. Good supervision should also protect junior authors from the idea that a review is valuable only if it covers everything: a shorter and more critical synopsis can be more useful than an exhaustive but weakly interpreted catalogue.

Editors and reviewers can play a decisive role by asking a simple question: does the review explain, or only summarize? Coverage alone should not be a guarantee of quality. A review that cites hundreds of papers without clarifying mechanisms, assumptions, regimes, contradictions, and future discriminating experiments may be useful as a bibliography, but it does not fully perform the explanatory function that reviews should have (Chatterjee et al., 2025).

During peer review, editors and reviewers could assess whether the manuscript is organized around explicit questions rather than only around materials, applications, or chronological progress. They could ask whether the compared studies operate under compatible boundary conditions, whether performance metrics are interpreted considering kinetics and transport phenomena, and whether mechanistic claims are supported by appropriate evidence. Reviewers should also encourage authors to treat contradictions and negative results as informative rather than inconvenient. Instead of asking only for broader coverage, they can ask authors to clarify why studies disagree, which hidden variables may explain the disagreement, and what experiments would resolve the uncertainty. By rewarding depth of interpretation rather than the number of cited papers, editors and reviewers can help shift reviews from literature accumulation toward explanatory synopsis.

Finally, institutions and funders shape the incentives under which review writing occurs. If evaluation systems reward publication counts and short-term visibility more than critical synthesis, researchers will rationally prioritize output over durable understanding. Recognizing rigorous reviews, negative results, protocol standardization, and long-term clarification as valuable contributions would help align career incentives with cumulative knowledge.

6 Conclusion

Chemical engineering advances when it can turn observations into transferable understanding: mechanisms, regimes, and models that survive beyond a single dataset. In an era of information overload and strong publication incentives, reviews and perspectives are more necessary than ever, but only if they restore their explanatory function. Re-centering mechanism-first reviews is not nostalgia; it is a pragmatic strategy to reduce wasted effort, accelerate genuine learning, and help early-career researchers enter complex fields with clarity rather than exhaustion. A good review should clarify what can be inferred, under which conditions, with what evidence, and what experiment would change our mind.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

OT: Conceptualization, Investigation, Writing – original draft, Writing – review and editing, Data curation, Methodology. MG: Conceptualization, Investigation, Writing – original draft, Writing – review and editing, Data curation, Methodology.

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The author(s) declared that generative AI was used in the creation of this manuscript. Generative AI tools were used to support language editing, improve clarity and fluency. The authors reviewed, edited, and verified all AI-assisted content and take full responsibility for the accuracy, originality, interpretation, and integrity of the final manuscript.

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