

Overcoming Ignorance: Meta-Creative Problem-Solving as a Methodology of Scientific Discovery

1 Abstract

At the frontier of knowledge, we feel ignorant about a subject—but at the edge of inquiry, we also feel uncertain about how to proceed. Scientists lack **instrumental norms of inquiry**, guiding choices among discovery paths. Scientists develop them by generating novelty in their inquiry, evaluating it against the object of inquiry, and reflecting on the process amid metacognitive feelings that provide essential feedback. This **meta-creative problem-solving (MCPS)** approach can ground a methodology of scientific discovery, to study and improve discovering practices and norms.

2 Introduction

Recent studies of scientific discovery emphasize methods rather than their integration. Shea's work in philosophy of mind shows how concepts transmit causal information across methods, with feelings guiding transitions. In this direction, I claim that concepts, methods, and goals are organized through problems amid metacognitive feelings.

- ▶ Scientists don't just solve problems but discover how to do inquiry itself (Chang)
- ▶ Scientific models serve as cognitive artifacts whose consequences guide model refinement (Nersessian)
- ▶ Breakthroughs require reformulating problems themselves (Boden)

MCPS integrates these insights: Scientists change discovering practices and norms, producing consequences that guide further refinement through metacognitive feedback.

Unlike traditional philosophy of science, which analyzes discovery outcomes, we begin from scientists' self-reported experiences of "not knowing how to proceed." Following the Cartesian method of doubt, I approach ignorance by stripping away what we know—but in practice, knowledge and ignorance remain intertwined in inquiry

3 Instrumental Norms

Ignorance is defined as a lack of instrumental norms:

Intentional: X wants to solve problem p1.
Material: If X selects path m1 instead of m2,X is more likely to solve p1.
Normative: X should select more effective paths.

Therefore, X should select m1.

Examples:

- ▶ Avoid ad hoc modifications to theories
- ▶ When stuck, redefine the problem
- ▶ Choose distinct causal variables

Overcoming ignorance concerns developing these premises:

- ▶ **Intentional:** (Re)defining problems via frameworks, methodologies, norms
- ▶ **Material:** Justified theoretically, empirically, through metacognitive feelings, or via experiments on inquiry (box 7)
- ▶ **Normative:** Efficiency matters due to limited resources, subsequent norms justified by better realization of current norms (box 8)

4 MCProblem-Solving

Think of problem landscape as graphs between problems:

Problem Space	Solving Space	Reflective Space
<i>What is the problem?</i> (state, methods, goals)	<i>How do we solve it?</i> (plan, solution)	<i>Why solve this?</i> (past, present, future problems)

Meta-problems are problems whose goal is to solve given first-order problems by monitoring and controlling their spaces. Navigation is non-linear but guided by instrumental norms.

They transform ill-defined problems into computable chains, combining questions with methods to form plans. Progress is tracked and updated in real time. When progress halts, reflection explores new steps, alternative formulations, connections, and alignment with broader goals.

5 MetaCPS

Metacognitive feelings monitor cognitive processes and outcomes, guiding complex problem-solving. They arise from past relationships between inquiry and subject matter, triggered by present experience.

Scientists may not know exactly what to do, but they sense what might or might not work.

Feelings range from basic (confidence, fluency) to complex (experimental feasibility). Though often grounded in theory or evidence, they remain fallible—e.g., misplaced confidence in low p-values. Yet MCPS embraces failure as informative.

Why they work:

Metacognitive feelings, like experimental results, are the common effect of epistemic activities interacting with the subject. Just as surprising results prompt reexamination of experimental design ("did we err?") and theoretical understanding ('were we wrong?'), feelings misaligned with expectation help calibrate them or assumptions about a given subject.

By manipulating epistemic activities and observing feeling changes, scientists can learn new causal information about the subject of inquiry.

Productive problem landscape confusion: When reading a poster, you sense tension: the author connects concepts A and B for their problem, which seems reasonable. Yet concept A links to other ideas that, in similar problems, conflict with B's associations. This confusion—emerging from multiple problems—prompts you to ask the author how these connections resolve. The feeling integrates information across the problem landscape, suggesting deeper tensions.

6 MCreativePS

Creativity is the **directed integration** of generation and evaluation, producing novel value. Independence is crucial: what helps generation may hinder evaluation and vice versa. Scientists direct creativity toward the subject, guided by instrumental norms.

Generation	Evaluation	Integration
produce variations (experiments, code)	assess variations (results, judgment)	guide the loop (evolutionary, AI)

Despite how it really happened:

Kekule generated potential benzene structures by analogy, but none met empirical evaluative criteria. Given failures with known chemical organizations, embodied instrumental norms progressively loosened constraints, allowing increasingly distant analogical sources. Lacking progress, Kekule deliberately tried from the other side, looking for specifically unusual organizations, leading the ouroboros as generative input of analogy that ultimately met empirical criteria. This illustrates integration (box 2) of creativity in the discovery process.

7 How Inquiry Develops

To uncover knowledge, we search for **invariances** between epistemic practices and the subject of inquiry. MCPS operates through directed integration: generating variations in epistemic activities and evaluating changes against the subject.

The Infinite Regress Problem:

Since monitoring and controlling epistemic activities is itself a (meta)epistemic activity, we face potential infinite regress—if every epistemic change requires another epistemic act to guide it, where does it end?

It's resolved by embracing it:

When inquiry with existing norms keeps failing, scientist generates variations in instrumental norms themselves. These variations together with subject of inquiry produce feelings used for evaluation.

This self-consistent loop resolves the infinite regress—we develop inquiry through inquiry means. Scientists discover how to do inquiry itself by changing their problem-solving capacities against the subject of inquiry, using metacognitive feedback to monitor and control while they improve.

8 Intuitions & Virtues

Development of intuitions:

Scientists start with metacognitive feelings, but aim for justifications beyond them. When initial feelings remain stable across problems, we attempt to explicate them. When explicated feelings help solve problems, we invest in formal justification. Even false intuitions are useful, as reflecting on them fosters correction. They function as "half-baked conjectures" or "half-baked heuristics" that guide inquiry.

Origin of virtues:

Scientific virtues are second-order directions in navigating problem landscape. Consider simplicity virtue. We start with efficiency premise, therefore we prefer what we feel easier to store, retrieve, learn, and debug. Reflecting on their similarity, we generated the concept of "simplicity". The new virtue is justified because checking simplicity proves more efficient than checking easiness of each path separately. Later formalized into rigorous principles like Occam's razor and algorithmic complexity.

9 Grounding Methodology

Methodology should both study and improve inquiry practices and norms.

AI applications: In AlphaFold, scientists requested granular confidence scores. First mathematical discovery with LLMs contributing variations in strategies, later evaluated symbolically and integrated evolutionary. Expert intuitions remain crucial. Current works explore neurosymbolic, self-acquiring skills workflows.

Implementation idea:

A self-modifying universal algorithm designed for eternal improvement rather than halting.

```
problems = {problem, meta_problem, instrumental norm}
experience = stream_of_events()
agents = {IF event THEN action rules→events}

while True:
    for event in experience:
        for norm in agents:
            if norm.matches(event, problems):
                experience += norm.create(event)
```

My work: Digital analysis of papers using causal discovery algorithms reveals gaps between norms used and norms optimal, challenge of merging domain-specific theories with the causal framework, and confidence practice checklist as solution.

From Playbook to Scaffolding:

MCPS enables practical playbooks for scientists to manage what they already do. Such evidence can ground digital platforms that provide real-time scaffolding: tracking problem landscapes, suggesting methodological paths, and ultimately, solving problems better.

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