

Web 7.0 Foundation

Scientific Discovery Process

Developed under the governance of the Web 7.0 Foundation Standards Development Organization (SDO).

Operational Specification · SDP-OPS-002 · Version 2.1.0

Status: This document defines a standards-based direction and testable requirements; it is not a published international standard, certification, or proof that a scientific claim is true.

Document control

Field	Value
Specification ID	SDP-OPS-002
Version	2.1.0
Version status	Proposed implementation profile
Normative schema dialect	JSON Schema Draft 2020-12
Provenance alignment	W3C PROV-DM / PROV-O mapping recommended; not automatic conformance
Workflow semantics	Custom state and transition rules; no BPMN conformance claimed
Primary principle	Process conformance, evidence adequacy, epistemic status, and truth are distinct.
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Executive summary

The Scientific Discovery Process (SDP) is a research lifecycle framework designed to support disciplined inquiry without assuming that scientific work is linear. It includes ten connected stages, explicit decision gates, evidence and claim records, provenance, uncertainty, correction pathways, and context-sensitive validation. Version 2.1 adds a machine-validatable record profile and explicit workflow invariants.

- JSON Schema validates record structure and controlled values; it does not validate scientific reasoning or truth.
- W3C PROV concepts can represent entities, activities, and agents involved in creating or transforming research artifacts; a mapping must be specified before claiming interoperability.
- Workflow state transitions are separately defined and must be checked by an application or workflow engine.
- Claims carry scope, supporting evidence, counterevidence, uncertainty, status, maturity, and review history.
- Stage gates evaluate readiness and process quality; claim maturity changes only when evidence and validation criteria justify the change.
- Corrections, withdrawals, and superseded versions remain part of the audit trail.

Scientific Discovery Process 2.1 — Visual Architecture

Figure 1 presents the proposed system architecture and information flow: the ten-stage research lifecycle, linked evidence and claim records, provenance, workflow services, cross-cutting governance, and claim-maturity model. The diagram is explanatory; the normative requirements remain those stated in this specification and its machine-readable artifacts.



Figure 1. Scientific Discovery Process v2.1 — architecture and information flow.

1. Scope and design principles

1.1 Purpose

This specification describes a reusable framework for planning, conducting, evaluating, communicating, and revising scientific research. It is intended to support researchers, reviewers, research organizations, data stewards, software implementers, and auditors.

1.2 In scope

- Ten-stage research process and feedback paths.
- Stage entry conditions, activities, decision gates, evidence requirements, outputs, and re-entry triggers.
- Typed records for projects, claims, evidence, decisions, validation, and provenance.
- Controlled vocabularies for states, gate outcomes, claim types, and maturity labels.
- Structural validation through JSON Schema Draft 2020-12.
- Semantic workflow rules and conformance test cases.
- Versioning, corrections, uncertainty, responsible openness, and risk-proportionate governance.

1.3 Out of scope

- Replacing discipline-specific methods, ethics review, legal duties, or regulatory requirements.
- Declaring one universal method of science or requiring every stage to be strictly sequential.
- Automatically determining whether a hypothesis is true, novel, important, or socially beneficial.
- Mandating universal numerical confidence scores or one evidence-grading scale.
- Claiming that this proposed profile is certified or formally endorsed by JSON Schema, W3C, or another standards body.

1.4 Design principles

Principle	Operational interpretation
Methodological pluralism	Adapt evidence and gate criteria to experimental, observational, theoretical, computational, qualitative, archival, formal, and mixed-method research.
Traceability	Major claims link to evidence, methods, analyses, assumptions, and versioned artifacts.
Explicit uncertainty	Record relevant uncertainty dimensions and how they affect interpretation.
Counterevidence	Capture material contradictory, weakening, null, anomalous, or qualifying evidence.
Proportionality	Increase review and controls with potential consequence, uncertainty, irreversibility, and misuse risk.
Responsible openness	Share methods and artifacts where appropriate, subject to privacy, consent, safety, intellectual-property, and legal constraints.
Versioned change control	Preserve original plans and record material changes, especially changes made after access to results.
Correction without stigma	Make correction and withdrawal routine integrity mechanisms, not reasons to erase history.
Process is not truth	Passing a gate establishes a process decision, not the truth of a claim.

2. Standards architecture

2.1 Layer separation

Layer	Specification mechanism	What it can establish	What it cannot establish
Serialization	JSON syntax	A document parses as JSON.	That fields are meaningful or correct.
Structural validation	JSON Schema Draft 2020-12	Required fields, types, enums, constraints, and record shape.	Legal transitions, complete evidence, valid inference, or truth.
Semantic validation	Application rules and cross-record checks	Referential integrity, conditional requirements, valid state changes, consistency rules.	Truth or adequacy of the scientific argument by itself.
Provenance interoperability	Explicit mapping to W3C PROV concepts	Portable descriptions of entities, activities, and agents in artifact histories.	That provenance is complete, honest, or scientifically sufficient.
Scientific assessment	Discipline-appropriate methods and expert review	Whether evidence and inference are adequate for a defined claim.	Universal certainty or value-free application decisions.
Application assurance	Purpose-specific validation and governance	Fitness for a defined use under stated conditions.	Universal safety or transfer to untested contexts.

2.2 JSON Schema Draft 2020-12

The package uses the meta-schema URI <https://json-schema.org/draft/2020-12/schema>. JSON Schema is used for structural constraints: object shape, required fields, controlled vocabularies, arrays, patterns, and selected formats. The schema is not a workflow engine.

Implementers **MUST** validate records against the declared dialect. They **SHOULD** test the schema itself and use a validator with documented Draft 2020-12 support. Implementers **SHOULD** decide explicitly whether format annotations such as date-time are enforced as assertions by their validator.

2.3 W3C PROV alignment

W3C PROV provides a model for provenance involving entities, activities, and agents. The SDP records can be mapped to those concepts: datasets, methods, analyses, claims, and reports can be modeled as entities; collection, transformation, analysis, review, and release as activities; and researchers, organizations, instruments, or software agents as agents. This specification recommends a mapping but does not claim that the JSON documents are themselves PROV-O RDF or PROV-conformant serializations.

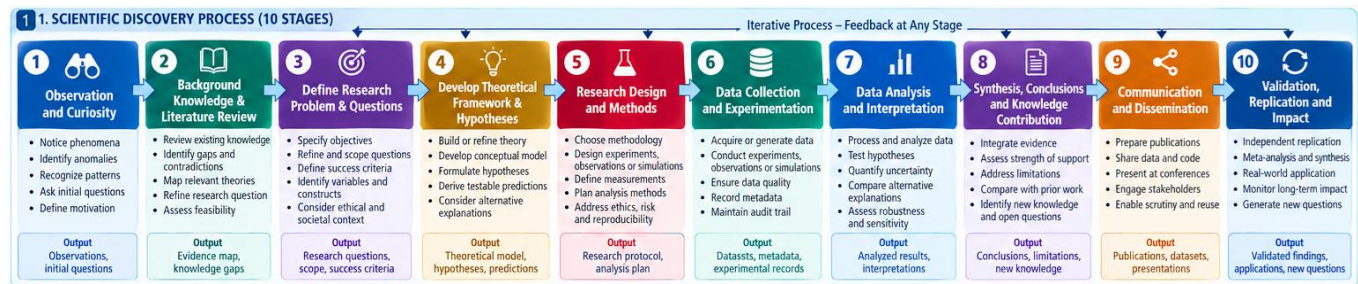
SDP concept	Potential PROV mapping	Mapping caution
Evidence item, dataset, claim, report	prov:Entity	A claim is an information artifact; its epistemic status needs SDP-specific fields.
Collection, transformation, analysis, validation	prov:Activity	Capture time, inputs, outputs, and responsible agents where useful.
Researcher, organization, software agent	prov:Agent	Distinguish human responsibility from automated execution.
Generated/derived artifacts	wasGeneratedBy, used, wasDerivedFrom	Do not infer provenance links without records supporting them.
Review and responsibility	wasAssociatedWith, wasAttributedTo	Association is not proof of independence or competence.

2.4 What not to conflate

- JSON Schema is not JSON itself; the schema constrains JSON instances.
- PROV is a provenance model, not a complete scientific method or workflow.
- A workflow state machine is not the same as BPMN conformance.
- FAIR data principles concern data stewardship and reuse; FAIR status does not prove data quality or truth.
- Preregistration can reduce certain researcher degrees of freedom, but it is not appropriate or sufficient for every research mode.
- Peer review, reproducibility, replication, external validation, and application evaluation answer different questions.

3. Ten-stage lifecycle and stage contracts

The default path is S1→S2→S3→S4→S5→S6→S7→S8→S9→S10. This is a navigational scaffold, not a universal linear law. Stages may be parallelized, revisited, or marked not applicable with rationale. Feedback loops are expected when evidence, theory, feasibility, or context changes.



S1. Observe and formulate curiosity

Contract element	Requirement
Entry conditions	A phenomenon, anomaly, need, theoretical inconsistency, or opportunity has been recorded.
Activities	Separate observation from interpretation; record source/context; check artifacts and uncertainty; generate candidate questions; assess relevance, feasibility, and risk.
Decision gate	The observation/problem is credible enough to investigate, bounded provisionally, and accompanied by provenance and uncertainty notes.
Outputs	Observation/problem statement; initial questions; provenance record; preliminary risk note.
Feedback paths	Revisit S2 when literature reframes the phenomenon; S3 when scope is unclear.

Evidence expectations: preserve the artifacts needed to explain the stage decision; identify missing or restricted evidence; record deviations and uncertainty proportionate to consequence.

S2. Establish existing knowledge

Contract element	Requirement
Entry conditions	A provisional phenomenon or problem statement exists.
Activities	Choose review type; search relevant sources; document search strategy; screen/appraise sources; compare findings and alternatives; record coverage limits.
Decision gate	Review coverage is appropriate to purpose; contrary evidence and search limitations are documented; no claim of exhaustiveness beyond the method.
Outputs	Evidence map; search log; synthesis of current knowledge; refined questions.
Feedback paths	Return to S1 if the apparent phenomenon is already explained; revisit S3/S4 when gaps or theories change.

Evidence expectations: preserve the artifacts needed to explain the stage decision; identify missing or restricted evidence; record deviations and uncertainty proportionate to consequence.

S3. Define problem and questions

Contract element	Requirement
Entry conditions	Initial context and evidence are available.
Activities	Define problem, objectives, scope, constructs, units, population/system, time horizon, and intended inference; set useful-result criteria; assess feasibility and ethics.
Decision gate	Question is consequential, bounded, feasible, and answerable by a plausible inquiry; terms and success criteria are sufficiently operational.
Outputs	Research question; objectives/scope; success criteria; protocol direction.
Feedback paths	Return to S2 if novelty or context is weak; S4 if theoretical framing changes; S5 if no suitable design exists.

Evidence expectations: preserve the artifacts needed to explain the stage decision; identify missing or restricted evidence; record deviations and uncertainty proportionate to consequence.

S4. Develop explanations and predictions

Contract element	Requirement
Entry conditions	The question is defined and theory/model development is relevant or explicitly not applicable.
Activities	Identify theories and assumptions; develop models/hypotheses where appropriate; generate alternatives; derive predictions or organizing concepts; identify discriminating evidence.
Decision gate	Assumptions, alternatives, scope boundaries, and testable implications—or reasons a testable hypothesis is not appropriate—are explicit.
Outputs	Versioned model; hypotheses/propositions if applicable; alternatives; predictions.
Feedback paths	Revise S2/S3 if assumptions conflict with prior evidence or the question needs reframing; revisit after S7.

Evidence expectations: preserve the artifacts needed to explain the stage decision; identify missing or restricted evidence; record deviations and uncertainty proportionate to consequence.

S5. Design the investigation

Contract element	Requirement
Entry conditions	Question and intended inference are defined; theoretical commitments are sufficiently clear for design.
Activities	Choose fit-for-purpose method; define sampling, measures, controls, procedures, analysis and uncertainty plans; address ethics, safety, data governance; pilot and preregister where appropriate.
Decision gate	Design can answer the question to a stated level of precision; approvals, risks, analysis choices, and contingencies are addressed.
Outputs	Protocol; analysis plan; sampling/measurement plan; approvals/safeguards; preregistration where used.
Feedback paths	Return to S3/S4 if design cannot discriminate alternatives; return to S6 if pilot exposes data-quality issues.

Evidence expectations: preserve the artifacts needed to explain the stage decision; identify missing or restricted evidence; record deviations and uncertainty proportionate to consequence.

S6. Acquire and manage evidence

Contract element	Requirement
Entry conditions	Protocol/resources are available and required approvals are in place.
Activities	Execute and log procedures; preserve source records; capture metadata/provenance; run quality checks; record deviations, missingness, failures, and exclusions; protect participants/data.
Decision gate	Evidence is traceable and fit for planned analysis, or limitations are explicitly assessed and accepted by an authorized reviewer.
Outputs	Raw/source evidence; metadata; quality logs; deviation register; analysis-ready versions.
Feedback paths	Return to S5 for material protocol amendment; revisit S3 if collected evidence cannot address the question.

Evidence expectations: preserve the artifacts needed to explain the stage decision; identify missing or restricted evidence; record deviations and uncertainty proportionate to consequence.

S7. Analyze and interpret

Contract element	Requirement
Entry conditions	Usable evidence and a documented analysis rationale are available.
Activities	Run versioned analyses; inspect assumptions and diagnostics; separate confirmatory from exploratory work; assess uncertainty/robustness; compare alternatives; investigate anomalies and counterevidence.
Decision gate	Analysis is appropriate and checked; claims are calibrated to uncertainty, missingness, design limits, and rival explanations.
Outputs	Analysis artifacts; results; diagnostics; uncertainty/sensitivity assessments; evidence-to-claim map.
Feedback paths	Return to S6 for data-quality defects; S4 for model revision; S2 for comparison with new literature.

Evidence expectations: preserve the artifacts needed to explain the stage decision; identify missing or restricted evidence; record deviations and uncertainty proportionate to consequence.

S8. Synthesize contribution

Contract element	Requirement
Entry conditions	Analyses are stable enough to support synthesis, including inconclusive or null outcomes.
Activities	Integrate results with prior knowledge; state contribution and novelty cautiously; assess limitations and applicability; update claim ledger and future questions.
Decision gate	Contribution is distinct from prior knowledge, traceable to evidence, and bounded to the demonstrated scope.
Outputs	Integrated synthesis; claim ledger updates; limitations; future research agenda.
Feedback paths	Return to S7 if synthesis exposes analytic gaps; S2/S3 if the contribution reframes the field or question.

Evidence expectations: preserve the artifacts needed to explain the stage decision; identify missing or restricted evidence; record deviations and uncertainty proportionate to consequence.

S9. Communicate and preserve

Contract element	Requirement
Entry conditions	Claims and supporting artifacts are stable enough for responsible disclosure.
Activities	Choose reporting format; report methods, deviations, uncertainty and limitations; share artifacts where lawful/ethical; enable scrutiny; preserve versions and correction routes.
Decision gate	Readers can assess how claims follow from evidence and can inspect the relevant records or understand access restrictions.
Outputs	Report/publication; artifact links or access rationale; review/correction records; archived versions.
Feedback paths	Return to S7/S8 for material review findings; S10 for validation and follow-up.

Evidence expectations: preserve the artifacts needed to explain the stage decision; identify missing or restricted evidence; record deviations and uncertainty proportionate to consequence.

S10. Validate, translate, and extend

Contract element	Requirement
Entry conditions	Finding or artifact is documented sufficiently to be checked.
Activities	Select validation type; define criteria; test independently or externally where appropriate; assess transfer, safety, and application risks; document discrepancies and follow-up.
Decision gate	Validation matches the claim and intended use; validated scope, residual uncertainty, and next actions are explicit.
Outputs	Validation record; updated claim status; application guidance/limits; new questions.
Feedback paths	Feed S1/S3/S5/S8/S9 as new anomalies, revised questions, redesigned tests, synthesis changes, or corrections require.

Evidence expectations: preserve the artifacts needed to explain the stage decision; identify missing or restricted evidence; record deviations and uncertainty proportionate to consequence.

4. Gate records and state machine

4.1 Stage states

State	Meaning
NOT_STARTED	No work has begun or no valid entry assessment exists.
READY	Entry conditions are met or an authorized exception is documented.
ACTIVE	Stage work is underway.
UNDER_REVIEW	Outputs have been submitted for gate evaluation.
PASSED	Gate decision PASS was recorded for specific artifact versions.
CONDITIONAL	Gate passed only with explicit conditions and owners.
REWORK_REQUIRED	The gate requires corrective work before another review.
ON_HOLD	Work is paused pending a defined resolution.
STOPPED	Work has been stopped or redirected; records are preserved.
SUPERSEDED	This stage/artifact version has been replaced by a later one.

4.2 Gate outcomes

Outcome	Required interpretation
PASS	The defined gate criteria are met for the reviewed artifact versions.
PASS_WITH_CONDITIONS	Progress is permitted only under listed, owned, time-bounded conditions.
REWORK	Specified criteria are unmet and corrective work is required.
HOLD	A blocking question, approval, risk, or dependency remains unresolved.
STOP_REDIRECT	Stop or redirect work with a documented rationale and preservation of records.
NOT_APPLICABLE	The gate does not apply to this research mode or stage; rationale is required.

4.3 Minimum gate record

- Stable gate ID, project ID, stage ID, and timestamp.
- Exact artifact versions reviewed.
- Decision and criteria applied, including criteria deemed not applicable.
- Evidence references and rationale sufficient for later review.
- Decision maker, reviewers, and conflicts of interest where relevant.
- Conditions, owners, due dates, and consequences if conditions are unmet.
- Reopening triggers and a link to any later reassessment.

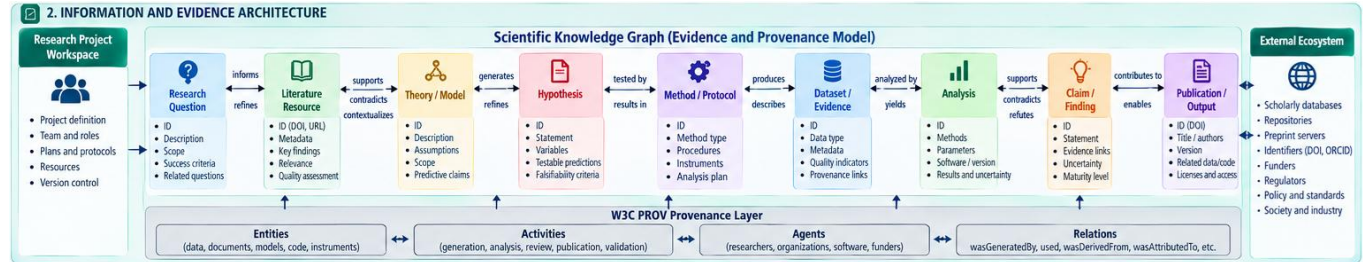
4.4 State-transition invariants

1. A stage **MUST NOT** enter READY unless entry conditions are met or an authorized, documented exception exists.
2. A stage **MUST NOT** enter PASSED without a gate record for identified artifact versions.
3. PASS_WITH_CONDITIONS **MUST** include actionable conditions, owners, and consequences if unmet.
4. A material protocol, outcome, exclusion, stopping-rule, model, or analysis change **MUST** create a versioned change record.
5. A claim's maturity **MUST NOT** be promoted solely because a workflow stage passed.
6. A material change in evidence or claim status **MUST** trigger impact assessment for dependent claims, reports, and decisions.
7. STOPPED and SUPERSEDED records **MUST** remain addressable; history **MUST NOT** be silently erased.
8. Reopened gates **MUST** identify the exact versions being reassessed.

4.5 Event log

Every state change SHOULD produce an append-only event record containing event ID, project and stage IDs, prior state, event, new state, actor, timestamp, rationale, artifact versions, and evidence references. Corrections should append a correcting event rather than silently rewriting historical decisions.

5. Information model and identifiers



5.1 Core record types

Type	Role	Key fields
Project	Research effort and governance context	ID, title, version, accountable lead, research mode, risk tier, timestamps.
ResearchQuestion	Question and scope	ID, wording, objectives, scope, version.
HypothesisOrModel	Proposed explanation or formal structure	ID, description, assumptions, alternatives, predictions, boundaries, version.
Observation	Recorded observation	ID, description, context, source, time, method, uncertainty.
EvidenceItem	Record bearing on a claim	ID, kind, source, version, access status, provenance, quality notes.
Dataset	Structured evidence collection	ID, schema, provenance, version, access conditions, transformations.
Method	Procedure, instrument, algorithm, or protocol	ID, description, version, dependencies, calibration, limitations.
Analysis	Transformation or inferential process	ID, inputs, code/method, environment, parameters, outputs, diagnostics.
Claim	Precisely scoped proposition	ID, text, type, scope, support, counterevidence, uncertainty, status.
SupportRelation	Typed relationship between evidence and claim	Subject, relation, object, rationale, scope/context.
DecisionRecord	Gate or consequential interpretive decision	ID, decision, criteria, rationale, authority, versions, timestamp.
ValidationEvent	A defined test of a claim or artifact	ID, target, type, protocol, criteria, result, independence, limitations.
ProvenanceEvent	Creation or change history	ID, event type, entity, agent, time, inputs, outputs.
PublicationOrReport	Communicated scientific record	ID, version, claims, artifact links, limitations, corrections.
RiskOrEthicsRecord	Risk, approval, safeguard, or incident	ID, risk/requirement, control, status, owner, evidence.

5.2 Identifier policy

- Each record MUST have a stable identifier unique within its declared identifier authority.
- Identifiers MUST NOT be reused after withdrawal, deletion from a user interface, or supersession.
- Production deployments SHOULD use a documented URI or equivalent identifier policy; example.org in the sample schema is a placeholder only.
- Cross-record references SHOULD resolve to the exact record, not merely a mutable display name.
- Versions MUST distinguish materially different content. A content hash MAY supplement but does not replace version metadata.

5.3 Referential integrity

JSON Schema can validate the syntax of a reference field but ordinarily cannot establish that the referenced record exists in a separate registry. Implementations MUST perform semantic checks for reference resolution, record type, access authorization, and version compatibility.

6. Claim-to-evidence reasoning

6.1 Minimum claim record

Field	Purpose
claim_id and version	Stable identity and revision history.
claim_text	One clear proposition; separate observation, interpretation, and recommendation.
claim_type	Observation, descriptive, associational, causal, predictive, explanatory, theoretical, methodological, normative, or applied.
scope_conditions	Population/system, context, time, conditions, units, and boundaries.
supporting_evidence	Evidence that bears in favor of the claim.
counterevidence	Contradictory, weakening, null, anomalous, or qualifying evidence.
assumptions	Premises and dependencies needed for the inference.
uncertainty	Relevant uncertainty dimensions and their effect on interpretation.
status and maturity	Current communication status and evidence/validation maturity.
confidence_rationale	Reasoned explanation or discipline-specific assessment.
limitations	Known biases, untested contexts, measurement limits, and caveats.
review and validation history	Who checked what, when, by which method, and with what outcome.
supersedes / superseded_by	Links to prior or subsequent versions.

6.2 Evidence relationship vocabulary

Relation	Meaning	Caution
SUPPORTS	Evidence favors the claim relative to relevant alternatives under stated assumptions.	Support is rarely absolute.
WEAKENS	Evidence reduces plausibility or narrows the defensible scope.	Consider precision, power, and measurement quality.
CONTRADICTS	Evidence materially conflicts with the claim as stated.	Check context, definitions, and method differences.
QUALIFIES	Evidence narrows conditions or scope.	May improve the claim rather than refute it.
CONTEXTUALIZES	Evidence changes interpretation but is not a direct test.	Do not present it as direct confirmation.
DERIVED_FROM	An artifact depends on a source or transformation.	Record the derivation path and versions.
REPLICATES / FAILS_TO_REPLICATE	A validation event assesses recurrence under specified conditions.	One replication result does not settle every context.

6.3 Observation, result, inference, claim, decision

Layer	Question answered	Required discipline
Observation	What was recorded?	Source, measurement, context, calibration, uncertainty.
Result	What did the analysis produce?	Method, inputs, parameters, diagnostics, uncertainty.
Inference	What explanation is supported over alternatives?	Inferential bridge, assumptions, rival explanations.
Claim	What proposition is defensible, and within what scope?	Precise wording, evidence, uncertainty, limitations.
Decision	What should be done, if anything?	Values, costs, risks, thresholds, authority, and accountability.

6.4 Uncertainty dimensions

- Measurement: instrument, coding, operational definition, or observer limitations.
- Sampling: representativeness and sampling variation.
- Model: structure, assumptions, priors, parameters, omitted mechanisms.
- Analytical: preprocessing, specification, researcher choices, or computational environment.
- Contextual: transfer to other populations, settings, times, or systems.
- Interpretive: ambiguity in qualitative, historical, theoretical, or formal interpretation.
- Evidence-base: publication bias, missing studies, selective reporting, inaccessible evidence.
- Implementation: performance under real-world operating conditions.

A numerical confidence score **MUST NOT** be used as a universal substitute for explanation. If a rating scale is used, its criteria, unit of assessment, assessor, and limitations must be defined.

7. Claim maturity model

Maturity is a property of a particular claim, in a specified scope, at a particular time. It is not a ranking of a researcher, discipline, project, or publication. Maturity can move backward, branch, or be withdrawn.



Level	Name	Minimum basis	Communication limit
M0	Opportunity / question	A problem or question is identified; no explanatory claim is established.	Question only
M1	Preliminary observation	An observation is recorded with context, but artifact and uncertainty concerns may remain.	Preliminary observation
M2	Plausible hypothesis / model	An explanation/model is articulated with assumptions and alternatives.	Proposed explanation
M3	Initial evidence-supported finding	Relevant evidence and a fit-for-purpose analysis or argument support a defined claim.	Supported in this study
M4	Robust within studied context	Meaningful robustness checks, triangulation, or independent analysis support stability within scope.	Robust within studied context
M5	Independently corroborated	Independent data, investigators, methods, settings, or sources meaningfully corroborate the claim.	Independently corroborated
M6	Generalized or externally validated	Evidence supports extension to specified additional contexts.	Validated in named contexts
M7	Application validated for defined purpose	The system/intervention meets specified performance, safety, and operational criteria for a defined use.	Validated for defined use

7.1 Maturity profile dimensions

Dimension	Question
Evidence adequacy	Is evidence relevant, direct, sufficient, and of appropriate quality?
Methodological robustness	Does the result survive reasonable analytic challenges?
Independence	Are sources, data, teams, methods, or source chains meaningfully independent?
External validity	Does the claim hold in additional specified contexts?
Explanatory depth	Is a mechanism established, or only a pattern observed?
Reproducibility/traceability	Can steps be inspected, rerun, or reconstructed where meaningful?
Application readiness	Is the result fit for the intended use?
Ethical/social readiness	Are impacts, consent, equity, misuse, and governance addressed?

7.2 Promotion and demotion rules

- Promotion requires evidence or review meeting explicit criteria; publication, citations, popularity, or elapsed time alone are insufficient.
- Demotion is appropriate when new evidence, reanalysis, criticism, or correction weakens support.
- Split broad claims when their subclaims have materially different evidence profiles.
- Qualify a claim when its defensible scope narrows.
- Withdraw a claim when it is no longer defensible; preserve history and link the reason.
- Validation records MUST identify the exact claim version assessed.

8. Change control, corrections, and auditability

8.1 Material changes

A material change includes a change likely to affect inference, interpretation, reproducibility, risk, or claim scope: outcome definitions, exclusions, sampling, stopping rules, transformations, model structure, priors, analysis methods, or claim wording. Record who changed what, when, why, which artifacts were affected, and whether the change preceded or followed access to relevant results.

8.2 Exploratory versus confirmatory

Post hoc analyses can be valuable discoveries. They **MUST NOT** be relabelled as prospectively specified merely because they produce a coherent result. When the distinction affects interpretation, mark analyses as confirmatory, exploratory, sensitivity, or post hoc, and disclose the decision path.

8.3 Correction propagation

- Record the new evidence, error, challenge, or retraction trigger.
- Identify claims and artifacts directly affected.
- Traverse dependencies to identify reports, decisions, applications, and downstream claims that may rely on them.
- Assign an impact reviewer and decision deadline proportional to consequence.
- Update status, maturity, limitations, and communication records where warranted.
- Preserve prior versions and publish a correction or withdrawal notice when required.

9. Governance and risk proportionality

Tier	Typical context	Controls to consider
Tier 1	Exploratory, low immediate consequence	Basic provenance, method record, preliminary status.
Tier 2	Material scientific claim influencing follow-on work or practice	Formal protocol, claim ledger, independent methods review, robustness checks.
Tier 3	Health, safety, environment, major policy, or significant investment implications	Stronger independent review, explicit risk assessment, validation plan, preregistration where appropriate.
Tier 4	Potential severe harm, irreversible effects, sensitive data, or dual-use risk	Specialist governance, enhanced testing, controlled access/release where justified, staged deployment, monitoring, stop authority.

Risk tiers are contextual and must be revisited as the work changes. They do not replace applicable law, institutional review, or domain-specific standards.

10. Implementation requirements

10.1 Required validation layers

Layer	Required checks	Failure response
L0: Parse	Valid JSON text and encoding.	Reject malformed document.
L1: Schema	Validate against Draft 2020-12 schema.	Return field-level validation errors.
L2: Referential	Resolve IDs, types, versions, permissions, and dependency links.	Flag broken, inaccessible, or incompatible references.
L3: Semantic	Validate conditional requirements and cross-record consistency.	Block transition or request review.
L4: Workflow	Validate current state, event, transition, gate record, and invariants.	Reject illegal transition and preserve attempted event.
L5: Scientific review	Assess evidence, design, inference, uncertainty, and limitations.	Record expert decision; do not substitute automated field checks.
L6: Application assurance	Evaluate performance, safety, transfer, monitoring, and stop criteria.	Restrict use or require additional validation.

10.2 Automation boundaries

- Automation **MAY** enforce required fields, enumerations, unique IDs, and state-transition rules.
- Automation **MAY** flag missing claim-evidence links, stale artifact versions, unresolved conditions, and unreviewed material changes.
- Automation **MAY** generate reports from structured records, provided source links and versions remain visible.
- Automation **MUST NOT** infer truth from a valid schema, complete form, passed gate, or maturity label.
- AI-assisted work **SHOULD** record tools and versions where known, tasks performed, relevant prompts/configurations, source artifacts, and human verification.
- Human review **MUST** be available for ambiguous evidence, exceptions, contested interpretation, and consequential decisions.

10.3 Security, privacy, and responsible openness

- Apply access controls to sensitive records and separately record the reason for restrictions.
- Do not publish personal, confidential, hazardous, or dual-use information merely to maximize openness.
- Preserve enough metadata for audit without exposing protected content.
- Use hashes to support integrity checks where useful, but do not treat hashes as evidence of truth or quality.
- Define retention, backup, export, correction, and access-revocation procedures.

11. Conformance classes

Class	Minimum requirements	Explicit non-claim
C0: Parseable	JSON records parse.	No schema or workflow conformance implied.
C1: Structurally valid	Records validate against the published JSON Schema dialect/profile.	No cross-record consistency or scientific adequacy implied.
C2: Semantically consistent	Reference resolution, conditional rules, and controlled vocabularies are enforced.	No scientific truth implied.
C3: Workflow conformant	Transitions and invariants are enforced; gate/event logs preserved.	No proof that gate criteria are scientifically sufficient.
C4: Traceable/auditable	Claims link to versioned evidence, methods, analyses, counterevidence, and provenance; change history preserved.	No guarantee that records are complete or honest.
C5: Purpose-validated	Purpose-specific external validation, risk controls, monitoring, and stop rules are evidenced.	No universal transfer or safety claim beyond tested scope.

12. Conformance test suite

The companion conformance test file defines 12 starter cases. An implementation **SHOULD** add positive and negative tests for every schema definition, each transition, each invariant, reference failures, access-control behavior, version migration, and correction propagation.

ID	Test	Expected outcome
CT-001	Valid claim record	PASS
CT-002	Claim without scope	FAIL
CT-003	Invalid gate outcome	FAIL
CT-004	Conditional gate without conditions	FAIL
CT-005	Pass without gate record	FAIL
CT-006	Claim maturity promoted by stage completion alone	FAIL
CT-007	Material analysis change after result access	REVIEW_REQUIRED
CT-008	Contradictory evidence added	REVIEW_REQUIRED
CT-009	Withdrawn claim remains in history	PASS
CT-010	Independent replication is not actually independent	REVIEW_REQUIRED
CT-011	Open data conflicts with privacy obligations	REVIEW_REQUIRED
CT-012	Valid JSON but invalid transition	FAIL

13. Migration from Version 2.0

15. Retain the Version 2.0 model as an immutable historical artifact.
16. Assign persistent IDs and explicit versions to projects, stages, claims, evidence, and decisions.
17. Add record_type discriminators and validate records with the Version 2.1 schema.
18. Map existing stage descriptions to the ten stage contracts without assuming every legacy record has all new fields.
19. Create provenance events for transformations where history is known; mark unknown provenance honestly rather than inventing it.
20. Review maturity assignments; do not automatically promote claims based on their old labels.
21. Run conformance tests and document unsupported fields, mapping losses, and unresolved references.
22. Publish a migration report and retain links from new records to source versions.

14. Worked example: soil water-retention claim

Illustrative only: the example shows record structure, not evidence for any specific agricultural practice.

Element	Example
Question	Under specified soil, weather, and management conditions, does practice P increase measured water retention relative to comparator K?
Protocol	Versioned plot/observational design, outcome definition, sampling plan, confounder strategy, analysis plan.
Evidence	Raw sensor/field records, calibration notes, weather data, metadata, treatment records.
Analysis	Versioned code, inputs, model assumptions, diagnostics, effect estimate, uncertainty, sensitivity checks.
Claim	Under conditions C, practice P increased measured water retention relative to comparator K.
Counterevidence	Null or opposite effects at another site; sensor error; weather imbalance; missingness; alternative mechanism.
Maturity	M3 only if the single study provides appropriate support; higher levels require additional robustness or independent evidence.
Next validation	Independent site/season, alternate measurement method, or prospectively specified replication.

15. Evaluation and anti-gaming

Dimension	Example measures	Guardrail
Traceability	Major claims with evidence links; provenance completeness.	More links do not mean truer claims.
Process reliability	Gate records complete; overdue conditions; deviations recorded.	Do not reward paperwork volume alone.
Method quality	Independent review findings; suitable robustness checks.	Do not impose one checklist on every research mode.
Reproducibility	Successful reruns/reconstruction where meaningful.	A rerun is not the same as independent replication.
Correction responsiveness	Time to assess credible challenges and update dependencies.	Do not punish honest correction.
Learning efficiency	Time from anomaly to discriminating test; unresolved uncertainty reduced.	Speed must not override rigor.
Impact	Usefulness or outcomes evaluated in context.	Citations/popularity are not truth proxies.

- Do not reward positive results or high maturity labels alone.
- Recognize null, negative, inconclusive, replication, and correction work.
- Audit samples of claim-evidence links rather than relying solely on self-report.
- Record justified exceptions and keep them reviewable.
- Display maturity with scope, evidence summary, and assessment date.

16. Rollout and governance of the specification

Phase	Work	Exit evidence
0. Expert review	Cross-disciplinary review of terminology, contracts, schema, transitions, maturity, and risks.	Issue log and scope agreement.
1. Schema/tool tests	Validate schema with independent Draft 2020-12 implementations; test positive/negative records.	Reproducible test report.
2. Tabletop exercises	Simulate contradictory results, protocol changes, null results, retractions, and stopped projects.	No unrepresented critical transitions; documented exceptions.
3. Multidisciplinary pilot	Apply to different research modes and assess burden and utility.	Pilot findings and revision proposal.
4. Interoperability	Define PROV mapping, identifier policy, export format, and version migration.	Mapping tests and round-trip examples.
5. Release review	Review unresolved issues, normative wording, and implementation guidance.	Versioned release with change log and limitations.

17. Known limitations and open decisions

- The schema is a proposed profile; production publication needs a controlled namespace and stable release URL.
- Cross-record constraints and state transitions cannot be fully enforced by JSON Schema alone.
- The current schema defines common record shapes, not a complete ontology or database design.
- The PROV mapping is recommended but not fully formalized in this version.
- The conformance tests are starter cases and require executable test fixtures and implementation runs.
- Discipline-specific evidence appraisal, reporting, and ethics requirements must be layered on.
- Version 2.1 has not yet been validated through a multidisciplinary pilot.

18. Selected standards and guidance

- JSON Schema, Draft 2020-12: <https://json-schema.org/draft/2020-12>
- JSON Schema specification overview: <https://json-schema.org/specification>
- W3C PROV Overview: <https://www.w3.org/TR/prov-overview/>
- W3C PROV Primer: <https://www.w3.org/TR/prov-primer/>
- W3C SHACL Recommendation (relevant if a future provenance representation uses RDF graphs): <https://www.w3.org/TR/shacl/>
- National Academies, Reproducibility and Replicability in Science (2019): <https://doi.org/10.17226/25303>
- FAIR Guiding Principles: <https://doi.org/10.1038/sdata.2016.18>
- EQUATOR Network reporting guidelines: <https://www.equator-network.org/>

Appendix A. Minimum release checklist

- Schema declares Draft 2020-12 and has a stable \$id.
- Schema passes meta-schema validation in at least one conforming validator; ideally test multiple implementations.
- Positive and negative fixtures cover each record type and key conditional rule.
- Transition engine enforces all invariants and preserves failed transition attempts.
- Cross-record reference checks and version checks are implemented.
- Provenance mapping is documented separately and tested if interoperability is claimed.
- Claim maturity cannot be promoted by workflow completion alone.
- Corrections and withdrawals preserve history and trigger impact assessment.
- Privacy, access, retention, export, and backup behaviors are documented.
- Limitations, known non-conformances, and version history are published.

Appendix B. Artifact inventory

Artifact	Purpose
Scientific_Discovery_Process_v2.1_model.json	Ten-stage process, controlled vocabularies, principles, maturity levels.
Scientific_Discovery_Process_v2.1_schema.json	JSON Schema Draft 2020-12 profile for project, gate, claim, evidence, validation, and provenance records.
Scientific_Discovery_Process_v2.1_transition_rules.json	Custom transition rules and invariants.
Scientific_Discovery_Process_v2.1_conformance_tests.json	Starter conformance test catalog.

Appendix C. Version history

Version	Summary
2.0	Operational ten-stage workflow, evidence/provenance concepts, claim ledger, maturity model, governance and rollout plan.
2.1.0	Adds explicit standards architecture, JSON Schema Draft 2020-12 profile, state-transition invariants, semantic validation layers, starter conformance tests, migration guidance, and clearer separation between process compliance and scientific truth.

End of specification.