

WAYS OF KNOWING

Children's Edition

Twenty-four ways to ask, check and think

Juan Segurola

Version v1.0 · 22 September 2026

© 2026 Juan Segurola. All Rights Reserved.

How to read this volume

This edition is designed for guided reading. Every chapter has a big idea, something we can check, something we should not guess, a small activity and a science habit: separate what we observe from what we infer.

Contents

KNO	Chapter	Page
KNO-001	A Mark on a Stone	4
KNO-002	Counting Before Numbers	5
KNO-003	From Marks to Symbols	6
KNO-004	From Symbols to Writing	7
KNO-005	Oral Language and Transmission	8
KNO-006	Maps and Spatial Representation	9
KNO-007	Calendars and Time Measurement	10
KNO-008	Instruments That Extend the Senses	11
KNO-009	Archives, Libraries and Collective Memory	12
KNO-010	Classification as a Knowledge Tool	13
KNO-011	Measuring Before Theorising	14
KNO-012	Experiments and Variable Control	15
KNO-013	Models, Maps and Reality	16
KNO-014	Causality and Correlation	17
KNO-015	Uncertainty and Probability	18
KNO-016	How Evidence Is Built: Putting the Tools Together	19
KNO-017	Is Mathematics a Language?	20
KNO-018	Images, Diagrams and Visualisation	21
KNO-019	Data, Tables and Records	22
KNO-020	Review, Consensus and Disagreement	23

KNO	Chapter	Page
KNO-021	Open Science and Reproducibility	24
KNO-022	Computation as External Memory	25
KNO-023	How Groups Know More Than Individuals	26
KNO-024	Lost Knowledge and Preservation Bias	27

KNO-001 · A Mark on a Stone

Big idea

A mark can last for a very long time, but we should not guess what it meant without more evidence.

What can we check?

Microscopy, chemistry, experiments and context can establish that many ancient marks were deliberately produced and can often reconstruct tools, gestures and sequence. Cognitive experiments show that external states can redistribute memory and comparison.

What should we not guess?

For most early objects, we do not know what a mark meant, whether anyone revisited it, whether its rule was shared, or whether its units were numerical. We also cannot measure the vanished record on wood, fibre, skin or temporary surfaces.

Your turn

Look at three marks around you. Which facts can you observe directly, and which meanings would you only be guessing?

Science habit

Ask: **What did we observe? What did we infer? What could prove us wrong?**

KNO-002 · Counting Before Numbers

Big idea

People can notice and compare amounts before they learn exact number words, but exact counting needs shared rules.

What can we check?

Controlled experiments distinguish approximate magnitude, small-set tracking and learned exact-number practices. Developmental studies show that reciting count words precedes full understanding of cardinality.

What should we not guess?

We should not claim more than the evidence can show.

Your turn

Put 7 small objects on a table. Find two different ways to keep track of the exact quantity without saying the word seven.

Science habit

Ask: **What did we observe? What did we infer? What could prove us wrong?**

KNO-003 · From Marks to Symbols

Big idea

A mark becomes a symbol when people share a rule about what the mark stands for.

What can we check?

Developmental studies distinguish an object's physical identity from its representational role and document early joint attention and pointing. Interaction experiments show that feedback and common ground can stabilise novel signs.

What should we not guess?

We should not claim more than the evidence can show.

Your turn

Invent a symbol with a friend. What rule must both of you share for it to work?

Science habit

Ask: **What did we observe? What did we infer? What could prove us wrong?**

KNO-004 · From Symbols to Writing

Big idea

Writing is a special kind of symbol system that can represent language; not every symbol system is writing.

What can we check?

Stratified fourth-millennium material from southwest Asia preserves the only sequence in which tokens, sealed envelopes, impressed numerical tablets and proto-cuneiform can be examined together, though that order is one of first attestation rather than descent. Documented modern inventions establish the pace: the Cherokee syllabary was in use by the early 1820s and received council recognition in 1821, and the Vai syllabary followed within about a decade.

What should we not guess?

We should not claim more than the evidence can show.

Your turn

Try to record a short spoken sentence using only pictures. What parts of the language are hard to represent?

Science habit

Ask: **What did we observe? What did we infer? What could prove us wrong?**

KNO-005 · Oral Language and Transmission

Big idea

Stories and knowledge can travel by speech, but accuracy depends on the rules and practices used to remember them.

What can we check?

Cognitive work on strong traditions establishes that stability comes from many individually weak constraints acting at once — metre, melody, formula, imagery and narrative sequence — which together often leave one option where each alone leaves many. Parry and Lord's fieldwork shows a singer producing the same plot at similar length in substantially different words without treating it as failure.

What should we not guess?

We should not claim more than the evidence can show.

Your turn

Tell a short story to someone, ask them to retell it, and compare what changed.

Science habit

Ask: **What did we observe? What did we infer? What could prove us wrong?**

KNO-006 · Maps and Spatial Representation

Big idea

A map is a useful model of space, and every map keeps some things accurate while distorting others.

What can we check?

- Grid cells are an established finding from single-unit recording in rats (Hafting et al. 2005). O'Keefe and Nadel proposed that the hippocampus supports an allocentric representation (O'Keefe and Nadel 1978).

What should we not guess?

We should not claim more than the evidence can show.

Your turn

Draw a map of your room. Decide what you want to keep accurate: shape, distance, direction or useful landmarks.

Science habit

Ask: **What did we observe? What did we infer? What could prove us wrong?**

KNO-007 · Calendars and Time Measurement

Big idea

Calendars are human solutions to astronomical cycles that do not fit together perfectly.

What can we check?

For epoch 2000 a standard astronomical reference gives a mean tropical year of 365.24219 days and a mean synodic month of 29.53059 days, and stresses that both are approximate means that change slowly. Everything this article derives from them is its own arithmetic, marked as such: twelve synodic months fall 10.87511 days short of a year, and nineteen tropical years differ from 235 synodic months by 0.08704 days.

What should we not guess?

We should not claim more than the evidence can show.

Your turn

Track the Moon for a week. Notice how a repeating cycle can be used to organise time.

Science habit

Ask: **What did we observe? What did we infer? What could prove us wrong?**

KNO-008 · Instruments That Extend the Senses

Big idea

Scientific instruments turn things we cannot sense directly into signals we can measure and check.

What can we check?

Experts at Bologna reported seeing little or nothing through Galileo's telescope in April 1610, the Collegio Romano withheld confirmation until October, and credibility was established by independent replication; the source for this was read only as far as its accessible pages go. The circularity of validating a measuring instrument without the law that justifies it is called the problem of nomic measurement and is attributed to a 2004 study of thermometry, which argues the circle was worn away by iterative self correcting refinement rather than broken by decree.

What should we not guess?

We should not claim more than the evidence can show.

Your turn

Choose a thermometer or ruler. Write down the chain from the thing being measured to the number you read.

Science habit

Ask: **What did we observe? What did we infer? What could prove us wrong?**

KNO-009 · Archives, Libraries and Collective Memory

Big idea

Archives and libraries preserve knowledge, but what survives also depends on what people chose to keep.

What can we check?

Appraisal is defined by the professional dictionary as identifying materials offered to an archives that have sufficient value to be accessioned, with the debate behind it framed as what to save and what to destroy. Archival theory has described the archivist moving from passive curator to active appraiser across shifting paradigms.

What should we not guess?

We should not claim more than the evidence can show.

Your turn

Imagine you can save only five objects from today for a museum. What future story would your choices create?

Science habit

Ask: **What did we observe? What did we infer? What could prove us wrong?**

KNO-010 · Classification as a Knowledge Tool

Big idea

Classifications put things into groups for a purpose, so the groups are tools rather than perfect copies of nature.

What can we check?

Bowker and Star define a classification system as a set of boxes into which things can be put to then do some kind of work, set out three properties an ideal classification would have, and report that none of the working systems they examined satisfies all three. They observe that the residual phrase runs throughout the ICD but never as a top-level category, and they name torque for the mutual twisting of a biography and a process of metrication.

What should we not guess?

We should not claim more than the evidence can show.

Your turn

Sort ten objects in two different ways. How does the purpose change the categories?

Science habit

Ask: **What did we observe? What did we infer? What could prove us wrong?**

KNO-011 · Measuring Before Theorising

Big idea

Scientists often learn how to measure something before they fully understand why the measurements behave as they do.

What can we check?

The permissive definition takes measurement to be the assignment of numerals to objects or events according to rules, and separates four scale types by the empirical operation each supports. The restrictive objection is that under such a view any rule at all already defines a nominal scale, so whether the attribute is quantitative is never put to test.

What should we not guess?

We should not claim more than the evidence can show.

Your turn

Measure the same object several times. What stays stable and what changes?

Science habit

Ask: **What did we observe? What did we infer? What could prove us wrong?**

KNO-012 · Experiments and Variable Control

Big idea

A good experiment creates a fair comparison and makes the reason for the comparison as clear as possible.

What can we check?

Fisher titled section 9 of *The Design of Experiments* Randomisation; the Physical Basis of the Validity of the Test, and argued there that the simple precaution of randomisation suffices to guarantee the validity of the test of significance. That is a claim about the validity of a test and not about the balance of any particular experiment, and the surrounding context also makes clear that validity is not a claim that randomisation removes every other avoidable source of error.

What should we not guess?

We should not claim more than the evidence can show.

Your turn

Design a fair test with two groups. Change one planned factor and keep the comparison as clear as possible.

Science habit

Ask: **What did we observe? What did we infer? What could prove us wrong?**

KNO-013 · Models, Maps and Reality

Big idea

A model is a simplified representation built for a job; it is useful because it leaves some things out.

What can we check?

The reference formulation states that many scientific models are representational and stand in for a selected part or aspect of the world, and that idealised models involve a deliberate simplification or distortion aimed at tractability. Cartwright is reported, from the publisher's description of the book rather than from its argument, as holding that fundamental explanatory laws do not describe regularities in nature while localised laws and theoretical entities may still be read realistically.

What should we not guess?

We should not claim more than the evidence can show.

Your turn

Make a simple model of something familiar. List one useful simplification and one thing the model cannot answer.

Science habit

Ask: **What did we observe? What did we infer? What could prove us wrong?**

KNO-014 · Causality and Correlation

Big idea

Two things moving together does not prove that one causes the other; causal claims need design and assumptions.

What can we check?

Association and causal effect are distinct targets. Randomisation, causal diagrams, potential outcomes, negative controls, instrumental variables and target-trial emulation each make different parts of the causal problem inspectable.

What should we not guess?

Observed data cannot by themselves establish causal direction, the absence of unmeasured confounding, a valid exclusion restriction or the correctness of an assumed causal graph. Those questions require external knowledge, design information and tests whose scope is itself limited.

Your turn

Think of two things that often happen together. List at least two possible explanations besides direct causation.

Science habit

Ask: **What did we observe? What did we infer? What could prove us wrong?**

KNO-015 · Uncertainty and Probability

Big idea

Uncertainty has different sources, so scientists must say what kind of uncertainty they are measuring and what remains unknown.

What can we check?

Uncertainty can arise from measurement, sampling, parameters, prediction, model structure and judgement, and these sources are not interchangeable. Statistical intervals and probabilities have meanings fixed by their inferential framework, while sensitivity analysis exposes dependence on assumptions.

What should we not guess?

No finite interval automatically contains every relevant unknown. Structural omissions, unmodelled mechanisms and genuinely unforeseen possibilities can remain outside a probability model even when the arithmetic inside that model is correct.

Your turn

Repeat a measurement and write down what could make the result uncertain.

Science habit

Ask: **What did we observe? What did we infer? What could prove us wrong?**

KNO-016 · How Evidence Is Built: Putting the Tools Together

Big idea

Evidence is strongest when we can follow the chain from observation to claim and inspect the assumptions in between.

What can we check?

Evidence is built by linking precise claims to observations through measurement, design, models and inferential assumptions. Replication, reproducibility, triangulation, directness and transparency strengthen different links, especially when their failure modes are not shared.

What should we not guess?

No audit can guarantee that every relevant alternative has been imagined, that every source of bias is independent or that a well-supported model is the only possible explanation. Evidence can therefore become stronger without becoming logically final.

Your turn

Take one claim from a news story and draw a chain: claim → evidence → method → assumptions.

Science habit

Ask: **What did we observe? What did we infer? What could prove us wrong?**

KNO-017 · Is Mathematics a Language?

Big idea

Mathematics uses formal languages, but mathematical thinking includes more than symbols and formulas.

What can we check?

Mathematics uses formal languages with syntax and interpretation, and notation can make reasoning more inspectable and computationally tractable. Proof, meaning, modelling and explanation nevertheless depend on practices and interpretations that are not exhausted by symbol strings.

What should we not guess?

The language analogy does not settle philosophical questions about what mathematics is, why mathematical structures apply so effectively in science or whether mathematical entities are discovered, invented or described in some other way.

Your turn

Explain a mathematical idea once with symbols and once with words or a picture. What changes?

Science habit

Ask: **What did we observe? What did we infer? What could prove us wrong?**

KNO-018 · Images, Diagrams and Visualisation

Big idea

A picture or graph can reveal patterns, but it is trustworthy only when we can understand how it was made from the data.

What can we check?

Visual representations transform data into spatial and perceptual encodings. Those choices affect what patterns are easy to detect, how accurately quantities are decoded and which aspects of acquisition or processing remain visible to the reader.

What should we not guess?

No single visual encoding is optimal for every task, audience or dataset, and an attractive or reproducible rendering does not establish the correctness of the scientific interpretation. Important structure can remain hidden outside the chosen view.

Your turn

Draw the same small dataset in two different graph types. Which pattern becomes easier or harder to see?

Science habit

Ask: **What did we observe? What did we infer? What could prove us wrong?**

KNO-019 · Data, Tables and Records

Big idea

Data stay useful only when we preserve what the values mean, where they came from and how they changed.

What can we check?

We know that explicit tabular organization can make variables and observations easier to analyse , that spreadsheet conventions can reduce avoidable ambiguity and mixing of raw and derived content , that provenance can represent entities, activities and agents involved in producing data , and that data citation requires specificity sufficient to identify the object or version being cited . NIST RDaF Version 2.0 explicitly treats metadata, provenance, versioning, instruments, processing operations and reproducibility as parts of research-data management .

What should we not guess?

We should not claim more than the evidence can show.

Your turn

Create a tiny table and add notes explaining units, date, source and any changes you make.

Science habit

Ask: **What did we observe? What did we infer? What could prove us wrong?**

KNO-020 · Review, Consensus and Disagreement

Big idea

Review and consensus help organise criticism, but they do not replace the evidence itself.

What can we check?

- Structured peer review can expose problems before publication, but reviewer judgments vary and are not certificates of truth. - Editorial decisions can incorporate conflicting reviewer advice rather than simply count votes. - Reproducibility and replicability extend scrutiny beyond publication and can strengthen, qualify or challenge claims. - Formal scientific consensus processes can combine evidence review, expert deliberation and independent review. - Corrections can preserve an auditable record of errors found after publication.

What should we not guess?

We should not claim more than the evidence can show.

Your turn

Take a disagreement and list what evidence could actually discriminate between the competing explanations.

Science habit

Ask: **What did we observe? What did we infer? What could prove us wrong?**

KNO-021 · Open Science and Reproducibility

Big idea

Open science makes more of the path from evidence to claim visible so other people can inspect and correct it.

What can we check?

- Reproducibility and replicability test different kinds of consistency and should not be treated as synonyms. - Preregistration can make the timing of hypotheses and analysis choices visible. - Open data, code and provenance can make more of an analysis inspectable, but access without context is insufficient. - Versioning and visible corrections preserve which scientific object a claim refers to.

What should we not guess?

- How much each open-science intervention improves reliability across different disciplines and study designs. - Which combinations of openness and controlled access best preserve both auditability and legitimate privacy. - How long contemporary research objects remain executable as software and hardware ecosystems change. - How incentive systems alter the real use, rather than nominal adoption, of open practices.

Your turn

Imagine another person must reproduce your school experiment. What files, notes or steps would they need?

Science habit

Ask: **What did we observe? What did we infer? What could prove us wrong?**

KNO-022 · Computation as External Memory

Big idea

Computers can remember and repeat procedures for us, but they can also preserve mistakes unless we keep context and checks.

What can we check?

- People use external representations and actions to reduce internal cognitive demand. - External representations can change the structure and cost of reasoning, not only storage requirements. - Expectations of external access can affect what people remember about information and its location. - Executable code can preserve procedures with greater operational specificity than prose alone.

What should we not guess?

- How different forms of cognitive offloading reshape long-term learning rather than immediate task performance. - Which computational dependencies are necessary to preserve for century-scale executability. - How much automation changes users' ability to detect conceptual rather than implementation errors. - Where responsibility should sit in highly distributed human-computer workflows.

Your turn

Write a short set of instructions a computer could repeat exactly. Where could an unnoticed mistake be repeated too?

Science habit

Ask: **What did we observe? What did we infer? What could prove us wrong?**

KNO-023 · How Groups Know More Than Individuals

Big idea

Groups can know more than individuals when they combine different information without losing independence to conformity.

What can we check?

- Groups can outperform their best members on some structured intellectual tasks. - Diverse problem-solving heuristics can improve group search under specified model assumptions. - Social influence can reduce diversity of estimates and undermine some wisdom-of-crowds benefits. - Interaction patterns such as conversational turn-taking are associated with collective performance in laboratory groups.

What should we not guess?

- How well laboratory measures of collective intelligence generalize to long-lived institutions and high-stakes expert teams. - Which diversity dimensions matter for which kinds of scientific and engineering problems. - How to weight expertise without suppressing informative minority evidence. - How digital communication and AI mediation change independence, conformity and information pooling in human groups.

Your turn

Ask several people to estimate something independently before they discuss it. Compare the individual and group answers.

Science habit

Ask: **What did we observe? What did we infer? What could prove us wrong?**

KNO-024 · Lost Knowledge and Preservation Bias

Big idea

What survives from the past is only a filtered sample, so an absence in the record is not automatically proof that something never existed.

What can we check?

- Archaeological records are shaped by formation processes between use and recovery. - Bone weathering and other taphonomic processes affect which biological traces survive and how they are interpreted. - Archives embody decisions about creation, appraisal, description and access rather than functioning as neutral containers. - Research datasets can become unavailable over time when preservation depends on individual custodians.

What should we not guess?

- How much undocumented material has already been lost from contemporary digital research ecosystems. - How preservation probabilities vary across underrepresented communities and informal record-keeping systems. - Which digital preservation strategies will remain interpretable over century-scale technological change. - How best to quantify preservation bias when creation, loss and discovery probabilities are all uncertain.

Your turn

List three reasons why an object or record from the past might disappear before anyone can study it.

Science habit

Ask: **What did we observe? What did we infer? What could prove us wrong?**