Cultivating

STEM Habits

G Nagarjuna in a dialogue with Bhas Bapat

Gnowledge Lab • HBCSE, TIFR • IISER Pune • Living Academy

metaStudio.org • gnowledge.org

"What makes scientific temper possible?"

Not methodology — observations, hypothesis, experiment, conclusion

But

habits — concrete, daily, cultivable practices

Science is Mediated Knowledge

1. Scientific knowledge doesn't live in the head alone
2. It lives in the interplay between the us, our bodies and its mediating artifacts
3. Notebooks, diagrams, instruments, terminology, publications, feedback loops
4. Every STEM habit is a habit of engaging with a mediating artifact
5. Science is not read — it is done, done as a practice

Act 1: The Habit of Recording

Michael Faraday (1791–1867)

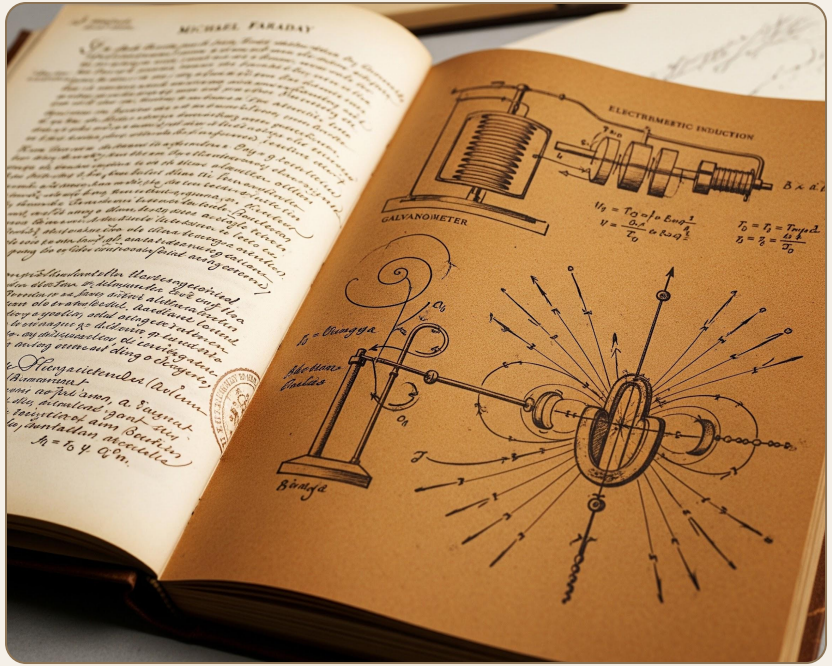
Faraday's Notebooks

The Practice

- A bookbinder's apprentice — no formal scientific education
- Over 16,000 numbered paragraphs across decades of notebooks
- Recorded observations, failed attempts, half-formed ideas, sketches

The Philosophy

- Notebooks were not reports — they were the workspace where thinking happened
- Drew his apparatus, field lines, and experimental setups meticulously
- The discipline of externalizing thinking so it becomes reviewable and correctable



"A thought you don't write down is a thought you can't scrutinize."

🛠 Tools for Recording & Journaling

nodeBook — Collaborative Knowledge Journaling

- nodeBook — A fork of HedgeDoc for structured journaling — write in markdown, build knowledge graphs inline using Controlled Natural Language (CNL) (nodebook.co.in)
- — Consolidates concept mapping, process mapping (Petri nets), inference, and collaborative editing in one open-source tool

Other Digital Lab Notebooks

- Joplin — Open-source note-taking with markdown, tagging, and notebooks (joplinapp.org)
- Logseq — Outliner with daily journals and bidirectional linking (logseq.com)
- Jupyter Notebooks — Combine code, notes, and results in one reproducible document (jupyter.org)

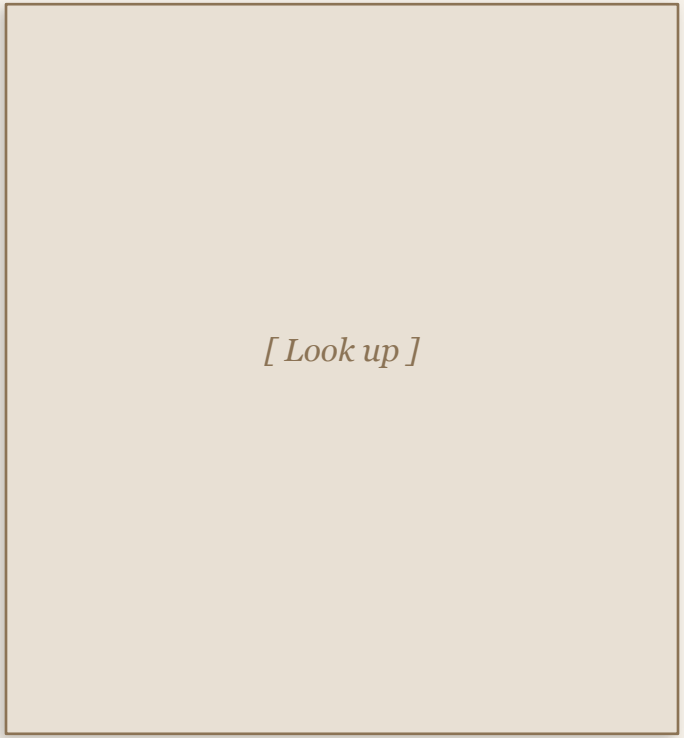
Collaborative Platforms

- metaStudio.org / chatShaala — Students blog about experiments, maintain ongoing records of investigations

Act 2: The Habit of Drawing

Robert Hooke (1635–1703)

Hooke's Micrographia (1665)



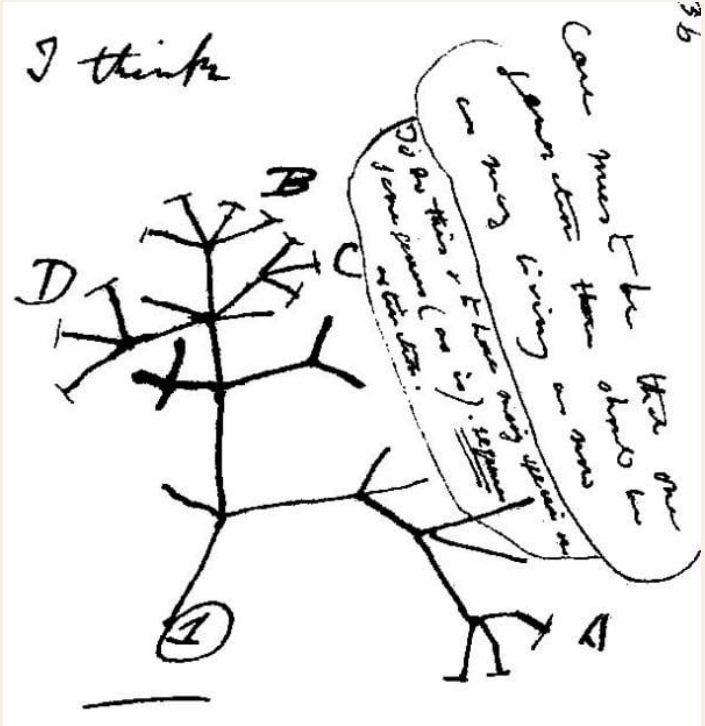
- Hooke looked through a microscope and drew what he saw
- The illustrations were the evidence — not decorations for text
- Without the drawing, the observation dies with the observer
- Drawing forces precise observation: you must look carefully to draw accurately
- Coined the word 'cell' — the drawing led to the concept
- The diagram is not decoration — it is discovery

Act 3: Thinking Through Sketching

Charles Darwin (1809–1882)

Darwin's "I Think" Tree

- Notebook B, 1837: Darwin sketches a branching tree with 'I think' scrawled above
- He didn't arrive at the idea and then illustrate it — the sketch was the moment of arrival
- Journaling + Diagramming + Precise language = Insight
- Three habits converging in a single notebook page
- Darwin kept multiple notebooks organized by topic, and returned to cross-reference them



🛠 Tools for Drawing, Diagramming & Graphicacy

nodeBook — Knowledge Graphs in Markdown

- nodeBook — Renders Controlled Natural Language as interactive knowledge graphs (Cytoscape.js) — concept maps, Petri net process models, inference chains, all inline in markdown (nodebook.co.in)

Dynamic Mathematics & Data

- GeoGebra — Free dynamic math software — visualize, model, explore (geogebra.org)
- netlogo — ultimate modeling platform for simple to comlex systems (netlogo.org)

Drawing & Diagramming

- Turtle Blocks / TurtleArt — Create visual representations through programming
- draw.io / diagrams.net — Flowcharts, concept maps, system diagrams (diagrams.net)
- Inkscape — Vector graphics for precise scientific figures (inkscape.org)

Act 4: The Habit of Building

Boyle, Bose, Raman

Building Instruments, Building Understanding

Robert Boyle

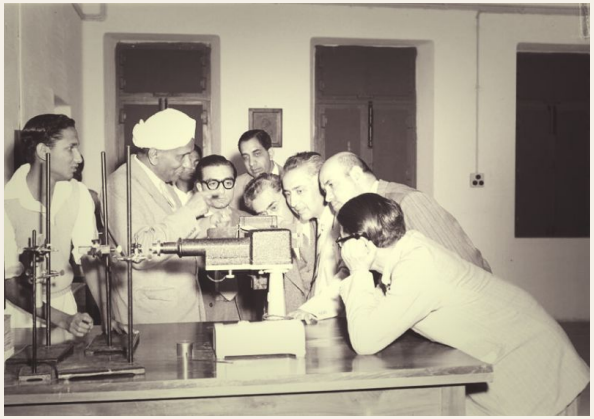
(1627–1691)

Built the air pump with Hooke. Published detailed engravings so others could replicate. The instrument made the invisible (vacuum) visible.

J.C. Bose

(1858–1937)

Invented the crescograph to measure plant growth. Built his own microwave apparatus. Instruments were extensions of the investigator's senses.



C.V. Raman

(1888–1970)

Nobel Prize with modest equipment. Asked 'Why is the sea blue?' and built experiments to answer it. Frugal innovation in practice.

🛠 Tools for Building & Tinkering

Open Hardware

- expEYES — Open-source pocket science lab — oscilloscope, function generator, datalogger (expeyes.in)
- Arduino — Open-source electronics platform for building instruments (arduino.cc)

Fabrication & Design

- FreeCAD — 3D parametric modeler for designing lab instruments (freecad.org)
- KiCad — Open-source electronics design automation (kicad.org)
- MakerSpace chatShaala — Community for making and tinkering projects

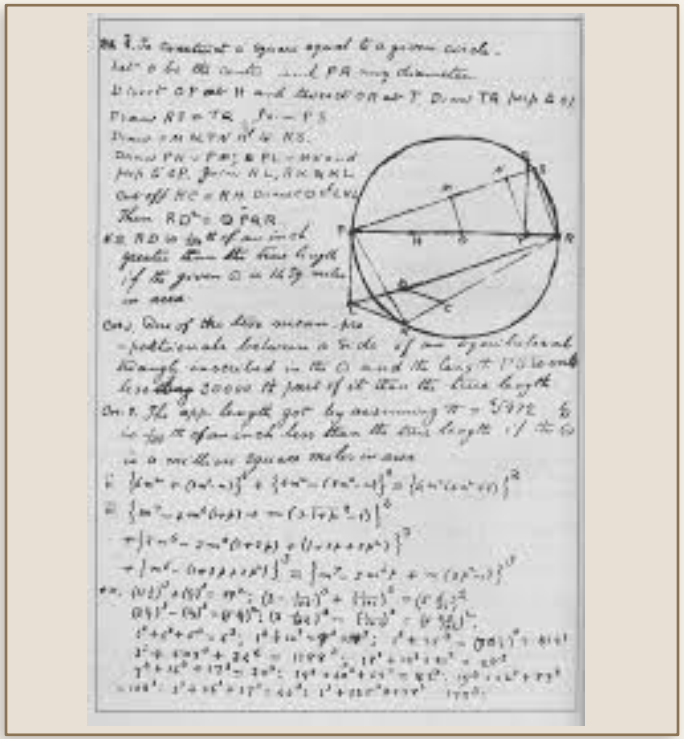
Programming

- Python + SciPy — Free scientific computing stack (scipy.org)
- GNU Octave — Numerical computing, MATLAB-compatible (octave.org)

Act 5: Habits Close to Home

Ramanujan (1887–1920)

Ramanujan's Notebooks



- Developed extraordinary mathematics through the sheer habit of writing things down
- Worked through ideas on paper, often in isolation, with minimal resources
- His notebooks — not formal papers — were the primary artifacts of his thinking
- Three notebooks containing nearly 3,900 results, many still being studied today
- The habit of recording was the habit that made everything else possible
- Proof that you don't need a well-funded lab — you need the practice

Act 6: The Habit of Sharing

The Royal Society & Beyond

Making Knowledge Public

1665 — Philosophical Transactions — the first scientific journal. Knowledge becomes cumulative.

1991 — arXiv — preprints shared freely before formal peer review.

2001 — Wikipedia & Creative Commons — open knowledge as a movement.

Today — metaStudio.org — students share investigations openly; CUBE participants blog daily.

An idea that stays in your head cannot be tested, challenged, refined, or built upon.

🛠 Tools for Sharing, Publication & Collaboration

Collaborative Knowledge Platforms

- nodeBook — Real-time collaborative markdown with inline knowledge graphs — share structured thinking, not just text (nodebook.co.in)
- metaStudio.org — chatShaala for lifelong STEM education — blog, wiki, badges (metaStudio.org)
- Discourse — Open-source civilized discussion platform (powers metaStudio) (discourse.org)

Publishing & Writing

- Open Journal Systems (OJS) — Journal management and publishing (pkp.sfu.ca)
- Etherpad — Real-time collaborative text editor (etherpad.org)
- LaTeX / Overleaf — Precise scientific typesetting

Version Control & Collaboration

- Git / GitHub — Track every change, collaborate transparently (github.com)
- Matrix / Element — Decentralized open-source messaging (matrix.org)

Act 7: The Habit of Feedback

From Peer Review to Lab Meetings

Giving and Receiving Feedback

Formal Feedback

- Peer review before publication
- Journal referee reports
- Thesis defense and examination
- Code review in software development
- COOOL STEMGames badge system — referees grant badges when participants display STEM habits

Informal Feedback

- Lab meetings and journal clubs
- Conference Q&A sessions
- Corridor conversations between colleagues
- Online forum discussions (chatShaala)
- The willingness to expose your work before you're certain it's right

What's missing in education: feedback flows one direction — teacher to student. The scientific habit is mutual.

🛠 Tools for Feedback & Annotation

Annotation & Review

- Hypothesis — Open-source web annotation — annotate any text collaboratively (hypothes.is)
- Review Board — Structured peer feedback for documents and code (reviewboard.org)

Badging & Recognition

- COOOL STEMGames Badges — Referees recognize STEM habits: Mathematical, Empirical, Experimental, Design, Social, Communication, Reasoning
- Open Badges (Mozilla) — Portable, verifiable digital badges for skills and achievements

Act 8: The Habit of Precision

Naming, Defining, Clarifying

Precise Terminology

Linnaeus	Binomial nomenclature — one organism, one name, worldwide
SI System	Standardized units so a 'meter' means the same in Mumbai and Munich
Euclid	Begin with definitions and axioms — make your starting assumptions explicit
Berzelius	Chemical notation — H_2O replaces pages of verbal description

The habit: When you use a word, can you define it precisely?
When two people disagree, is it because they actually disagree, or because they're using the same word to mean different things?

nodeBook — Where Habits Converge

A fork of HedgeDoc that consolidates multiple STEM habits in one open-source tool

Journaling in Markdown

Real-time collaborative writing. Notes, observations, hypotheses — all in structured markdown with full version history.

Habit: Recording

Knowledge Graphs (CNL)

Write Controlled Natural Language inside code fences. nodeBook renders interactive concept maps powered by Cytoscape.js — Refined Concept Mapping made digital.

Habit: Drawing + Precision

Process Mapping (Petri Nets)

Model processes, workflows, and experimental protocols as Petri nets. Visualize transitions, states, and dependencies — making reasoning about sequences explicit.

Habit: Building + Precision

Inference & Classification

Typed nodes, weighted relations, transitive inference, Prolog queries, schema validation. Forces you to classify, organize, and reason — not just list.

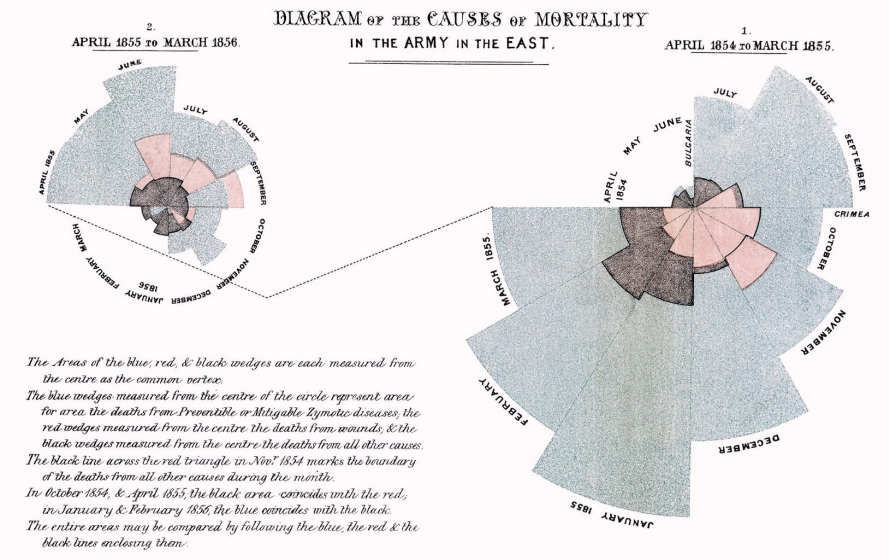
Habit: Precision + Updating

nodebook.co.in • github.com/gnowgi/hedgedoc-nb • Open Source (AGPL-3.0)

Act 9: The Habit of Visualization

Florence Nightingale (1820–1910)

Nightingale's Rose Diagram



- Collected mortality data from the Crimean War
- Invented a new visual form — the polar area diagram — to make the data argue
- Showed that most soldiers died of preventable disease, not battle wounds
- The graphic was so persuasive it changed government policy
- Graphicacy as a civic habit, not just a scientific one
- "Critical Graphicacy" — the poverty of graph skills in school textbooks (Gnowledge Lab research)

The Habits of Science

Recording

Journaling, note-taking, lab notebooks

Drawing

Diagrams, sketches, concept maps

Precision

Defined terms, rigorous language

Building

Instruments, apparatus, prototypes

Sharing

Publication, open discussion

Collaborating

Working across expertise and perspectives

Feedback

Giving and receiving critique

Visualizing

Graphs, data representation, graphicacy

Updating

Comfort with being wrong, revising beliefs

Not methodology, but habits. Not theory, but practice.

What Can You Do Tomorrow?

1. Start a notebook — digital or paper. Try nodebook.co.in to journal in markdown with knowledge graphs.
2. Draw before you explain — sketch a diagram of something you're trying to understand.
3. Define your terms — when you use a word, ask: can I define this precisely?
4. Share something — post an observation, a question, a sketch on metaStudio.org. Make your thinking public.
5. Ask for feedback — show your work to someone and ask: what am I missing?
6. Build something — even a simple instrument extends your ability to observe.

Join us at metaStudio.org • nodebook.co.in • gnowledge.org

Thank You

dhanyavaad / धन्यवाद

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