

# Using Scientists' Notebooks to Foster Authentic Scientific Practices

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**Abstract.** *Scientific Inquiry* is an introductory undergraduate course for preservice elementary teachers that aims to engage students in authentic scientific practices where these practices are not viewed as a mere course requirement but are understood as essential practices for constructing knowledge in the discipline. Many of these practices (e.g., representational practices, control-of-variables) evolve over the course of the semester as we work to answer complex questions. However, we hoped to have students- from the start of the term- keep detailed scientific notebooks. We describe an activity designed to foster practices related to the use of scientific notebooks, detail how we use images from scientists' notebooks, discuss the rubrics students create for their own notebooks, and share outcomes, including images of students' notebooks and students' reactions to the activity. Funding provided by NSF #0837058.

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## WRITING IN SCIENCE, WRITING IN SCIENCE CLASS

“Writing” is often thought of as a generic ability, the teaching of which is accomplished in English departments, rather than a discipline-specific practice that should be explicitly considered by all instructors, regardless of discipline. However, there is increasing recognition, particularly from the English departments that are asked to teach our students how to write, that one does not generically *write*, but one writes *something*: a poem, literary critique, law brief or journal article. Instruction in writing, then, is not something that can be delegated (or relegated) to “English Comp” classes and calls for “writing across the disciplines” are commonly heard across campuses.

When considering the variety of writing media that practitioners use when constructing and sharing ideas in science — e.g., the back-of-the-envelope argument, the chalkboard space where we construct and share ideas, experimentalists' meticulous lab notebooks, the arXiv, journal articles, posters, slides for 10-minute talks—each serves a unique role in constructing and critiquing scientific claims, and instruction in these genres has a natural home in science departments.

Of course, we cannot expect students in introductory science courses to use the arXiv, but we might ask if they have a similar manner in which they share and have access to others' ideas. We would not expect lab notebooks to be the property of the department and stored in the lab after students graduate (as is common in scientific laboratories)—but we might expect that their notebooks serve a function that mirrors the roles that notebooks serve in

scientific practice, rather than the more common role they play in transcribing professors' notes.

However, when we reflect on the kinds of writing that happen in physics courses, most would agree that students' writing—their notebooks, lab reports, problem sets, worksheets and exams—are distinctly *school-like* practices that introduce students to writing genres that are not on a continuum with those present in scientific practice. This may not seem surprising or perhaps even problematic: most physics courses emphasize conceptual development, prepare students for further coursework and examinations, and, since most physics students are not continuing on to physics careers, these courses are not concerned with introducing students to forms of writing that are unique to scientific practice.

And yet, as research calls attention to students' understanding of the nature of science[1], their epistemic beliefs[2], attitudes about learning science[3], and the role that these play in developing scientific content knowledge, it is becoming increasingly clear that developing conceptual understanding may best be achieved through engaging students in authentic scientific practices[4]. So while scientific forms of writing—lab notebooks, journal writing, presentations—are usually attended to during graduate school with an eye towards preparing a select few for scientific work, we should not neglect these practices in undergraduate or non-science major courses. For if one goal of science education is engaging all students in authentic scientific practices as they construct scientific understandings, then this ought to include the range of *writing* practices that students engage in and doing so to address the epistemic functions such media play in the scientific

community. **That is, these forms of writing are not only an outcome of scientific inquiry but a way of performing scientific inquiry.** We do not write solely to demonstrate our scientific ideas, but as a way of *having* scientific ideas.

Our course, *Scientific Inquiry*[5], is designed with this goal in mind: to build a classroom community that constructs knowledge in scientific ways, engaging students in practices that, while not indistinguishable from those of practicing scientists, are on a continuum with such practices. This paper reports on the first activity from our course that introduces students to scientific notebooks, outcomes from that activity, and the notebooks that students then create over the course of a semester. This paper does not represent the conclusion of our research efforts in science writing, but describes our method for introducing a certain type of writing in science, initial results, and directions for future research.

## DEVELOPING A RUBRIC

One of our goals for this course is that the epistemic demands of scientific inquiry, that is, developing explanatory models for physical phenomena that are vetted and agreed on by our classroom community—would necessitate the development of scientific practices. That is, rather than requiring students construct operational definitions as a course requirement, this practice—we hope—would emerge through the need for intersubjectivity in vetting one another’s claims. Careful diagrams and documentation of data would be recognized as necessary for both their persuasive power and role in operationalization of key ideas. In envisioning how practices related to lab notebooks might emerge, we initially imagined many dead-ends as students would initially keep scant notes, and, through relaying their work to others and needing access to others’ findings, realize the need for norms around scientific notebooks.

However, we quickly determined that, in a 15-week semester, we wanted to hasten that process, with students taking careful notes from the start. This presented a challenge: we did not want students to keep notebooks solely to meet a course requirement but because they understood the role the notebook would play. That is, we hoped that notebooks would be primarily used as a meaning-making practice and not a grade-getting practice—students would be “doing science” rather than “doing the lesson”[6]. To accomplish this, we developed the following activity, which we use on the first day of class.

Our claim in this paper is that engaging with authentic images of scientific writing, and using those to set expectations for own classroom practices and assessment of those practices, plays a strong role promoting the authentic inquiry that students’ notebooks ultimately reveal. Though other classroom

practices—whole group discussions, assignments, whiteboards, group investigations—also promote inquiry, the record of ideas that the notebooks hold plays a unique role in creating the narrative backdrop against which experiments and activities are enacted. In addition, the notebooks provide a way for instructors to assess and value work that is not “final form” science, to say “this, too, is a critical piece of scientific practice.”

## Introducing the activity

On the first day, we begin with the syllabus[8] and a brief description of the course as one in which they will construct ideas. (The syllabus notes: “The primary goal for the course is to learn how to *do* science rather than to learn any one particular scientific fact. Along the way, of course, we expect that you will learn a great deal of science, and you will be expected to understand the scientific ideas that are developed in the course.”) We then group students into small groups (3 - 4) and give them a packet of images from notebooks from famous scientists (Fig. 1), including Darwin, Einstein, Pauling and McClintock. These images are taken from publicly available online images, and are chosen to show a range of styles, scientific disciplines, and types of information that are recorded.

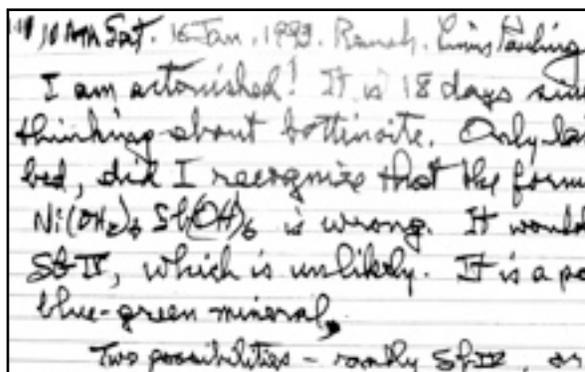


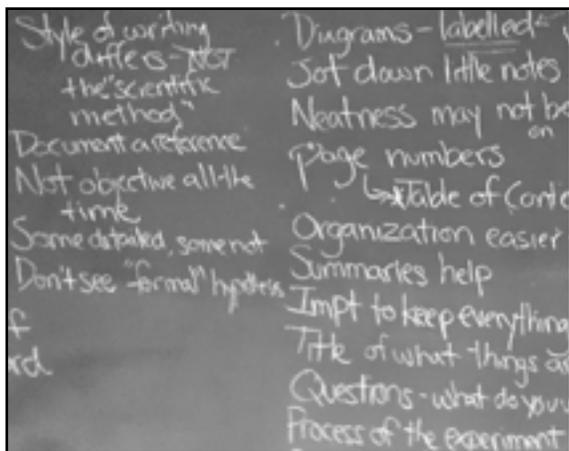
FIGURE 1. Image from Linus Pauling’s notebook

We inform students that the goal of the activity is to generate a rubric for our own notebooks. Using scientists’ notebooks, the groups are asked to generate a list of things they notice - for example: *what does the page look like? does the scientist write down observations only, or interpretations of observations? are there procedures described? what is the style of writing? Personal, objective, colloquial, etc.?*

## From group ideas to a class rubric

After a half-hour of small group work, in which instructors circulate to discuss ideas and answer questions, we generate a list of observations on the board (Fig. 2). As shown in this figures, students not

only note features they see (“page numbers,” “little notes”), but also note the absence of features they expected to see: “NOT the scientific method,” “not objective all the time,” “Don’t see ‘formal’ hypothesis” and “neatness may not be important.”



**FIGURE 2.** Notes from class discussion.

Looking at the list of student ideas, we call explicit attention to *why*, asking the group to consider what role the lab notebook plays in the scientific community. Instructors share how their notebooks were used (LAE did research at Argonne, IYS was a neuroscientist), and the recent story of Marc Hauser’s [7] field notes. From this discussion, students generally describe two distinct roles of the notebook: a *public* role that it serves for all members of the scientific community, and a *private* role that it serves to the individual scientist. It is neither a diary nor an objective cataloging of activities and results, but a blend of the two. With these roles in mind, we then proceed to develop a rubric: what elements of the notebooks should be *required*? How should we assess our own progress in keeping a meaningful and useful notebook? With those items listed and agreed to, the instructor types up a rubric and hands it out during the next class meeting.

An example of items from a rubric follows (Box 1); a complete rubric is available online[8]. Students use the rubric to self-assess their notebooks throughout the semester; instructors then grade the notebooks, using sticky notes to add comments and suggestions.

In many ways, this rubric calls students’ attention to the kinds of things they should be doing in class—not only the mechanics of investigation, with which they are often familiar[9], but also to the rationale for those investigations and how they fit into the larger picture of scientific inquiry. And so the rubric—particularly the need for “progression of ideas” and “explanations”—sets expectations for a narrative backdrop against which experimentation, evidence, procedures, and organization are meaningful.

### Personal relevance

- Shows evidence of a “*progression*” of ideas...
- As part of this progression of ideas, *mistakes and wrong ideas are expected and included*
- *Brainstorming and tangential thoughts* (as they come up) should be included
- *Explanations* - not just questions and data
- Some obvious *personal expression*, personality, individual style, engagement, and creativity...

### Publicly useful

- All days are *dated*
- Information is *organized* (labels; data is in sequential order)
- *Procedures and processes* are carefully described so you know where the ideas came from
- *Detailed, accurate observations*
- References to *others’ ideas* when they influence your own.

**BOX 1.** Student-generated rubric for notebooks

## STUDENTS’ NOTEBOOKS

How are these requirements taken up in the class? Specific research questions include: do students use the notebooks as a way of having ideas, reflecting on others’ ideas, and noting progress? Are they an essential piece of scientific practice rather than as a school genre?

### Beginning-of-term notebooks

Perhaps not surprisingly, the “publicly useful” elements of the rubric are the parts students have the least trouble with from the beginning, and grades for this section are higher than the other. Since students are not yet familiar with scientific inquiry—developing their own explanations, progressing through ideas, viewing experiments as a means of verifying the implications of a model, and the kinds of tangential ideas that are worth noting—their early notebooks often lack these elements.

In early grading, we choose a day where we feel a narrative of model-building, debate, gathering evidence and revising the model is clear, and evaluate students’ notebooks carefully for that day, using sticky notes to comment on their notes. For example, early in the Spring 2011 term, students discussed whether light rays “bounced” off of one another, with reasonable claims for both answers; students determined that shining two flashlight beams through one another and examining the pattern of the spotlights would answer the question. The experiment was done and the results conclusive. Many students simply commented on the experiment, rather than why it was conducted and what the results tell us about light. We used this day to

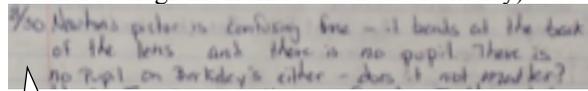
comment on notebooks, the role and goals of their use.

### End-of-term notebooks

Later notebook images begin to capture the full range of scientific inquiry. Other students' and scientists' ideas are included, but not as notes: they are considered, responded to, sketched. Models are constructed prior to testing. The implications of an observation are considered.

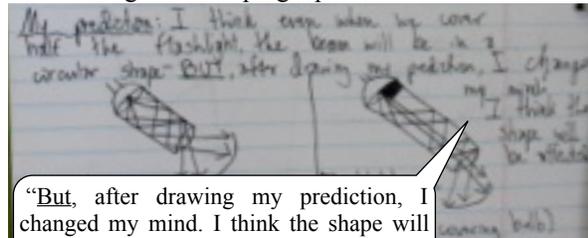
Below are images from students' notebooks, with brief comments on how students are using notebooks in meaningful ways. These are meant to be exemplars: strong examples of student work that is seen in most notebooks.

1. Students critically reflect on scientists' ideas (after students had investigated the eye for some time, we shared diagrams from Newton and Berkeley):



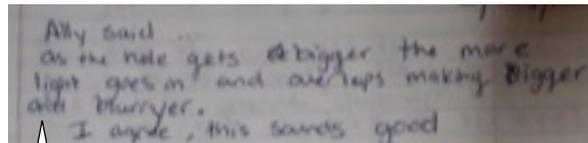
"Newton's pictur[e] is confusing me- it bends at the back of the lens and there is no pupil. There is no pupil on Berkeley's either- does it not matter?..."

2. Students reflect on methods and the role of modeling in developing a prediction.



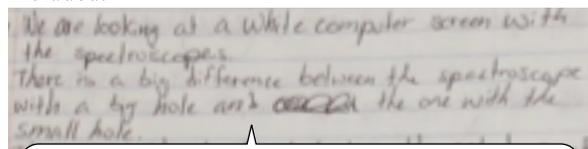
"But, after drawing my prediction, I changed my mind. I think the shape will be affected."

3. Ideas from other students are noted and agreed with:



"Ally said... as the hole gets bigger the more light goes in and overlaps making bigger and blurrier. I agree."

4. Early ideas (ultimately shown to be incorrect) are included.



"There is a big difference between the spectroscope with the big hole and the one with the small hole... is this because the colors we see in the spectroscope with the big hole are bigger so they overlap more?"

## DISCUSSION

This paper represents early work in understanding the role that scientists' notebooks (and the rubrics they inspire) play in scaffolding scientific inquiry. At the very least we can claim that the notebooks are productive for formative assessments and fostering conversations around inquiry. It is premature to claim that the notebooks are *affecting* the inquiry—it may be that students are simply transcribing into their notebooks the things that they are doing and thinking, rather than the writing itself influencing what they do and think. Nonetheless, we do see evidence in the notes that students may be using the writing (or diagramming) to have, agree, or disagree with ideas: "after drawing my prediction, I changed my mind...", "does it not matter?," "is this because...".

Future work will examine more carefully the specific role that writing plays in aiding students in performing versus describing scientific inquiry.

## ACKNOWLEDGEMENTS

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