

LABORATORY NOTEBOOKS IN THE SCIENCE CLASSROOM

*Useful tools to prepare students
for authentic science*

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In a professional laboratory setting, the laboratory notebook is a fundamental tool that captures questions, procedures, observations, raw data, data analysis, potential problems, solutions, and new questions. In the science classroom, the lab notebook provides an ongoing record of students' thinking and their laboratory methods and processes. These notebooks help students place science in a meaningful context and emphasize the importance of critical thinking and communication (Edelson 1997).

Lab notebooks provide students with authentic science experiences as they become active, practicing scientists. Teachers gain insight into students' understanding of science content and processes, while students create a lasting personal resource. This article provides high school science teachers with guidelines for implementing lab notebooks in the classroom.

A powerful tool

Inside the high school classroom, the lab notebook is a powerful tool—it engages students in the authentic practice of science while providing the teacher with insight into student thinking and comprehension of content (Edelson 1997). The lab notebook can also help assess students during performance events—which require a great deal of time and a number of expert observers to simultaneously assess numerous students. Notebooks preserve a great deal of the investigation while reducing the need for expert observers. A student notebook can thus be used as a substitute for, or a supplement to, direct observation (Shavelson, Baxter, and Pine 1991).

Laboratory notebooks also provide an intersection for the individual and communal nature of science. Through the use of lab notebooks, the science teacher simultaneously addresses course content, engages students in exploring the nature of science, and provides a venue for practicing a broad range of communication skills (Edelson and O'Neill 1994).

Although there is no doubt that the lab notebook will eventually go electronic, the information and detail that must be captured will not change with the media. In fact, the added collaboration associated with electronic lab notebooks will require sharpened communication skills.

Introducing the lab notebook

Students accustomed to fill-in-the-blank worksheets may balk at the additional work that a lab notebook requires. Establishing the authenticity of a laboratory notebook is fundamental to nurturing student buy-in. There are many ways to show students that the notebook is more than just a classroom exercise. This section presents a few possible activities that teachers can implement to engage students with this tool.

Invite a guest speaker from the industry or a researcher from a local college or university to talk to the class. They can share the importance of documentation in the laboratory. For example, they might explain how they use a lab notebook to document

unique protocols for future use. Guest speakers may also talk about referring to the lab notebook when troubleshooting an assay or when there are unexpected results.

Have students use the internet to search for the phrase “laboratory notebook guidelines.” Cooperative learning groups can compile, compare, and present the commonalities in their findings.

As a warm-up activity, give students a list of items that they could grab during a lab fire and ask them which they would save. After discussion, inform students that incoming staff members at Cold Spring Harbor Laboratory, a major research institute in New York, are advised to grab only one item in a fire—their laboratory notebooks—because everything else can be recreated using it (Barker 1998).

Ask students how long their lab notebooks will be relevant. Share well-known examples, such as Leonardo da Vinci's notebooks, which sell for millions of dollars. Introduce the work of Jeffery L. Bada, who used Stanley Miller's notebooks after Miller's death in 2007 to identify specific amino acid samples generated in 1953 during the Miller–Urey experiments. Using current analytical techniques, and the 1953 samples identified by Miller's notebooks, Bada detected 22 amino acids—more than twice the number that Miller was initially able to detect. The updated results were published in 2008, and have scientists rethinking the origin of life's building blocks—55 years after the experiments were conducted (Chang 2008).

Encourage students to put themselves in the place of the Medichem scientists. Scientists at Medichem were competing with other labs to develop and patent a way to produce the active ingredient in Claritin. Even though they made the discovery, they did not follow the standard procedures for documenting data or counter signing. Their poor notebook practice was cited as the reason that the pharmaceutical manufacturer lost a multimillion dollar patent lawsuit to Rolabo for the production of Claritin (*Medichem v. Rolabo* 2006). Ask your students to talk about the consequences of notebook practice for this company and the scientists involved.

Note that teacher notebooks are also useful tools. If you keep a notebook for your lab preps or for designing lab activities, share your notebook with students. If you do not keep a notebook, now is the time to start. Let students see that a lab notebook is a tool with multiple applications.

Help students embrace the idea that they are creating their own enduring resource that can be used for future reference. Many of my former students report using their notebooks as a resource tool and reference for other high school and college courses.

Classroom implementation

The lab notebook's dual purpose—as a personal journal and as a public (and potentially legal) document—is addressed

in the student guidelines presented in Figure 1. Everything inside a lab notebook is there to guarantee the repeatability of procedures; document thinking and practice; and ensure the quality, integrity, and authenticity of the data collected. This practice reinforces the nature of science as a collaborative pursuit based on evidence.

By keeping a laboratory notebook, students develop and practice the skills required to design experiments and capture observations. Students learn to record dependable, high-quality data in these notebooks, an invaluable skill as they move toward more open-ended, student-directed, inquiry-based science. With the skills acquired from

this experience, students can develop a much stronger understanding of the concepts and processes of science as they gather, organize, and interpret their own data.

Meeting challenges

Most high school students have never kept a laboratory notebook, so before it becomes a natural part of the laboratory process, practice is required. It is important to note that students are often most successful when they work on one skill at a time. Teachers should introduce student use of lab notebooks with the most simple laboratory investigations to allow students to focus on

FIGURE 1

Laboratory notebook guidelines handout.

Your laboratory notebook is a legal document. It can be used in lawsuits and criminal trials—but its value depends on your careful record keeping. You must write in an orderly, legible manner to ensure clarity for others.

1. Always write in ink, starting at the top of the page and finishing at the bottom.
2. Never cut or remove a page. If you make a mistake, cross it out with a single line, write in the correct entry, and sign (or initial) and date your correction. The original entry should still be legible.
3. Give your entry a title that reflects your investigation.
4. List the objectives of the procedure or experiment:
 - ◆ What are you investigating?
 - ◆ If you have an expectation for this experiment (a hypothesis), what is it?
5. Describe the procedure in enough detail that someone could repeat your experiment or procedure by reading your lab notebook. If you are following a procedure you have already recorded, you may refer to it by page number. Note any deviations from the original method.
6. Design data tables so that all pertinent information can be recorded. You may have to record equipment numbers, calibration data, reagent numbers, and so on.
7. You must always record raw data in the lab notebook—do not transcribe data into the notebook.
8. Analyze your data in depth. Include any tables, graphs, pictures, and so on. If these are printed separately, tape them into your notebook. Never rely solely on any supplemental attachments. Always include your own entry describing the attachment

and add any conclusions that you might draw from its substance.

9. Summarize the results of your procedure.
10. Sign the bottom of the page with your name and the date formatted as day/month/year (e.g., 12/May/2001). (In the United States, we would write this 05/12/2001, but in Europe it would be 12/05/2001. By spelling out the month you prevent confusion.)
11. Periodically, have someone check your work and sign as “read and understood by (name).”

As you record your activities in the laboratory, ask yourself, “Did I...”

- ◆ update the table of contents?
- ◆ date each page?
- ◆ number each page consecutively?
- ◆ use continuation notes when necessary?
- ◆ properly void all blank pages or portions of pages (front and back)?
- ◆ enter all information directly into the notebook?
- ◆ properly introduce and summarize each experiment?
- ◆ include complete details of all first-time procedures?
- ◆ include calculations?

The bare minimum entries for each lab study should include the title of the lab study, the introduction and objectives, detailed procedures and data (recorded in the lab itself), discussion of results, and a summary of the experiment.

content and process while building strategies to support student-directed, inquiry-based laboratories. Teachers can provide student guidance in the form of notebook guidelines (Figure 1), exemplars, rubrics, and formative assessment—this allows students to apply teacher feedback.

A sample rubric that teachers can use to assess student notebooks is available online and may be adapted for specific assignments (see “On the web”). Each category’s weight may be adjusted depending on the investigation’s focus and the skills being emphasized.

One of the best ways to help students understand how to use the lab notebook is to have them analyze several anonymous examples using the notebook guidelines and rubrics. Seeing examples and understanding the strengths and weaknesses of each can help students overcome their initial trepidation and attend to their own laboratory work.

Peer review

As students gain experience with the laboratory notebook, adding a peer review component provides another level of feedback and supports metacognition. A peer review encourages students to reflect upon their work and make necessary corrections within the body of the text, or add major corrections to the end of the text. Peer editing also accurately reflects authentic scientific practice, as researchers are expected to review their lab-mates’ notebooks.

To encourage sound writing, peer reviewers are assigned so that students who have worked together do not review each others’ notebooks. Students are told that an in-depth peer review will improve the quality of a product turned in for a grade. Through verbal feedback, my students have indicated that they benefit both from receiving their peers’ feedback and from reviewing their peers’ work. Figure 2 provides an example of the peer-review guidelines.

Having lab notebook guidelines and a rubric for each experiment allows the teacher to give targeted feedback regarding student work, and gives students a structure for future laboratory investigations. Keeping a notebook takes practice; students should learn from their mistakes by using formative assessments to critique and improve their work.

The take-home message should be that the notebook is an ongoing project. The purpose of this work-in-progress is not just to earn a grade but to serve as a valuable reference for future student work. Feedback from my former students and local employers indicates the value of notebooking skills in collegiate, research, and industrial settings.

FIGURE 2

Guidelines for peer review of lab notebooks.

Never make changes in someone else’s lab notebook. If you find a miscalculation, ask the author to correct it. Sticky notes are great for this purpose. If you cannot follow the procedure from what is written, ask the author to clarify his or her entry.

Never sign a notebook until you are satisfied with the entry you are reviewing. Because this is a legally binding document, when you sign, you are saying that you are a witness and that you agree with the entries on the page.

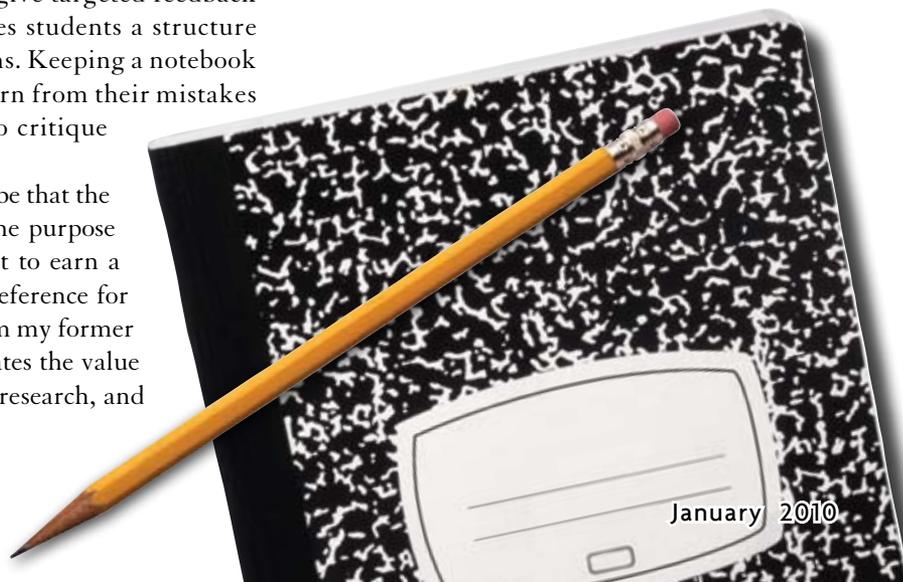
Check the following:

- Is the procedure clear and repeatable?
- Are all raw data recorded?
- Are instruments or equipment identified?
- Is the data table understandable, are the units correct, and so on?
- Are the calculations used to analyze the data appropriate?
- Are the computations accurate?
- Are all attachments secured?
- Is the appropriate format used?
- Are all entries signed and dated?
- Is unused space marked?

What you do not have to check:

1. Spelling, unless it is critical to the understanding of the notebook entry. Reagent names and organism names, for example, could be critical.
2. Grammar.

Remember, this document will carry your name as a witness. When you sign another’s notebook, it becomes your responsibility.



A major challenge for teachers, however, is grading the lab notebooks. A rubric that outlines specific areas that will be addressed is helpful to both students and the teacher. Notebooks that have a carbonless copy are a tremendous help, so teachers can grade a lab while students continue with the following one. Pick one area to focus on for each lab, and have the grading rubric reflect that emphasis. For example, focus on the data table for the first lab, and the procedure for the second. Labs can be graded one at a time, or several at a time after students have had sufficient feedback to know what is expected of them. An open lab notebook quiz or section on a test can serve as a grading tool rather than reading through every lab. Open book quiz or test items are a great tool to both assess student understanding quickly and reinforce the lab notebook as an ongoing resource.

Benefits of lab notebooks

The laboratory notebook encourages students to actively engage in critical analysis of even the most basic lab activities. As with any writing, when students translate a procedure into their own words, they digest the entire procedure prior to beginning the exercise. This inspires questions about the procedure and results in a deeper understanding of the experiment and related scientific concepts.

Writing is a thinking tool (Klentscky and Molina-De La Torre 2004). Students take greater responsibility for their learning as they develop procedures and design data tables for themselves, instead of passively following teacher directions. It is critical that procedures and data tables make sense to the student and his or her peers and teacher.

The lab notebook is student thinking made visible. How a student thinks about the data is reflected in how he or she designs the data table. Student thinking about the meaning of an experiment is clear; analysis and conclusions indicate the depth to which a student examines his or her own data and thinks about it as evidence to support claims. Using laboratory notebooks allows the teacher to see into students' understanding of both content and scientific processes and gives students the opportunity to reflect upon their growing skill sets and apply those skills to future endeavors.

Relationship to inquiry

The biggest benefit of a laboratory notebook is that through practice, students are able to make meaningful claims that are based on well-documented, high-quality data. The notebook supports students' generation and interpretation of data, allowing them to confidently make claims using their own data as evidence. This is particularly critical when they conduct their own inquiry-based investigations, as students can examine questions generated from their own research.

It is important to remember that inquiry is focused on learning by doing science, not simply learning about it. Understanding the link between data, evidence, and claims is important for all students' scientific literacy—and is supported by the National Science Education Standards (NRC 1996). As our world continues to be more technologically and scientifically dependent, the experience of doing science is key to achieving scientific literacy for all citizens, no matter their future plans (Phillips 2007). Keeping a lab notebook is a vital part of the scientific process. By using lab notebooks as a learning tool, every student has the opportunity to experience authentic science in the classroom. ■

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On the web

Sample grading rubrics: www.nsta.org/highschool/connections.aspx

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