Writing the Laboratory Notebook

Extended version (from http://home.clara.net/rod.beavon/lab_book.htm)

Faraday's hand-written notebooks…have long been of interest to historians and philosophers of science because of the extraordinarily direct insight they give into the way his thinking developed…. They are also remarkable in the amount of detail that they give about the design and setting up of experiments, interspersed with comments about their outcome and thoughts of a more philosophical kind. All are couched in plain language, with many vivid phrases of delightful spontaneity….
Peter Day, 'The Philosopher's Tree: A Selection of Michael Faraday's Writings'[1]

The skill of writing the Laboratory Notebook – even the existence of such a Notebook – has probably fallen somewhat into disuse with the advent of the photocopied worksheet. Yet it is a vital part of industrial and academic research, and indeed can in these activities be required in law to establish, for example, patent rights. Kanare[2] offers many insights into how such rights may be protected, and I am indebted to his book for numerous things that I had not thought of. This page offers some hints for the revival of the Art of the Laboratory Notebook in a school or university undergraduate setting.

Plain language

It would be a brave professional scientist, let alone teacher or student, who would take issue with Faraday. Notebooks 'couched in plain language, with vivid phrases….'. What a marvellous image Peter Day conjures up. All of Faraday's notebooks exist and remain at the Royal Institution in Albemarle St. where they were all written.

The whole point of a laboratory notebook is that it should

- say exactly what was done, and when;
- make clear who did it;
- enable someone else to do the same thing at some future date;
- be durable and verifiable.

Any rules that are used must attend to these points; anything else is spurious. Plain language is the least spurious of all.

Hardware

Books, pens and paper are the tools of your academic trade; skimping on them is absurd. Paper trees are a crop – paper is not made from rainforest timber, it's made from spruce or larch grown for the purpose – so do not be mean with paper. (I have an interest in paper and in writing and writing tools, and can bore for hours on this. It'll appear in these pages sooner or later, have no fear.)

Here are some rules for hardware:

- Laboratory notebooks should be hardback bound notebooks – you can stick worksheets in where needed.
- Writing must be done **in ink**. Black ballpoint pen is best; fountain pen inks are not as durable as ballpen inks and are more prone to fading, and do not withstand solvent spills as well as ballpen does. Blue ink fades more readily than black, and red is least fade-proof of all. Some pens contain waterproof fade-resistant inks and are made in many colours, e.g. Mitsubishi's Uniball Eye pens.
- Pencil should not be used for anything.

Organising your notebook

Anyone should be able to pick up your notebook and understand what you have written[3]. This must be the main thing - you are writing for someone else. If the writing is clear to them, then it certainly will be to you. Achieving this requires some organisation as well as a certain style.

- **Title page.** Give a page to state your name, address (you might lose the book) and a brief indication of its purpose - 'Chemistry Practicals', for example.
- **Table of contents.** Give two pages to the Contents so that you can list the experiments and find them easily when needed. But you will need to....
- **Number the pages.** Tedious but essential. Do it when the notebook is new.
- **Table of abbreviations.** I use abbreviations a lot - they save time and effort. If you use them, give a table to explain them.
- **Start each new piece of work on a fresh page.** I love the sound of 'fresh page'. A fresh page is a challenge; rise to it.

Good notebook practices

The Experimental Introduction.

The introduction to your experimental report should have the following:

- the title of the experiment - and this should appear on any added pieces of paper, graphs, whatever, that are pasted into the notebook.
- a statement of the problem or task - short and to the point. The elaboration of this comes later.
- the date. In industry or research this is exceedingly important, and may be in your work too. Write the date unambigously and include the year - for example 2 July 2000 or, for purists, 2nd July 2000. Do not write 2/7/2000 since those who use the American date system will think you mean 7th February.

The experimental plan.

This is the part of the account that tells what you are going to do. It may be that you have detailed instructions already, in which case they can be written or pasted into the notebook. If you are planning an investigation you will have to write out your own plan. If so:

- use simple, direct statements or a bulleted or numbered list of instructions;
- look forwards to what you intend to do - do not repeat the introduction;
- comment on any special features of the materials to be used - perhaps they require special storage or handling, or there may be several varieties of the compound available (hydrates or anhydrous, maybe). Such factors are very important and must be recorded.
- **Safety!** Part of chemical education is the instruction in handling potentially hazardous materials safely. There are still plenty of hazards around, and you should take these into account when planning the experiment. It may affect the quantities you use, or whether a fume cupboard is needed or not, and many other things. You need to make a **risk assessment**. Standard practical exercises will have been assessed by teachers, but this does not remove the need for you to consider safety for your own experiments.

Observations and Data.

The observations you make and the data that you record will lead to the acceptance or rejection of your hypothesis, and will decide what future experiments may be done. The observations and data are therefore **central to the whole exercise.** They need to be:

- recorded honestly
- recorded as you go along, in the notebook, in ink, immediately.
- do not trust to memory, even for a minute or so - someone talks to you, and that data's forgotten.
- do not trust to memory; you do not want your mind occupied with trivial things and small details. You need to keep the overall experimental plan in mind.
- do not use odd scraps of paper or the edge of your lab coat to record data
- the raw data is **precious** - Kanare[2] suggests that the data is treated with the care you'd bestow on a family heirloom
- the data must be recorded as completely as is possible. Don't worry too much about interpreting the data as you go along, and don't worry if some of the observations appear banal.
- use good penmanship. Take care with numbers - **never over-write**, always cross out erroneous material with a single line and re-write the correct data.
- **NEVER** use Tipp-ex or other white-out liquids.

Format

- spread your work out - paper is a crop, not a rarity, and you are not depleting rainforests. It is a necessary resource for your work
- tables must be written in vertical columns, each column being headed with the quantity and the appropraite units
- drawings need only illustrate novel apparatus - everyone knows what a beaker looks like.
- drawings should ne **sectional** - do not draw the apparatus as you see it on the bench
- drawings should be large enough to allow labelling
- drawings should be simple and to the point.

Graphs

- do not computer-plot your graphs. Graph-plotting is an art, and once you have learned it you can then decide whether to use machines, and whether the graphs they plot are silly or useful.
- each graph should have the experimental title and the date written clearly
- the axes must be labelled with the quantity divided by its unit
- include error bars if you know the error limits
- give a clear table of the data you used to plot the graph

Discussion and conclusion

- write any calculations out clearly, showing all the steps and using units throughout
- relate your results to your hypothesis - do they support or refute it? Comparisons must be as quantitative as possible. Of course a simple analysis practical will only produce a result.
- record any ideas you have, however brief - if you don't write them down, you'll forget them
- your **conclusions** should state
    - what you found out;
    - whether the hypothesis was supported or not, if appropriate;
    - the error limits on your answer(s); a quantitative assessment of error

should be made if possible, so that you can decide whether the use of a measuring cylinder rather than a pipette, say, really did make any meaningful difference to the result;

  - suggestions for improvement in experimental design, if appropriate; the error analysis will be useful here.
  - what to do next, if appropriate.

Remember....

Science does not take place on the pages of textbooks or learned journals, but it is recorded there. The quality of any work is only as good as the report that remembers it when the test-tubes have long been washed up.

Bibliography

1. Day, Peter: The Philosopher's Tree, A Selection of Michael Faraday's Writings. Bristol: Institute of Physics Publishing, 1999. ISBN 0 7503 0571
2. Kanare, Howard M: Writing the Laboratory Notebook. Washington D.C.: American Chemical Society, 1985. ISBN 0 8412 0933 2
3. Kanare, *op. cit.* p 63.

Writing the Laboratory Notebook

Condensed version (from http://www.phys.ust.hk/penger/notebookrules.html)

1. Notebooks are to be bound (a spiral binding will do) with pages numbered. The numbers may be printed or added by hand. Number all pages sequentially before using the book. Reserve the first few page for a "Table of Contents", to be filled out as the laboratory assignments are completed.

2. At the top of each page record the date and the title of the experiment.

3. If you have a partner for the experiment, be sure to record his or her name.

4. Record the time of day beside each notebook entry. There must be at least one time entry on each page of the notebook.

5. All data entries are to be made in ink. Errors should be noted by crossing through the mistake with a single line. Calculations or graphs may be made in pencil if desired. All computations done in the laboratory are to be entered in the notebook.

6. If you write anything down in the laboratory, put it in the laboratory notebook. You should write nothing, no matter how unimportant it seems, on loose sheets of paper.

7. If you must write something on a loose piece of paper, glue or tape it into your notebook.

8. Paste, tape, or staple all computer outputs, program listing, oscilloscope photographs, or other similar information obtained during the experiment directly into the notebook with an adequate description. Partners may photocopy original date for inclusion in the lab notebook. Any loose material turned in with the notebook will be discarded.

9. Experimental procedures actually used should be described. Do not copy instructions from the laboratory manual. Use your own words to describe what you are doing. These descriptions may be brief but they must be complete.

10. Diagrams are to be made of each setup, including names and model numbers of all measuring instruments. The philosophy that someone else in the lab should be able, with the aid of your notebook, to set up exactly the same apparatus and duplicate your experiment.

11. Each data reading recorded must also indicate the estimate of the uncertainty of the measurement. For a series of readings taken in the same manner under similar conditions, one uncertainty estimate may suffice. Data should be entered in tabular form. Graphs should be made right in the notebook preferably on the same page with the data.

12. Record all raw data. All calculations, no matter how simple, should be shown. Do not make the mistake, for example, of multiplying mentally by some scale factor and recording only the result of this calculation as raw data.

13. Never write any observation in your notebook that you did not personally make.

14. Be sure to record the scales on which instruments are set. Include units in the results of all calculations, either of expected values or of data.

15. Conclusions reached while performing the experiment should be described and noted as such. Show clearly the expected and measured values, even if they disagree.

16. After completing the experiment but before submitting your notebook, be sure to complete the table of contents in the front of the notebook.

17. In case a quantity exceeds the limits of measurability of an instrument, place a quantitative limit on the value (e.g. "the ripple is less than 5 mV", or "the resistance is greater than 10 MW")