

LEARNING SCIENTIFIC WRITING THROUGH SNOWPACK STUDY

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It is a pity that most people think a scientist is a specialized person in a special situation, like a lawyer or a diplomat. To practice law, you must be admitted to the bar. To practice diplomacy, you must be admitted to the Department of State. To practice science, you need only curiosity, patience, thoughtfulness, and time.

Alan Holden and Phylis Morrison
Preface to *Crystals and Crystal Growing*

Science is a fundamentally social activity, which implies that it depends on good communication.

Hermann Bondi

The goal of scientific research is publication. ... Thus the scientist must not only "do" science but must "write" science.

Robert A. Day

ABSTRACT

In my course in Technical Writing at Plymouth State College, students learn how to do scientific writing through snowpack study. In previous presentations in various publications, I have described the scope and nature of the course. This presentation describes how students learn to do scientific writing through both traditional and innovative activities. The aims of the course are as follows:

- Aim 1. *Learning scientific procedures.*
- Aim 2. *Learning and gathering scientific information.*
- Aim 3. *Synthesizing, interpreting, and applying scientific information.*
- Aim 4. *Creating and participating in a scientific community.*
- Aim 5. *Developing the individual scientist.*
- Aim 6. *Communicating to the scientific community.*

These aims are met through a sequence of linked activities, all of which culminate in writing. These activities have proved effective in helping students learn at every stage from initial field techniques, through learning snow science, to insightful reflection. All activities of the course culminate in a written report. These activities can be adapted for use in other courses on technical and scientific writing as well as in a wide variety of courses on snow science and applications such as avalanche safety.

Key words: Snowpack, avalanche safety, teaching and learning snow science, technical writing, scientific writing.

THE RATIONALE FOR TEACHING SCIENTIFIC WRITING THROUGH SNOWPACK STUDY

In my course in Technical Writing at Plymouth State College in New Hampshire, I have found that the scientific study of snow on the ground is a useful topic for helping students learn to write scientific reports. In other presentations (Chisholm 1995, 1996b), I have described the syllabus for this course. This presentation describes several methods I have found effective in helping students learn scientific writing through snowpack study. These methods can be generalized for teaching scientific writing about other topics as well as in courses on applications of snow science, such as avalanche safety.

The Aims of Snowpack Study

In my course, I set up situations in which students learn about science through discovery. In a guided sequence of activities, students master the fundamental principles of snow science through lecture, individual reading and study, a series of field trips, and classroom activities. This material is presented in detail in the *Field Guide to Snowpack*

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Study (Chisholm 1997) and the *Teacher's Guide to Snowpack Study* (Chisholm, 1996). Each phase of the course culminates in writing a report.

Within the scope of course work, students are expected to become proficient in each of the six aspects of science. The aims of the course are as follows: Aim 1. Learning scientific procedures; Aim 2. Learning and gathering scientific information; Aim 3. Synthesizing, interpreting, and applying scientific information; Aim 4. Creating and participating in a scientific community; Aim 5. Developing the individual scientist; Aim 6. Communicating to the scientific community. The cumulative effect of the course of study is that students learn what it means to be a scientist.

HOW STUDENTS LEARN SCIENTIFIC WRITING

Students in my course learn science and scientific writing at the same time. They learn by doing guided research under supervision, then designing a series of reports that describe their work during several stages of snowpack study.

The activities which are described below have proved effective in helping students learn at every stage from initial field techniques, through learning snow science, to insightful reflection. (It will be noted that this discussion does not follow the chronological sequence of the course syllabus.)

Reaching Aim 1. Learn Scientific Procedures

Learning to conduct a field trip I introduce students to the procedures of scientific observation by showing them how to conduct a field trip to study a snowpack. By means of lecture, reading, demonstration, and a preliminary field orientation, they learn to select a site, dig a snow pit, and use equipment appropriately. Directed activity and guided discovery are the main modes of learning.

Reaching Aim 2: Learn Scientific Knowledge and Gather Scientific Data

To help students learn snow science, I create a variety of contexts for learning scientific information and for applying it to solve concrete problems.

Learning the fundamentals of snow science Although I limit the scope of study in this course to snow on the ground and explicitly exclude the formation and deposition of snow and the applications of snow science, students undertake significant learning about snow. They learn the fundamentals of snow physics: the structure of a snowpack, the basic concepts of snow science (such as phase change and the composition of snow), and processes of mechanical and metamorphic change. They apply knowledge of the forces of mechanical change at work on a snowpack (gravity, wind, solar radiation, warm air, and liquid water). The technical material is drawn from the fundamental principles of snow science, especially snow physics and its applications.

The important principle here is that students learn the concepts, processes, and terminology of snow science so they can interpret what they observe during field trips to the snowpack. They come to understand the relation between individual bits of information and the interaction of complex forces.

Learning to identify types of snow Students learn how to identify the various particles of snow in a snowpack. They learn this unusual outdoor skill—analogue to field identification of birds, flowers, or rocks in other sciences—by comparing actual field specimens with descriptions in Chapter 5 of the *Field Guide*, "Identifying Types of Snow in a Snowpack."

First, students learn some principles of field identification: observe closely, sketch what you see, describe what you see, and check your observations with those in the book. Then they learn three approaches to identifying types of snow: identifying snow particles by overall pattern, by analogy, and by analysis. With the *Field Guide* in hand, they learn to identify the easy-to-recognize particles first, then more and more difficult forms. Throughout, they keep in mind the processes of mechanical and metamorphic change and the influence of weather history; they note the height of the specimen from the ground, its relative position in the snowpack, the thickness and density of the layer, its texture, and so on.

One of the chief aids for gaining information about the snowpack is the *Crystalscope*, a simplified cross-polarizing microscope. The contrasting colors of the particles revealed by the cross-polarizers in this instrument helps students identify types of crystals and boundaries of grains. They find the *Crystalscope* useful in determining types of snow in the snowpack. The principles and procedures are described in *How to Use Your Crystalscope* (Chisholm, 1996).

Although field identification of snow particles is a new and challenging experience for most students, they soon learn to identify particles with some skill.

Gathering information about a particular snowpack Using the scientific procedures and scientific knowledge they have learned, students conduct their first field trip. They look for evidence of boundaries between particles and layers. They identify layers and types of snow by observing differences in color, texture, particle size, and particle shape. They collect and record data on a Snow Pit Data Sheet and use this information to prepare their first report.

Learning by comparing and contrasting After an interval of two or three weeks following the first field trip, students return to the snowpack to re-examine it and determine how it has changed in the interim. In writing up

their observations, students focus on how mechanical and metamorphic processes have affected the snowpack: how it has changed and how it has remained unchanged. The significant procedure is that students learn the value of conducting repeated observations to compare and contrast snowpack profiles at two stages of development. This return to the snowpack is central to the experience of my students and probably is the most important aspect of the course.

Reaching Aim 3: Learn to Interpret and Apply Scientific Information

In this course, there is no body of information to be learned merely as scientific knowledge, but as information to be used. The knowledge that students gain from reading, lecture, and field observation at each stage in the snowpack unit becomes the basis for further inquiry and investigation. Students continually recombine information in various forms and re-interpret it to answer a series of research questions. This activity entails assimilating information, sorting it, selecting it, synthesizing it, and interpreting it. The evidence that they have learned these things is in the reports they write. There are no examinations.

Predicting the characteristics of a snowpack By the time they reach the mid-point of their snowpack study, students have developed a practical understanding of snowpack formation. They have conducted their first field trip and have written up their results in a report. They have learned the fundamentals of snow science and have studied local weather history in detail. Given this background, two or three weeks after the first field trip, students bring all of their learning together to predict changes in the snowpack.

To help students predict how the snowpack will have changed, I have them build a hypothetical snowpack profile. The procedure calls for students to identify significant weather events, design a cutaway diagram, label the layers, and describe the snowpack—as they hypothesize it—in ordinary prose.

Building a hypothetical snowpack To create a hypothetical snowpack, the students and I work through an archive weather history log from a previous year, then build the snowpack from the bottom up by accounting for every snowfall and every significant change in the weather. As students predict the height and characteristics of each layer, I record their predictions on the chalkboard in the form of a profile that depicts the snowpack we predict.

Figures 1 and 2 illustrate the relation between a set of weather data and a hypothetical snowpack.

Date	°C		cm		Snow Depth
	Temperature High	Low	New Snow	Rain	
1	-3	-10	15	0.0	15
2	-3	-12	T	0.0	14
3	-4	-16	0.0	0.0	12
4	2	-6	0.0	0.0	10
5	2	-9	0.0	0.0	9
6	5	-7	0.0	0.0	8
7	1	-11	0.0	0.0	8
8	-6	-15	0.0	0.0	8
9	-4	-15	0	0.0	8
10	-2	-16	1	0.0	8
11	-5	-16	35	0.0	43
12	-5	-19	0.0	0.0	41
13	-2	-17	0.0	0.0	41
14	-9	-20	0.0	0.0	41
15	-2	-9	0.0	0.0	41
16	-9	-5	0.0	0.0	40
17	0	-6	0.0	0.0	39
18	-1	-11	0.0	0.0	38
19	-6	-14	0.0	0.0	38
20	-3	-9	0.0	0.0	38
21	4	-10	T	0.5	30
22	-2	-14	16	0.0	45
23	-3	-14	T	0.0	43
24	0	-6	1	0.0	43
25	0	-7	0.0	0.0	42
26	-1	-8	T	0.0	41
27	-1	-9	T	0.0	41
28	-6	-6	0.0	0.0	40
29	-2	-9	T	0.0	39
30	0	-8	6	0.0	45
31	3	-4	0.0	0.0	43

Figure 1. Log of Weather History for January This figure illustrates the kind of raw data that students and I use to construct the hypothetical snowpack profile such as the one illustrated in Figure 2. Data are also hypothetical.

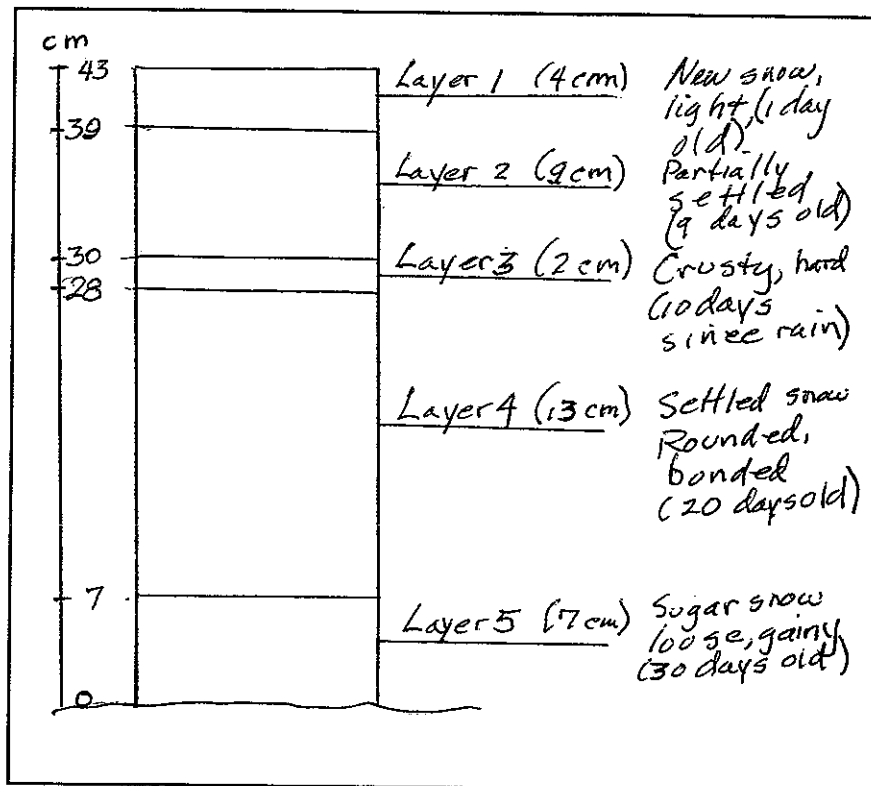


Figure 2. Profile of a Hypothetical Snowpack. Figure 2 presents a hypothetical cutaway view of the snowpack as we predicted it from the raw data in Figure 1. Descriptive words and phrases derive from the students' spontaneous suggestions as well as from "How to Identify Types of Snow in a Snowpack," Chapter 5 of the *Filed Guide to Snowpack Study* (Chisholm, 1997).

After practicing with old data, students construct their own hypothetical snowpack based on weather data from the current season.

Checking out the prediction The exercise in predicting is only partially completed when students have formulated their predictions. The next step is to return to the field to check out the accuracy of their predictions. In a second field trip, students gather data that will help them either verify or correct their predictions.

Accounting for change as an exercise in synthesizing In the final activity in the technical part of the snowpack study unit, students have to account for both the similarities and the discrepancies between their predictions and what they found in the field. They have to interpret what they have observed on the basis of everything they have learned and everything they have thought, then write a critique of their predictions.

Writing this interpretation and critique requires students to synthesize material of several kinds: data from the first field trip, knowledge of snow science, data from weather history, data from the second field trip, and their own predictions. They have to discipline their imaginations to meld these disparate pieces of information into a coherent whole. Students experience what it means to convert *data* into *information* and *information* into *interpretation*. The complexity of the material makes the synthesis extremely challenging.

Numerous personal elements in this activity increase the challenge. By this time in the course, some of the initial appeal of snowpack study has evaporated, and some students are becoming tired of the subject. At this point, the students have to muster appropriate attitudes, values, and goals. They have to keep the aims in mind, be positively motivated, recognize the value of the synthesis, and pursue the goal intelligently. This means that I must explain the aims of the synthesis, show the values, and call up their motivation. For both instructor and students, the demands of this synthesis makes this phase of snowpack study the most challenging phase of the project.

This exercise helps students move from learning of theoretical knowledge and data collection to synthesis and from detached learning of inert information to interpretation. In making the prediction and checking it out, students learn that their procedures applied to the phenomena of nature produce data, but that data are only the raw material of thought. They learn that combining data and knowledge, and letting their imagination play over them, they can

produce interpretations. By linking appropriate procedures, knowledge, and interpretation, students have something to communicate other than raw data or mere facts.

Reaching Aim 4: Create and Participate in a Scientific Community

From time to time throughout the snowpack study unit, students participate in the neophyte scientific community made up of their peers in the class. They become aware of the world-wide scientific community through reading, writing, and using the Internet.

As every teacher of writing knows, students frequently resist working on collaborative projects. Throughout their academic careers, they have been rewarded for individual effort and punished for apparent collusion. They are not used to sharing information or responsibilities. Their few attempts at productive group work have often been failures.

Professional scientists, on the other hand, know that most scientists work collaboratively. It has become increasingly clear that students should learn the values and the limitations of collaborative work.

To help students learn how to work productively in a scientific community, I train them from the beginning to work in groups on collaborative exercises. Their field trips, in which they use a single set of tools to gather data and a single data sheet to record it on, make cooperation unavoidable. I also have them work together on smaller projects such as converting traditional units of measurement (degrees Fahrenheit and inches) to scientific units (SI) and to create a graph of weather data (as described below under Aim 6). Students must perforce cooperate. In these ways, students learn the potential power of a collaborative group with shared responsibilities.

Reaching Aim 5: Develop As Individual Scientists

Individual students develop personal abilities not only by engaging in these scientific activities but also by reflecting on and assessing their experience.

To help students understand the personal and social significance of their work in this course, I have them keep a daily journal. This is a log of their perceptions, their queries, and their concerns. It is a place for reflective thought on where they are, how they get there, where they are going next, and how they will get there—all seen from their own individual perspective.

Toward the end of the snowpack study unit, students write an essay in which they synthesize their journal entries. They trace their intellectual and emotional journey during the course by converting their raw daily journal entries into a unified retrospective essay.

This assignment has several values: it keeps students in touch with their feelings and their growing knowledge throughout the semester; it requires students to review their day-to-day experiences; and it helps them meld the fragments of journal entries into an autobiographical synthesis and interpretation. I personally enjoy reading these essays far more than the daily journals, because I can trace with the students their progress through the course.

In addition to learning traditional scientific material, students learn to handle excitement, then stress, discomfort, interpersonal problems, and the tedium of repeated revising. By the end of the course, they have an essay that demonstrates their change from uninformed to informed perspectives.

Reaching Aim 6. Learn to Communicate Effectively

In the snowpack study unit, students learn to communicate with the immediate scientific community of their classmates through reading, writing, speaking and listening, and especially through peer review of each other's writing. They learn to communicate with the wider scientific community through scientific reports, which include tables, graphic displays with captions, and the ordinary prose of narrative description and explanation.

Converting data to graphic and narrative form A major aim of technical writing is for students to gain facility in presenting information in a variety of forms and styles. For example, by converting data about weather history from tabular form to a line graph and narrative description, students learn how to communicate with readers who approach their report with a variety of needs and abilities.

Because students have to deal with the needs of both technical and non-technical readers, they learn to vary the content, form, and style in various sections of their reports. I am particularly careful to point out to students that visuals do not speak for themselves; they are not self-evident, and drawings and other graphics alone rarely present an object adequately.

Except for writing abstracts, which are notoriously the most difficult part of a report, writing captions causes students the most difficulty. I explain that captions serve several purposes and are made of several elements. Captions give enough information at the foot of an illustration so that a reader who skips and skims can get the gist of the report without reading the main text. Writers need to number and title each visual and to label its essential parts, using breakouts to label details and define symbols and abbreviations in a key. They need to point out what the visual illustrates and what they want readers to see in it. This is one of the few places in a report that writers ought to repeat what they have written elsewhere. A well-designed visual, accompanied by a well-conceived caption, often entices a flip-through reader to read the text for further information. Writing effective captions achieves an additional goal: it requires students to come right to the point. Most of these ideas are new to them. After some practice, students become adept at converting from one mode of expression to another.

An example of information in various forms The graph in Figure 3 illustrates the way that students convert data from one form of expression to another to create a visual presentation. It shows how students converted data about precipitation, temperature highs and lows, and snowpack depth into a graph that visualizes change in the snow depth during the period of study. Students used the data in Figure 1.

Here is the assignment that elicited this conversion:

Given a weather history table that shows precipitation, temperature highs and lows, and daily snowpack depths for a given period, convert the tabular information to graphic form. For the graph, write a suitable figure number, title, and caption. In the caption, point out the relation between the numerical information in the table and the visual information in the graph.

To design the graph of snow accumulation, students select information about snow depth from the weather log, and convert it to visual form. For the time being, they ignore the rest of the data. Students learn that the visual presentation of the graph helps readers visualize the changing depth of the snowpack. They realize that through the medium of a visual, readers can take in a lot of information at one glance and that a writer can easily reach visually-oriented readers through this medium.

Presenting the concrete facts of weather history in this form assures that students thoroughly assimilate the data. Knowing the data well helps them make informed predictions about the influence of the weather.

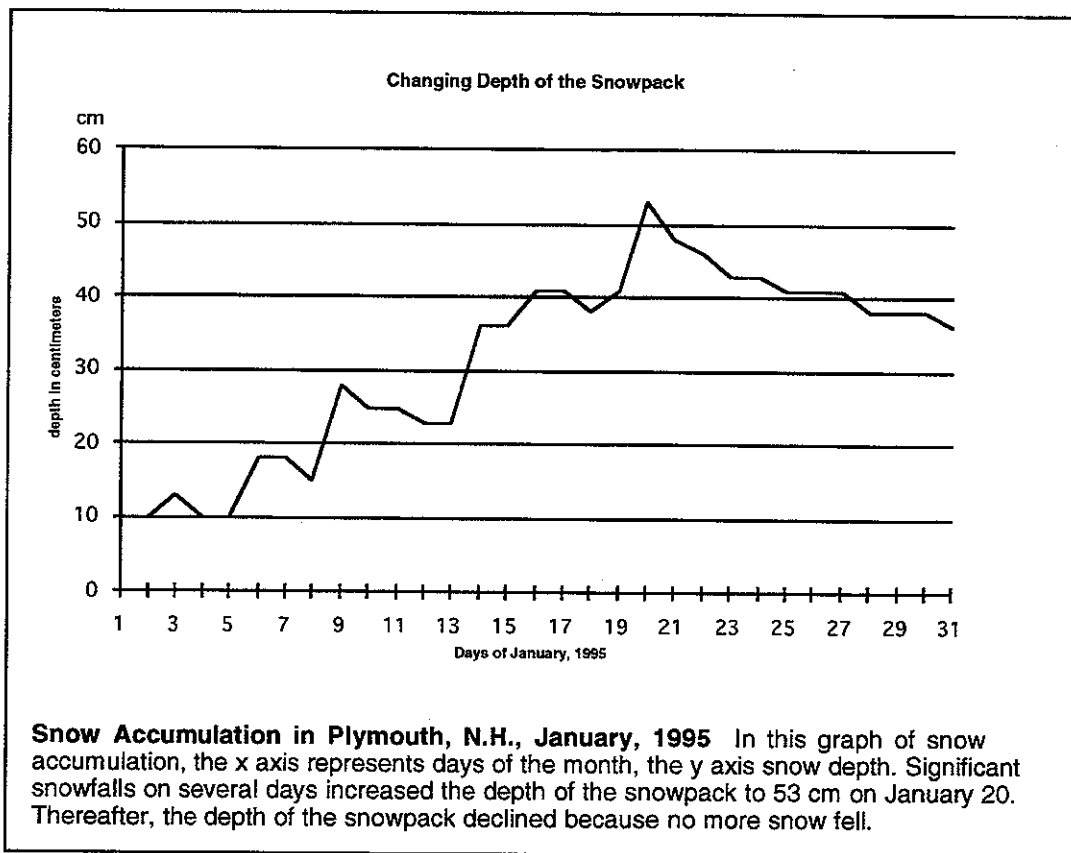


Figure 3. Visual, with Caption, Illustrating a Graph of Snow Depth. Students converted the raw data from the log in Figure 1 to create this graph that shows the changing depth of the snowpack. The caption directs the reader's attention to salient points in the profile and interprets it for readers. It points out explicitly what the graph represents, what readers are supposed to see in it, and why this information is significant.

For students who have not used logs or tables extensively, this exercise entails significant learning.

SUGGESTIONS FOR TEACHING SCIENCE AND SCIENTIFIC WRITING

The activities of my unit on snowpack study can be used in other courses in science and scientific writing. The key elements in creating effective assignments in scientific writing, I suggest, are to engage students in active learning and to place them in various contexts where they have to produce a particular kind of writing. Creating assignments with the following characteristics has helped my students learn to write more effectively:

- Assign tasks accompanied by clear guidelines and specifications. At the same time, provide ample room for individual variation and innovation.
- Assign tasks that engage students by connecting learning activities to their immediate environment.
- Provide rich content to be used as the materials for research, not merely as information to be learned and recited.
- Promote guided discovery by requiring students to solve concrete problems. State the problems in the form of research questions.
- Require students to synthesize and interpret information; have them bring together several bodies of information and explore their significance.
- Require students to present information in more than one form. Have them present written, visual, and oral forms of the same material. Have them convert a table to a chart, a caption, and a narrative description.
- Require students to check their initial uninformed impressions against guided and informed observation. Have them make predictions and check them out against the facts. Have them observe and account for change over time.

Snowpack study engages students personally in a way that typical case studies and textbook problems rarely do. Right from the start, students dig in the snow, test it, measure it, and make several observations about it. They soon become engaged.

When they complete the snowpack study unit, students will have learned the habit of asking and answering questions about the physical world around them and ways to communicate their knowledge effectively to others. It does not matter that students do not produce useful research or contribute to the general store of knowledge about snow, nor that they are collecting data about ephemeral conditions. What is important is that the students are learning to conduct actual scientific research. They are doing their own field work, collecting their own data, applying their own body of knowledge, making their own syntheses and interpretations, and writing up their own results. Although the lessons are highly contrived, none of the learning is artificial.

While the reports may be dubious as contributions to snow science, they are effective tools for learning scientific writing and for recording the experiences of young writers. Although the students remain novices, they are not mere observers or outsiders, but participants.

ACKNOWLEDGMENTS

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