INQUIRY & INVESTIGATION

Using Mini-reports to Teach Scientific Writing to Biology Students

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Abstract

Anyone who has taught an introductory biology lab has sat at their desk in front of a towering stack of lengthy lab reports and wondered if there was a better way to teach scientific writing. We propose the use of a one-page format that we have called a "mini-report," which we believe better allows students to understand the structure and characteristics of proper scientific writing and reduces the grading-time investment for instructors.

Key Words: *Scientific writing; lab report; scientific method; undergraduate biology.*

Competency in writing is essential to the success of students in any discipline. Scientific writing, however, is hard to master at all levels of scientific formation. The ability to write using logical arguments that are substantiated by evidence and sound reasoning is crucial in the science disciplines, and a key educational standard as articulated in the *Next Generation Science Standards* (NGSS) for elementary and secondary students in the United States (see http://www.nextgenscience.org/next-generation-science-standards). For most, good scientific writing is a skill that is personally developed through years of practice, but as instructors, we are faced with a different challenge: teaching our students how to write objectively, logically, and concisely, while understanding the importance of complying with the well-established scientific standards.

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Educating students on how to write in a specific scientific discipline is equivalent to teaching them how to think critically in that discipline (Nilson, 2003). It is important for students to learn the metacognitive model behind the scientific method, which means they must comprehend why, when, and how one uses specific methodologies to acquire information, record and interpret data, and convey the results effectively.

This task is difficult and quickly becomes cumbersome because every year instructors must, among many other responsibilities, read and grade dozens of lab reports, most of them very badly written. In our personal experience teaching general biology to incoming university freshmen, the problems tend to stem from the students' unfamiliarity with the process of scientific writing. For example, we conducted a survey on scientific literacy among 82 first-semester biology students in fall 2010 and found that 56% said they had never read a scientific article in a peer-reviewed magazine. As educators, we also need to keep in mind that most freshmen took their previous biology course during their first year in high school and now, 3 years later, they are somehow expected to produce a good-quality scientific lab report right off the bat. According to what we have observed, students also seem to struggle with the use of the discipline-specific technical vocabulary, mixing facts with personal opinions, supporting their arguments with information obtained from reliable resources, and citing those sources correctly.

Pechenik (2007) clearly portrays why science instructors should be concerned about their students' scientific writing skills: poor writing reflects that the student has an unclear thought process and may not understand the concepts being explored; and communicating appropriately is a key part of all sciences because it provides a way to examine, evaluate, and share thinking with the scientific community.

With the intention of (1) helping our students understand the purpose and importance of scientific writing, (2) helping our students grasp the metacognitive model of the discipline, and (3) helping ourselves by reducing the grading load and thereby ensuring a timely return of graded materials and providing feedback the students can use for their next writing assignment, we designed a short lab-report format: the mini-report. Contrary to the traditional multipaged lab report, the mini-report has a one-page layout and, in essence, is very similar to a scientific research poster (Figure 1). We believe that writing shorter reports better conforms to what one does when writing a peer-reviewed scientific paper: the research that has been conducted over a number of years using a variety of different

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Do Changes in Sodium Chloride Concentration Affect the Germination of Grass Seeds?

[redacted]., **Simmons, A.** Lab Section LA: 07/02/10

Introduction: If a plant embryo has enough water and oxygen, and if light and temperature conditions are suitable, the embryo may break through its seed and begin to mature (Stack, 2008). This germination process is sensitive to changes in extracellular sodium chloride ions (Cork, 2006). In 2002, Ajmal Khan and Salman Gulzar studied four species of perennial grasses under controlled laboratory conditions. They recorded that increases in salinity inhibited germination of all species (Khan, 2002). When sodium chloride concentrations rise, water molecules exit the plant cell to dilute the polarized salts and restore osmotic equilibrium (Stack, 2008). Here, the plant cell can no longer access enough water to continue germinating. It is currently estimated that salt stress renders around 20 % of worldwide agriculture unusable (Cull, 2009). The purpose of this experiment is to determine how changes in the concentration of sodium chloride affect the ability of grass seeds to germinate. The hypothesis is that **increasing concentrations of sodium chloride will inhibit the germination of grass seeds.**

Methods: For this experiment, the independent variable is the percent sodium chloride and the dependent variable is the number of grass seed germinations. Distilled water (0.0 % sodium chloride) is the negative control. The test solutions are 0.1 %, 0.5 % and 0.9 % sodium chloride. Three trials are conducted. Absorbent paper is placed into Petri dishes and 2.0 mL of either a test solution, or the negative control, are added. Forty grass seeds are placed into each Petri dish. They are allowed to sit in optimal sunlight for six days. After this period, the average number of germinated grass seeds is recorded at each concentration.

Results: The control solution had the greatest average number of seed germinations; the 0.1 % sodium chloride solution had a moderate number of seed germinations, and both the 0.5 % and 0.9 % sodium chloride solutions averaged just above zero seed germinations. The standard deviations for each of these were small. The 0.0 % and 0.1 % sodium chloride solutions had no error bar overlap (Figure 1).

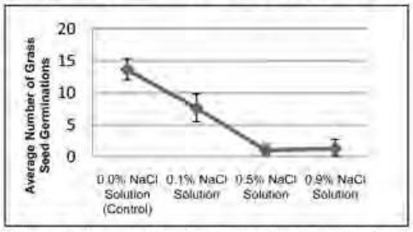

Figure 1: Average Number Grass Seed Germinations in Differing Concentrations of Sodium Chloride (Average of three trials)

Conclusion: The data supports the hypothesis that **a higher concentration of sodium chloride inhibits the germination of grass seeds.** Optimally, grasses are grown in conditions where the concentration of sodium chloride is close to 0.0 %. A recent study on germination at Dezhou University supports this conclusion by reporting that germination is greatly reduced, on average, in most plants when levels of sodium chloride increase (Li, 2008). Future research should investigate the tolerance of extracellular sodium chloride relative to specific plant species. It is likely that certain plants can stand greater concentrations of salt and thus could serve to fulfill unique agricultural needs.

Literature Cited:

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Stack, G. "Germination." *University of Illinois* (2008): pp. 1 -3. Web. 2 Jul 2010. <http://urbanext.illinois.edu/gpe/credits.html>.

Figure 1. Example of a mini-report generated by a group of students, showing the general layout and appearance of this format.

experiments must be described and discussed in a reduced format, which usually ends in an article that is under six pages. Below, we provide the instructions we give to our students for the preparation of mini-reports as well as the rubric used to grade them.

○ Writing Mini-reports & Our Experience Implementing Them

In our introductory undergraduate biology classes (laboratory and lecture), students learn about the scientific method and its importance. The mini-report, as a format to be used for all their lab reports, is introduced during the first few weeks of class in the BIOL 1151 General Biology I Laboratory. Our General Biology I Lab curriculum has a strong focus on scientific literature. We invest about half of the first semester in showing students what defines a primary research paper, what a review is, the parts of these types of papers, and how they are different from general-audience science magazines. We teach them how and where to find scientific literature and address the importance of ethical practices when reporting scientific results. Students are also taught some basic data analysis. The mini-report format is also used in the General Biology II Laboratory. Most of our laboratory exercises in the second semester require students to first learn a specific technique (or how to use a certain apparatus), and then they are asked to design a hypothesis and test it using that technique or apparatus. They collect and analyze the data individually or in teams (depending on the assignment) and are required to hand in their mini-reports within one or two weeks.

The implementation of this assignment in our General Biology Laboratory courses has been positive for both parties. As instructors, by moving away from the traditional "thesis-like" 10-page lab report, we have the opportunity to teach writing in a manner that seems more in tune with what writing in a scientific discipline is actually like. It is important to note that the mini-report format does not compromise the didactic value of the assignment and that the shorter format still enforces scientific writing skills for the students. When we compare student performance on their first reports to that on their second reports, we see the expected significant increase using both full and mini-report formats (Figure 2). Moreover, we do not see a significant difference in the second report grades using either format, which suggests that the shorter format has not hindered our ability to accurately assess student performance. As a result, we have been able to include more writing assignments (mini-reports) during the semester, providing the students with more opportunities to practice and perfect their skills, and ensuring that feedback can be received by the students sooner, as the mini-reports take less time to grade than a conventional full report. In short, the use of mini-reports has helped our students critically read, write, and think about science. So much so, that in the last year we have begun incorporating the short-report format in other upper-division courses (we have extended the page limit to two, three, or four pages, depending on the experiments done in these classes). We hope you find the mini-report as useful as we have, whatever level you teach.This short format is generally adaptable to any science class and can be easily used in secondary education, especially in AP Biology courses.

○ Student Assessment

In order to make grading as objective as possible and to evaluate each section independently, we designed a scoring rubric (Table 1).

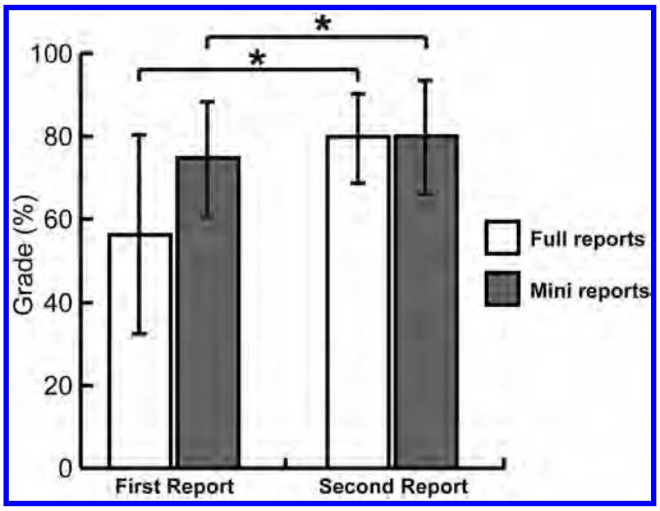

Figure 2. A comparison of student grades using full and mini-report formats. Students performed significantly better on their second submission than on their first using both report formats. Asterisks denote significance at $P < 0.05$ (Mann-Whitney U-test: full reports, $n = 25$; mini-reports, $n = 47$; all reports were done as individual assignments and were graded by the same instructor).

This was provided to the students ahead of time (so that they knew what the instructor would be looking for) and was used as a tool to provide feedback, allowing students to understand where they had trouble and what sections they should improve.

○ Writing a Mini-report: Student Instructions

The following are the instructions provided to the students (in the form of a handout) on how to write a mini-report.

General Information

The mini-report must include the following sections, identified with subtitles: Title, Introduction, Methods, Results, Discussion and Conclusions, Literature Cited. Additional information and hints are provided for each section (see italicized text).

Specific Section Instructions

1. **Title.** Here you will state the main question: what are you investigating? The title must be specific and allow the reader to know exactly what you are studying. Underneath the title you should write the last names of all the members of your

Table 1. Scoring rubric used for mini-reports.

Sections	Possible Points				
	A	B	C	D	F
1. Title (3 pts)					
Title is descriptive	2	1.5	1	0.5	0
Names of group members, professor, and section	1	0.8	0.7	0.6	0
2. Introduction (10 pts)					
Background information (with relevant outside source)	6	5	4	3	0
Rationale/hypothesis	4	3.5	2.5	2	0
3. Methods (8 pts)					
Experimental design (paragraph)	5	4	3	2	0
Correct format (paragraph, past tense, etc.)	1	0.8	0.7	0.6	0
Variables correctly identified, controls stated	1	0.8	0.7	0.6	0
Number of replicates stated	1	0.8	0.7	0.6	0
4. Results (12 pts)					
Description of results	5	4	3	2	0
Figure pointed out in text	1	0.8	0.7	0.6	0
Correct type of figure	2	1.5	1	0.5	0
Correct labeling of figure/table (descriptive legend/title)	2	1.5	1	0.5	0
Error bars present	1	0.8	0.7	0.6	0
Both treated and control groups in figure	1	0.8	0.7	0.6	0
5. Discussion and Conclusion (12 pts)					
Do the data support the hypothesis?	2	1.5	1	0.5	0
Interpretation of results	6	5	4	3	0
Comparison of data with previously published information	4	3.5	2.5	2	0
6. Literature Cited (5 pts)					
Literature is cited using the correct format (in text and in this section)	2	1.5	1	0.5	0
Good-quality, relevant citations	2	1.5	1	0.5	0
Good quantity of citations	1	0.8	0.7	0.6	0
TOTAL (out of 50 pts)					

lab team (followed by the initial of the first name), the name of your instructor (bold text), lab section, and date. If you are the author of an individual report, your name should be listed first and must be underlined, followed by the names of your group members.

Example:

Effect of light with three different wavelengths on photosynthetic rate
Carrasco, M., Jones, P., Smith, H., Vu, T., **Rosell, R**. Lab Section LA: 09/15/09

- *Write a descriptive title. Be specific. For example, "Choosing the best mouthwash" or "Which concentration kills more bacteria" are vague: they fail to describe what substances you used, what "best" means, how many different solutions or chemicals were tested, or what bacterial strains were used to conduct the experiment. A better title would be "The effects of three different brands of mouthwash on the growth of* S. aureus.*"*
- *The main conclusion of your research can also be used as a title, for example, "Listerine mouthwash inhibits growth of* S. aureus *more effectively than Scope."*
- *Writing the names of all your group members (and spelling them correctly) shows respect. Whether you are handing in an individual or group mini-report, all the names of your research colleagues must be there. This shows a good work ethic.*

2. **Introduction.** Select the two or three key concepts related to your experiment (usually your dependent and independent variables) and briefly explain them. For example, if your experiment involves enzymatic reactions and temperature, you should briefly describe enzymes, how they work, and what can affect their function. Then explain the consequences of changing the environmental conditions of the reaction, and finally focus on the effect of temperature. You should use 6 to 10 succinct sentences to convey this information. Cite your information sources within the text by putting the last name of the first author and year of publication in parentheses, for example (Perez, 1996). In the last 2 or 3 sentences of your introduction, state your rationale and hypothesis, which should portray the relationship you expect to find between the independent and dependent variables.

- *When you are conducting an experiment, pick the three or four topics you need to address in your introduction. For example, if your title is "Effect of mouthwash alcohol concentration on* E. coli *growth," you should discuss mouthwashes and the effect of alcohol on bacterial growth and describe* E. coli. *You should also make use of relevant primary literature and avoid making your introduction sound like a Wikipedia entry by providing information that is as specific as possible to your subject.*
- *Have a rationale for your hypothesis. The rationale is usually included in the Introduction, written in one or two sentences after the background information and before the hypothesis. The rationale must be clearly stated and express the reasoning that led you to the proposal of your specific hypothesis. It should be grounded on your observations or background research from the scientific literature. The rationale must be followed by your hypothesis, which should state the relationship between your dependent and independent variables.*

3. **Methods.** In this section, you will briefly describe how you conducted your experiment. In paragraph form, describe the experimental procedures performed to obtain your data. Use the past tense. You must be specific (give exact measurements, volumes, times, etc.), but at the same time be brief and include only details that are necessary if someone were to replicate the experiment. Remember to indicate the number of replicates. You may state that you followed a protocol described elsewhere (lab manual, book, or publication) as long as you cite the source properly. Mention if you have made any changes to the original procedure.

- *How you labeled your samples and the number of tubes you used are pieces of information that are not crucial for another researcher to be able to repeat your experiment. Write only what another person would need to know if he or she wanted to replicate your experiment. Mention the number of trials conducted (which usually is three in our experiments). Use your technical vocabulary and avoid using personal pronouns; for example, say "Paper disks soaked in the three test solutions were placed on bacterial lawns of* E. coli*" instead of "We used three paper circles for each solution, wet them and then put them on one of the quadrants of a Petri dish that had* E. coli *smeared all over." Make sure to include a description of your control.*

4. **Results.** This section should contain at least one paragraph (no more than 5 sentences) describing your most significant findings, followed by a graph or table that shows your data. Always refer to your table or graph in the text by citing it at the end of the sentence or using parentheses, for example "see Figure 1" or "see Table 3 below" or "(Figure 2)." Remember that your figures must have descriptive legends below them, and tables are to be identified by titles at the top. Never include raw data. Do not begin your sentences with "Figure 2 shows…." Keep in mind that you must describe the data – not the figure, graph, or table.

- *Describe all your results in the Results section. If there is anything particular about your standard deviation, mention it here. Mention exact values, as sometimes they cannot be estimated by observing the graph. For example, "Dr. Tichenor's mouthwash had the highest zone of inhibition (19.5 ± 0.5 mm), followed by…." Please remember that all numbers smaller than 1 should have a zero before the decimal point. Always use relevant units when mentioning data points.*
- *The graph (table or figure) should be presented AFTER the written description of your results. Understanding which are your dependent and independent variables allows you to decide which one goes on each axis, and whether you should use a column or line graph. DO NOT graph your raw data. DO graph your averages. Be critical (smart) about your error bars. Remember that tables have a title (above the table), and figures and graphs have a legend (detailed short paragraph under the graph or figure). Your title or legend must be descriptive and should not include the results of your experiment.*

5. **Discussion and Conclusion.** In your first sentence, state whether or not the data support your hypothesis. Then interpret your results in relation to the background information. Do not repeat what you stated in the Results section; instead compare your findings to those published in the scientific literature. These may support (or not) your findings. For example,

if you were testing salt concentration and its relationship to product formation in an enzymatic reaction, you should search publications in which the authors describe the effects of different salt concentrations on the enzymatic activity of similar enzymes. This should be the longest section of your report, and you may use up to 12 sentences for your data interpretation.

- *Begin this section by stating whether your data support your hypothesis. Since this is a short format, you do not need to restate the hypothesis. The main point of your discussion is to explain the effect of the independent variable on your dependent variable. What is the underlying mechanism? Why is product A more effective than product B? Do not repeat your results in this section. Discuss your findings in light of the findings of others who have conducted similar experiments, and remember to cite those primary references correctly. Because of the space limitation, please refrain from explaining what could have gone wrong or where your research could go in the future*.

6. **Literature Cited.** List the references and the sources you cited in your text following the author–year format. Include a list of your references at the end of the document. You must use the proper format for in-text citations and references, which is described in detail at the end of your syllabus. In the Literature Cited section of your report, include all authors' last names and initials, year of publication, and full title of the paper, article, or book. For journal articles, you must list the journal name (abbreviated form is fine), volume, issue number if available, and inclusive pages. Books must be identified by publisher, place of publication, and inclusive pages. Please refer to Pechenik's (2007) *A Short Guide to Writing about Biology*, chapter 5, for more information on how to cite your references correctly.

- *At minimum, you should have three references: one for your background information and two for your discussion. At least two of those, typically the ones you use in your discussion, should be primary references from peer-reviewed journals. In many cases, your textbook will be useful for the background information. If you do not include at least two primary references, the highest grade you can make for this section is 60%. Keep in mind that opinion articles, encyclopedias, and Wikipedia are not considered sources of scientific information.*

Miscellaneous Directions for Your Mini-report

- Always follow the verbal and written instructions provided by your instructor. Make notes so you don't forget.
- Use Arial font (size 11). The Literature Cited may be presented in a smaller font if extra space is required (size 9). Margins: 2 cm on every side.
- The maximum length of your mini-report is ONE page.
- If you are using scientific names of organisms, you must use the appropriate binomial nomenclature and italicize the text. For example, *Caenorhabditis elegans* or *C. elegans*.
- Make sure the font type, font size, margins, and maximum extension (one page) of your document are correct. If you do not have strong writing skills, take your work to the University Writing Center and get help.
- Make your report consistent. If your title reads "Effect of mouthwash alcohol concentration on *E. coli* growth," you are stating your dependent (growth) and independent (alcohol concentration) variables. Your hypothesis should reflect that you expect these variables to interact. Your graph must have "Average diameter of growth inhibition" on the y-axis and "Alcohol concentration" on the x-axis, along with the corresponding units for these measurements or calculations in parentheses. Since concentration is a continuous variable, you should have a line graph. This is what it means to be consistent. Your narrative and research of the literature should also relate directly to these general themes.
- Keep in mind that scientific writing is conventional, uses only established abbreviations, and should be clear, concise, and accurate. In addition, scientific writing uses formal language, avoids quotations, and is objective. Write with your audience in mind (college freshman level).

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