"*I received your letter about the fruit flies...*": Interdisciplinary Scientific Correspondence as a Means of Transforming the Laboratory Experience

Susan Manahan, Gardner-Webb University
Tom English, Guilford Technical Community College

In both general studies and major science courses, an important goal is to establish the process of doing science – not just the facts. Scientific ways of knowing and communicating are an important part of the process, a part that is sometimes neglected in courses that survey particular fields.

One means of evaluating student understanding of methods employed in science is through assessment of writing that attempts to convey the processes involved in doing particular scientific investigations. Traditional laboratory reports provide a well-worn way of doing this, but their formal structure can inhibit student expression. Alternative assignments can allow students to explore the material interactively and openly, and thus give better insight into their grasp of concepts and procedures. One such alternative is to shift the audience so that the students must write about the experiments for someone other than the instructor.

Examination of the correspondence between scientists working on different projects provides insight not always apparent from the final publications of the research results. These letters reveal a glimpse into the inner workings of scientific inquiry, shedding light on procedural details, flashes of recognition, and the struggle toward understanding. Given this model, we have developed a cross-disciplinary assignment that asks genetics and astronomy students to articulate the concepts behind their experiments and observations through correspondence between class members. The project was implemented during fall 2000 at Gardner-Webb University.

The Participating Classes

The astronomy and genetics courses at Gardner-Webb have followed somewhat traditional laboratory sequences during recent years. Assignments varied from the traditional lab reports to task-oriented exercises with result/observation forms and follow-up questions, but each course included a handful of long-term projects that required regular observation and analysis.

The Honors astronomy class has been offered at Gardner-Webb in alternate fall semesters for the past decade. Twelve students were enrolled in the fall 2000 class, and over half were freshmen. The course satisfies the university's core physical science requirement, so it is possible that it could be the only physical science course in a student's program of study.

By coincidence (thus simplifying the logistics of the assignments) the genetics class also had 12 enrollees. The course is a 300-level biology offering whose general population is non-freshman science majors. It is offered every fall semester. The fact that each class had twelve students allowed one-to-one partnerships for the letter-writing program, so no strategies for dealing with unmatched numbers were necessary.

Motivation

The idea for this project arose from discussions about our disappointment with the progress students were making in ongoing laboratory assignments involving effort outside of the actual laboratory period. A common goal of both courses was to give the students a laboratory experience which included more independent investigations and required critical analysis and interpretation of results. Attempts to do this through traditional laboratory reports had betrayed a lack of effort to keep up with extended assignments. The work students did perform was often shoddy, rushed, incomplete, or improperly sequenced. Lab reports often contained poorly interpreted data, or in some cases unfathomable results, and the students did not always provide adequate discussion of the laboratory purpose or procedure in their write-ups.

In a few extreme cases, students who waited too long to complete the assignments gave up because they were overwhelmed with the work which needed to be finished. These students never handed in final results and did not learn the major points of the assignments or benefit from the critical thinking experience needed to finish the lab work.

Astronomy observing projects had been disappointing because of a general lack of useful results. On one level, it was obvious that these problems stemmed from the fact that the students did not make enough observations to achieve the assignment objectives. Discussions with the students indicated, however, that the problem was not just laziness. Many of the students did not fully grasp the concepts behind the observations and were reluctant to expose themselves by asking questions. Thus as the semester rolled by and the students made inferior observations, or worse procrastinated due to their uncertainty, opportunities for learning were missed.

One year featured an uncomfortable early November meeting in lab where eight students presented their data from six weeks of regular observations of two variable stars. Only a dozen observations were offered, and no analysis could be done with the scant data. This episode did get their attention, and after several questions (never asked in the prior weeks) were cleared up and the observing criteria were re-established, project-salvaging data were collected over the closing weeks of the semester.

In prior years, genetics students completed lab experiments in biotechnology by performing DNA electrophoresis. These laboratory experiments were completed over two or three lab periods, and students were then required to submit a lab report on their results. These lab reports were often hastily written, poorly organized, and lacking pertinent information. Many students were following the directions for completing the lab assignment but did not understand or could not explain the main objectives of the exercise.

Situations like these called out for fresh approaches that would transform the assignments. To encourage students to confront issues earlier, we developed the scientific correspondence project. This required them to explain concepts, procedures, and results of the long-term lab exercises throughout the semester. Our intention was to raise the level of critical thinking and avoid past problems through peer interaction and inquiry.

We hoped that student correspondence between the classes would force the students to learn the details of the topics early in the semester so that they could articulate them in the letters. With the background material more firmly established through this approach, we expected better results. Additionally, we hoped that the shift of audience would encourage students to communicate their results more clearly. Knowing that not just their instructor would be reading the material, but that persons with less background would also have to be able to understand their writing, might be enough motivation for the students to submit more complete work.

Implementation

After a brief discussion of the assignment in the opening lab meetings, the scientific correspondence model was established through distribution of examples from well-known scientists in fields related to the courses. It was somewhat difficult for us to find readily available correspondence between scientists, especially in the library of a small university in rural North Carolina, but examination of the holdings at several larger state-universities turned up a number of collections of material relevant to this assignment. Easy access to archival material would provide an even greater body of material to use as examples for projects of this nature. The correspondence used for this project included exchanges between George Ellery Hale and Albert Einstein (Wright), and Charles Darwin and Alfred Wallace (Marchant). Letters to a variety of persons from Caroline Herschel (Herschel), William Herschel (Lubbock), and Gregor Mendel (Iltis) were also used. Mendel's correspondence was especially applicable for our assignments because it included notes on both genetics and solar observations.

Information was also distributed about expectations for the project. In the astronomy class this was done through a detailed guide sheet before each letter in the correspondence sequence (see Appendix). Students in the genetics class were given a guide sheet to help them initiate the correspondence with the astronomy students. For subsequent letters the genetics students were given oral instructions on expectations, rather than specific guide sheets. Questions about the letters or their format were discussed in class as needed, and occasionally specific discussions were necessary when the letters got ahead of the lecture material or topics required clarification. These discussions were sometimes initiated by students, but in most cases initiated by the instructors in anticipation of problems.

Following the initial laboratory exercises, students in the genetics class composed letters introducing themselves and their projects. After introducing themselves, they gave a brief overview of the fruit fly experiment. Explanations of their results would be forthcoming in additional letters. The letters were distributed to the correspondents in the astronomy class, with photocopies to the instructors for evaluation. The astronomy students responded to these letters, offering information about their own work. The resulting series of response/report/inquiry letters presented an interactive forum through which observation and analysis were shared—a dialogue was established between members of the corresponding classes.

The Fall 2000 astronomy class was taught as a "Great Works" course modeled on the history of our understanding of the universe, and the laboratory and observing exercises were built around this concept. They included measurement of Earth's circumference, observation of the seasonal variation of time and position of sunset, detailed sunspot observations (with a co-reading of Galileo's *Letters on Sunspots*), observations with homemade telescopes and position-measuring devices, and analyses of planetary motions and moon phases. Topics for the correspondence were limited to these projects, with emphasis placed on the solar observations.

The genetics laboratory experiments were divided into three areas: Mendelian genetics, cellular genetics, and molecular genetics. Extended laboratory experiments in which the students were to write letters included fruit fly matings and DNA electrophoresis. In the first extended lab, fruit fly matings were conducted to observe genetic inheritance of eye color and wing structure. After successful completion of the matings, student correspondence consisted of explanations of the statistical analysis conducted on the results. The second extended lab consisted of isolation and digestion of bacterial plasmids which were characterized via DNA electrophoresis. Explanations covering procedures and interpretation of DNA gel results were the major topics for later correspondence.

The criteria for evaluating the letters included clarity, interpretation and analysis, and response. We looked for clarity of explanation of concepts, procedures, results, and conclusions for the experiments and observations reported. It was necessary for the letter-writers to provide introductory information for their correspondents, who were assumed (with good reason) to have little background, so that the objectives of the lab exercises could be understood. Interpretation and analysis of the data were included as a basic requirement of the laboratory exercise, allowing the instructors to gauge the student understanding of the basic science being carried out. Finally, the students were instructed to interact with their correspondents about the materials in the letters. We wanted them to ask questions and make comments about the information they received. Scoring of the letters for the project grade depended on the individual instructor, but each included these three criteria as the major evaluation points.

Results: The Letters

The students were asked to introduce themselves in the first letters, but many were reluctant to talk much about themselves at first and instead dove right into the experiments and observations. There were a few exceptions, and one student even went so far as to indicate how he could be spotted on campus. The letters did get more conversational later as the connection was established between correspondents.

The old adage that "misery loves company" was borne out, as many took the opportunity to express sympathy and echo frustrations when experiments went awry or struggles with difficult concepts were indicated. "Don't be discouraged," one astronomy student wrote after learning of problems with the fruit flies, "now that you have the female flies, I am confident that you will figure out your results soon." Troubles with the fruit flies led the genetics class to pool their data for part of the studies, and brought many sympathetic responses from the astronomy students. "I'm disappointed to announce that our fly experiment has failed," one genetics student wrote, before detailing some of the partial successes and offering extensive error analysis. "I'm sorry that the second half of your experiment was unfortunately termed a failure," came the response. "It is obvious to me that you were up against many complicating factors… Still, it seems we learn from mistakes, though what we learn is not necessarily what we were searching after."

Some correspondents were familiar with the experiments the other classes were undertaking, and thus could comment without being led along. For instance, one astronomy student wrote, "You seemed to be having trouble with your electrophoresis! I've done that experiment before so I know how difficult it is. That was a great idea to put the child's DNA in between Father 1 and Father 2! I'll bet it made it a lot easier to compare the lines."

Sometimes frustration was expressed from the receiving end: "In your latest letter I found Chi Square analysis very confusing to try to comprehend without some form of explanation to go along with it. In your next letter if you could attempt to include at least some minimal explanation I would appreciate it a great deal." Many general questions appeared throughout the letters, for example: "It seems like the cross breeding of fruit flies is a pretty interesting experiment. My first question to you is, by how much do the vestigial wing types vary from the wild wing types? This observation sounds like it would be very difficult to make with the naked eye, because I wouldn't imagine these flies to be very big."

Some students, after struggling to provide their explanations, even expressed their own recognition of the difficulty involved in presenting the concepts clearly. "Wow, that is a difficult procedure and kind of difficult to explain," one student penned before adding that she'd be happy to answer any related questions. The connections between correspondents extended beyond information exchange and sympathy/frustration to include recognition of the general connections between the courses. One student reflected in his second letter, "Your class experiments seem to parallel ours in that both are hands-on explorations made in the same manner as those done in the formative stages of each discipline. Both of us, it seems, are acquiring an appreciation of the difficulty and peculiar frustrations of these pioneering experiments."

Most correspondents attempted to address the questions posed, typically with success: "I enjoyed reading your letter, and I understand what you are doing a lot better now." Occasionally, however, the exchange brought us into uncharted territory.

Since the astronomy class took the historical approach, we didn't really get into the cause of sunspots early on, but rather explored Galileo's arguments about their nature. So when the genetics students inevitably inquired, "I'm curious about what a sunspot really is…," there was a flurry research and in-class questions from the astronomy students. There were similar unexpected twists in the genetics class. One astronomy student conjectured, "Is it possible that a 'bottleneck effect' will occur, resulting in an abnormal representation of mutations because of the limited number of flies?" Upon reading this the genetics student was visibly shocked. She had not heard of such a thing, and did not know how to respond without doing further research. A class discussion unfolded from this inquiry, necessitating coverage of population genetics a few weeks earlier than planned.

Some students soldiered on without bringing questions from the letters into the class discussions. When one student was asked if Earth's motion influences the results for measured solar rotation, she thought the matter through and produced a lengthy (and correct) discussion of parallax effects. The exchange unfolded before the planned introduction of this particular wrinkle into the general course presentation. A few of the astronomy students took advantage of the letters to talk about other things they had learned in the class, such as meteor showers or eclipses. For instance, one student shared, "I want to make sure that you are aware of the eclipse on Christmas day this year. It should occur around lunchtime on the 25th."

The letters also provided opportunities for the instructors to catch and correct misconceptions. After receiving feedback about a miscue in an earlier letter, one student wrote, "The method I mentioned in the last letter was the correct one, but the diagram was not completed…." The letters thus transformed the standard method of feedback and revision by allowing both instructor and peer to interact with the material in a different format. In the traditional lab reports used before this project was introduced, there was little opportunity for such interchange.

Discussion: General

As can be seen from the samples above, results from our first attempt at this project were promising. Students had to deal with inquiries coming from different viewpoints, thus they were challenged to confront concepts in new ways. Some found themselves conducting additional research to answer the questions posed. The pressure to impress an audience apart from their instructors helped drive the students to make sure they had good observations and data to exchange. The sequence of letters also helped the instructors give feedback on the progress of the observations and experiments. As a result the students prepared more complete interpretations of their results and observations, helping themselves and their correspondents to better understand their experiments.

This was a popular assignment, as most participants freely admitted that it was a refreshing twist on the traditional laboratory report approach. Students compared their responses, and as the semester progressed they eagerly anticipated responses from their peers, as demonstrated by an interesting incident in the genetics class. Roughly mid-semester the students received the results from a recent test, followed immediately by the distribution of the letters from the astronomy students. One student had become so interested in the correspondence that she bypassed the test grade to look at the latest letter.

The need to communicate forced the students to confront aspects of the material or details of the observation/experimental processes that they may have glossed over in the past. This was especially evident in regard to the terminology related to the various projects. Faced with the necessity of explaining the details of a procedure, students made sure they had a firm grasp of the vocabulary associated with the projects at hand, and some even provided glossaries of terms with their letters.

Discussion: Astronomy

The observing projects that were reported in the letters were generally successful when compared with prior experiences. Though some students were still somewhat lacking in their observations, there was no episode like the variable star experience of the previous class.

The sunset observation program, which had been assigned in several earlier editions of the honors course, generated more and better observations in fall 2000 than in any other year. Given the wealth of observational data, the students were able to predict future behavior, explore the reasons behind the observed phenomena in detail, and communicate the nature of the phenomena.

In the case of the sunspot data, which required daily observation in order to gain a clear understanding of the phenomena at hand, the observing duties were split up during the week and data were shared among the students. Certain students claimed ownership of the project to such an extent that they participated in observations even on days they were not assigned. On several occasions, when observing opportunities were missed by other students, the data collected by these conscientious students helped make the letters successful for all astronomy participants.

As a whole, the class performed much better on the final summary assignments related to each of the observing projects than had been seen in the past. Having to keep on top of these projects all semester long so as to produce informative letters certainly played a role in this success.

Discussion: Genetics

The letter writing assignment also proved to be a successful tool to assist the genetics students in completing their assignments with greater understanding. The students were more focused on lab work and worked harder to complete their assignments. Most of the lab groups completed the fruit fly matings, allowing students to share data to conduct statistical analysis on their results. In a few groups, when the results did not agree with the expected hypothesis, the students were able to contribute reasons for these disagreements. One popular mistake made by several students was mating flies to get results that matched their hypothesis. Since the hypothesis was wrong, they would never successfully complete this mating. A few of the students realized this only after trying to write letters to explain what happened. They discovered they needed to change the hypothesis about what happens in the matings and not try to get the data to fit that hypothesis. Rarely has this level of critical thinking occurred in previous years when students conducted fruit fly matings. Successes extended beyond the fruit flies. The students' discussions concerning molecular genetics were quite thorough and organized. The students also were more enthusiastic about their interpretations of the gel electrophoresis than in previous years.

Conclusion

The scientific correspondence was a positive experience for all involved. Both the students and the instructors looked forward to reading the letters discussing the successes and failures that were occurring during the extended lab assignments. The correspondence provided an additional opportunity to observe student understanding and depth of exploration of the topics.

There is certainly room for improvement in this assignment. Students did not always adhere to the general instructions for content of the letters. We tried not to be so rigid that creativity was inhibited, but sometimes the students avoided certain issues or topics. For instance, many did not properly introduce themselves in the initial letters, and despite the occasional insightful question, many letters tended to be short on inquiry and long on explanation of specific results. Providing more detailed information on the expected interaction might help alleviate these shortcomings.

We were fortunate to have the same number of students in each class, allowing one-to-one partnerships for the letter-writing program. Before the semester we discussed potential strategies for dealing with unmatched numbers, such as working in small groups, allowing an instructor to participate as a mock student, or not having permanent partners. None of these options, however, would have worked as well as the matched partnerships we were able to apply.

In summary, the interdisciplinary correspondence project was worthwhile because it transformed the reporting of scientific results from the traditional dry lab report style to an interactive format that emphasized communication and inquiry. With expansion of the audience to include peers as well as instructors, we saw more thorough explanation and attention to detail in the analysis than in past editions of the courses (where the students wrote for the eyes of the instructors only). Students seemed to enjoy the new approach and even took the extended assignments more seriously. In addition, they were exposed to, and inquired about, topics from fields outside the disciplines of the courses in which they were enrolled, thus broadening their horizons.

Works Cited

Herschel, Mary Cornwalis. *Memoir and Correspondence of Caroline Herschel*. New York: Appleton, 1876.

Iltis, Hugo, *Life of Mendel*. New York: Hafner, 1966. 224.

Lubbock, Constance, ed. *The Herschel Chronicle: The Life-Story of William Herschel and His Sister Caroline Herschel*, Cambridge: Cambridge University Press, 1933.

Marchant, James. *Alfred Russell Wallace: Letters and Reminiscences*. New York: Harper & Brothers Publishers, 1916. 120-140.

Wright, Helen, John Warnow, and Charles Warner, ed. *The Legacy of George Ellery Hale*. Cambridge: MIT Press, 1972. 66.

Appendix: Sample Guide Sheet for the Letter-writing assignment

Honors Astronomy Writing Project: Scientific Correspondence

The First Letter

Objectives:

A) Introduce yourself.
B) React to the information you found in the letter to you.
C) Describe how you found the circumference of the earth.
D) Briefly discuss your plans to observe sunspots and sunsets.
E) Describe how our solar observations are made.

A) No long-winded introductions are necessary here - you will be given a letter from a student in the genetics class, so you'll already know the identity of the person with whom you will be corresponding. In addition to telling who you are it might be informative to say something about the nature of this class.

B) Read the letter you received from the geneticist. It should tell about an experiment they are working on this semester in such a way that you can follow what they are doing (and why they are doing it). Feel free to comment and inquire about the material in the letter. It is perfectly appropriate to ask questions about matters that you don't understand. If you're curious about anything that they're doing - ask about it!

C) By the time you write the letter we will have attempted to make observations associated with our effort to measure the circumference of the earth. Describe the observations we made and how we use them to find our result.

D) Introduce our two long-range solar observing projects: (1) the sunset observations, and (2) the proposed sunspot observations. Discuss them in general as you see fit. You'll have an opportunity to go into more detail regarding the sunsets in a later letter.

E) Adapt the sunspot observation description you turned in to me last week to describe for your correspondent the details of how the solar observations are made and what is visible.

Make sure that your discussion/description allows the reader to get a clear picture of what's going on. They should be able to understand enough of what you're doing to allow them to ask a few questions about your observations in their next letter.

Our letters should be a little longer than the ones we received from the genetics class - not only do we need to tell about our observations, but we also need to respond to the material sent to us. You should be able to generate about 2-3 single-spaced typed pages.

It might be informative to include sketches and diagrams with your descriptions. If you choose to do so, make sure that they are explained clearly.

It is also instructive to include discussion of any problems you are having making the observations or analyzing the data. Not only will this give your correspondent something to inquire about, but it can inform the instructor about any troubles that you are having.