Colleagues Explain the Value of Writing to Learn

One of the premier things that writing does for the student is that it forces them to clarify their own ideas. Writing assignments help mathematics instructors gage what their students’ processes of reasoning are—not just whether they’ve arrived at the right answer...the only way to actually get that kind of information is to actually ask them to explain it to you. And if they’re going to explain it to you, first of all, I believe they have to explain it clearly, and concisely, and that requires organized thinking. It’s not just for that sort of assessment purpose, but it has actually pedagogical value.

Robert Megginson, Arthur F. Thurnau Professor of Mathematics
http://www.lsa.umich.edu/sweetland/instructors/thurnauprofessorsontheimportanceofwriting

Students leave my course [Writing in Biology] looking at things in a different way [because of the writing], maybe being more aware that science is a three dimensional field, rather than just the science they see in a lab. We have lots of students doing undergrad research. But in a way, it’s really one dimensional to just do the research—to just stand and fill tubes and do enzyme assays or something like that. But to really know the scholarship behind it, and also the scholarship that comes from it—I really wanted to flesh that out for them…..with writing.

Laura Olsen, Arthur F. Thurnau Professor of Molecular, Cellular, and Developmental Biology
http://www.lsa.umich.edu/sweetland/instructors/thurnauprofessorsontheimportanceofwriting

If you look at alumni surveys that we do one, five, and ten years out, the importance of reading and technical writing rises to pretty much the top skill that alumni say they need. I think there’s probably nobody in engineering or the sciences who would not see and value the importance of writing. For example, I think that writing is a very important element of guiding you through the whole scientific process. If you cannot communicate what you plan to do or what you did, it’s as good as if it wasn’t done. I think it’s important for students to see and learn that writing is not optional; it’s an integrated and vital part of their engineering work.

Volker Sick, Arthur F. Thurnau Professor of Mechanical Engineering
Best Practices for Creating STEM Writing Assignments

Focus on Key Concepts
Identify areas where students typically encounter conceptual problems and create assignments that ask them to explain the relevant concept. Creative approaches, including specifying an audience outside the field, can be effective.

Use Accessible Sources
Rather than asking students to write about concepts based on class lectures and the textbook, provide them with accessible supplementary material on which to base their writing. Examples of possible sources include images, spectra, graphs or other data, popular science articles, historical literature, or authentic situations such as having students read about scuba diving in order to respond to an assignment about gas behavior.

Specify Genre or Type of Writing
In order to make assignments more engaging for students, consider a wide variety of genres such as letters, op ed pieces, instruction manuals, explanations, scripts, and blog entries.

Indicate Audience and Purpose
Another way to make assignments engaging for students is to specify audiences outside the class such as school children, groups organized around specific issues, or adults with a general interest in science. Similarly, specifying a purpose such as persuading a specific set of readers or conveying important information can engage students.

Provide Guiding Questions
Students often find it helpful to have questions that follow the assignment itself and suggest possible issues to consider in writing a response. Guiding questions direct students in their writing so that they focus on those aspects of writing that will contribute most to meaningful learning of the topic.

 Require Revision
To get maximum benefit from writing about a concept, students need an opportunity to think about the concept more than once, and requiring revision guarantees that they will do so.

Include Criteria or Rubric
In order to write effectively in response to an assignment, students need to understand what is expected of them, and a list of criteria for evaluation or a rubric will provide this.
Example Physics Writing Assignment: Sound and Waves

You are a high school music teacher. A few orchestra students begin arguing with some band students about how music is made. They have each been told different information about how their instruments work and become confused. Using what you have learned about waves, harmonics and resonance, you are able to clarify the differences and similarities for these students.

Writing Task: Write a 300-500 word lesson plan in which you explain to your students the physics of music. You should begin by explaining sound and waves in their most basic sense. Following this, discuss how wind instruments and string instruments differ, focusing on resonance and harmonics. Lastly, compare and contrast how different pitches are made on different types of instruments.

Questions to consider:
1. What is a standing wave and what is its role in creating sound in various instruments?
2. How does resonance play into the picture?
3. How do open and closed tubes differ?

Peer Review Rubric: Sound and Waves

Instructions:

1. Provide specific, constructive comments for the writer indicating to what extent their writing conforms to the material covered in class. Does their explanation of waves align with the explanation you learned in lecture? Are their examples easy to understand and accurate? Does the paper address the following aspects of the physics of music:
   • Open or closed tube
   • Destructive interference
   • Beat frequency
   • Tension and standing waves
   • Harmonies and overtones

2. Provide specific, constructive comments for the writer about the style of his/her paper. Is this paper easy for you to read, with a clear organization? Point out any specific sentences that need editing or revision and offer suggestions about how this writer might address the issues. If the paper is not of appropriate length, how might the writer add or condense content to meet the assignment requirements?

3. Does the article address a non-science audience? Does it explain sound and waves effectively to that audience?
Design a STEM Writing Assignment with Peer Review

Activity 1:

“If you can’t explain it simply, you don’t understand it well enough.” - Einstein

1. Select an important topic with which students in your class struggle to develop sufficient conceptual understanding.

2. Briefly describe the non-science audience for which the writing assignment will be focused.

3. Briefly describe the purpose of the writing.

Activity 2:

Identify and describe two guiding requirements that will direct students to engage with the specific content that they will be writing about. These requirements are also used during the peer review process to ensure that students carefully analyze each other’s writing for content. See the writing assignments on pages 9-12 for examples of content-directed requirements.

1.

2.
Best Practices for Automated Peer Review in STEM Classes

Provide a Help Guide for the Technology
Because students will be encountering the automated system outside of class, they may encounter difficulties uploading or downloading selections of writing. A troubleshooting guide will reduce their frustration and increase their productivity as writers.

Specify the Purpose and Process
Students need to understand that the primary purpose is not to improve their writing (although that may be a collateral benefit) but to deepen their understanding of important concepts. Given this purpose, students should be encouraged to focus on higher order concerns (rather than grammatical errors) in the writing.

Make Stakes Clear
Peer review needs to “count” in some way in order for students to take it seriously. Be sure to determine how the review process will be factored into students’ overall grade and make this clear to students.

Offer Models of the Process
Some students may not be familiar with drafting, receiving response and then revising writing, so it will be helpful to use examples to show them how the review process works.

Show Examples of Effective Commenting
Students will need guidance in providing feedback that includes concrete suggestions for improvement, examples, and rubric-based evaluations.

Insist on Respectful Language
Since the identity of reviewers may not be visible to the writers, make it clear that anonymity does not give students license to “flame” or otherwise.

Point Out Value for Responder
Students will often resist peer response because they don’t believe they can learn anything from another student, so they need to understand the value of reading another student’s response.

Examples of Automated Systems:

PeerCeptive (Formerly SWoRD): Panther Learning  http://www.peerceptiv.com/

Calibrated Peer Review: UCLA  http://cpr.molsci.ucla.edu/Home.aspx

ADDITIONAL Example Writing-to-Learn STEM ASSIGNMENTS

Physics Example 2: X-ray diffraction

In 1951, Rosalind Franklin, a researcher at King’s College in London, made a discovery that would influence all of modern genetics and understanding of molecular biology. Using x-ray diffraction crystallography, Franklin took pictures of DNA, revealing the helical form of the molecule among other important features. This contradicted the commonly held view that DNA had three chains, but Maurice Wilkins (one of her colleagues) presented her photographs to James Watson and Francis Crick. Within
weeks, Watson and Crick had built a model of DNA, for which they later received the Nobel Prize. During her lifetime, Franklin never received credit for her extremely important work. You are writing a journal article to explain the significance of her discoveries.

Writing Task: Write a 300-500 word article that explains how Franklin was able to determine the structure of DNA based on a simple x-ray crystallography photograph. Assume that your audience has some physics knowledge, but begin with an explanation on diffraction, interference and light waves in general. You must then explain the four major features in the x-ray that were key to understanding the structure of DNA.

Questions to Consider:
1. What is the significance of the missing 4th layer line?
2. What do the dark blobs at the top and bottom of the x-ray tell us?
3. How does a diffraction grating work?

The Requirements:
Assignments will be assessed primarily based on whether the author concisely explain diffraction, interference, and light waves. Authors should use these basic features in an accurate explanation of the major features of the x-ray that lead to understanding the structure of DNA. Writing should clearly convey key concepts, be easy to follow and be free of major errors (scientific and grammatical).

Peer Review Rubric: X-ray diffraction

Instructions:
1. Provide specific, constructive comments for the writer indicating to what extent their writing conforms to the material covered in class. Does their explanation of X-ray diffraction align with the explanation you learned in lecture? Are their examples easy to understand and accurate? Does the paper accurately use information from lectures about diffraction, interference, and light waves can be used to interpret X-ray data?
2. Does the paper adequately explain how Franklin was able to determine the structure of DNA based on X-ray data? Does the article address a non-science audience? Does it explain x-ray diffraction effectively to that audience?
3. Provide specific, constructive comments for the writer about the style of his/her paper. Is this paper easy for you to read, with a clear organization? Point out any specific sentences that need editing or revision and offer suggestions about how this writer might address the issues. If the paper is not of appropriate length, how might the writer add or condense content to meet the assignment requirements?

Chemistry Example 1: Oxidation-Reduction

One of the largest cellphone manufacturers has recently taken a hit in the market because of one major weakness in their product: inferior batteries. Compared with their competitors, their cellphones lack battery power. Once the cellphone is fully charged, the battery lasts for a maximum of eight hours. Customers have complained and the press is
predicting that the company will not survive unless they improve their product. The company’s product designers have failed to pinpoint the problem, and they’re looking for help.

**Writing Task:** As the resident chemist on staff your task is to help save the company by explaining why oxidation-reduction chemistry is key to building a better battery. You will write a 350-500 word memo to the company’s designers that explains what oxidation-reduction chemistry is, and how it is critical to creating an effective battery that will make their phones not only pretty, but also functional.

**The Requirements:**
Write a memo of 350--500 words that:
• Addresses a non-scientific audience of cellphone designers.
• Effectively explains oxidation-reduction chemistry.
• Explains how oxidation-reduction chemistry is critical to building effective batteries that hold their power.
• Includes an example oxidation-reduction reaction from the recent chemistry research literature with balanced equation. See hints below.

**Hints:**
Although you will not get in depth with battery chemistry in lecture there is a great chapter about it in your text. The most important thing is to demonstrate that you understand oxidation-reduction reactions.

To find a chemical equation from the literature, starting from any UM terminal you can do a Google Search of: Journal of American Chemical Society, Journal of Inorganic Chemistry, Journal of the Electrochemical Society, or Advanced Energy Materials. These journals are available electronically through the UM library. Or you can use Google Scholar, also from any UM terminal, and search "battery" or "cathode" and see what comes up.

See also the Purdue Online Writing Site for advice on how to write a professional memo: [https://owl.english.purdue.edu/owl/resource/590/04/](https://owl.english.purdue.edu/owl/resource/590/04/)

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**Peer Review Rubric: Oxidation-Reduction**

**Instructions:**

1. Provide specific, constructive comments for the writer indicating to what extent their writing conforms to the material covered in class. Does their explanation align with the explanation of oxidation-reduction chemistry that you learned in lecture? Are their examples easy to understand and accurate? Did the memo include an example oxidation-reduction reaction from the literature and was it correctly balanced?
2. Provide specific, constructive comments for the writer about the style of his/her paper. Is this paper easy for you to read, with a clear organization? Point out any specific sentences that need editing or revision and offer suggestions about how this writer might address the issues. If the paper is not of appropriate length, how might the writer add or condense content to meet the assignment requirements?

3. Does the memo address a non-science audience? Does it effectively explain oxidation-reduction effectively to that audience? Does it explain how this chemistry is crucial to building an effective battery?

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**Chemistry Example 2: Lewis Structures**

In 1916, Gilbert Lewis wrote an article for the *Journal of the American Chemical Society* explaining how, in his teaching, he used dots to explain the sharing of electrons between atoms.¹ On p. 774, after pages introducing the topic and explaining the background behind his ideas, he starts a section called “Molecular Structure.”

Imagine you are a student researcher in 1916, who has just been given this paper to read, and report on, for your chemistry research advisor. Your task is to summarize, in 350-500 words, Lewis’ main points in the “Molecular Structure” section (pp. 774-783).

**Questions to Consider:**
1. Can you use your understanding of Lewis structures, nearly 100 years later, to summarize it more clearly and concisely than Lewis did?
2. What are the most important points that Lewis proposed in the nine pages he published in 1916?
3. How did Lewis improve on previous theories of molecular structure and bonding?
4. How are the ideas that Lewis proposed in 1916 different from how we understand bonding and molecular structure today?

**The Requirements:**
Assignments will be assessed primarily based on their ability to concisely explain the usefulness and novelty of using Lewis structures to think about bonding and molecular structure. It should compare to pre-Lewis models and to the modern model described in Chemistry lecture and textbook. Writing should clearly convey key concepts, be easy to follow and be free of major errors (scientific and grammatical).

**Peer Review Rubric: Lewis Structures**

**Instructions:**

1. Provide specific, constructive comments for the writer indicating to what extent their writing conforms to the material covered in class. Does the paper include all of the most important points made by Lewis in the 1916 paper? Does their explanation align with the explanation of Lewis structures that you learned in lecture? Are their examples easy to understand and accurate?
2. Provide specific, constructive comments for the writer about the style of his/her paper. Is this paper easy for you to read, with a clear organization? Point out any specific sentences that need editing or revision and offer suggestions about how this writer might address the issues. If the paper is not of appropriate length, how might the writer add or condense content to meet the assignment requirements?

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paper. Is this paper easy for you to read, with a clear organization? Point out any specific sentences that need editing or revision and offer suggestions about how this writer might address the issues. If the paper is not of appropriate length, how might the writer add or condense content to meet the assignment requirements?

3. Did the summary discuss how Lewis improved on previous theories of molecular structure and bonding? Does it discuss how the ideas that Lewis proposed in 1916 differ from how we understand bonding and molecular structure today? Note that Lewis introduces several important terms in his paper. Are they included in this summary? Does the summary also include terms or vocabulary that are used in Chemistry 130 lecture?