Stony Brook University

How we can Improve Science Writing

A Thesis Presented

by

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to

The Graduate School

in Partial Fulfillment of the

Requirements

for the Degree of

Master of Arts

in

English

Stony Brook University

August 2009

Stony Brook University

The Graduate School

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Abstract of the Thesis

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Scientists often have difficulty in clearly and concisely communicating their thoughts on paper. However, there have been many who went against the grain in terms of standard scientific writing convention in order to bring out their ideas not only to the scientific community, but also to society. Famous scientists such as Charles Darwin, James Watson and Francis Crick can be largely credited to their fame not only due to their landmark findings but also largely due to their unique and well-written papers where they went outside of accepted conventions to effectively make their points. Many scientists, especially those who discover remarkable new findings, cannot effectively communicate their ideas to their target audience in a way that is readable, understandable and interesting. Students, especially those in college pursuing careers that require a considerable amount of writing, need to learn these important skills before going out into the work force. Knowing how to produce clear, effective, writing makes for a huge advantage in a career such as one involving research, where having this skill makes a tremendous difference in improving a reader's understanding of a complicated scientific topic.

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Introduction

Many scientists I speak to ask me, having been a student of Biology, Chemistry and English, to help them revise and edit their writing. To my dismay, I see that many of these very intelligent people do not exhibit anywhere near the writing proficiency and ability that is expected of a student majoring in English. This leads to problems when, in their real world careers, they need to submit a paper to their superiors, or especially when it comes time to submit work to scientific journals. Through the cooperation of English and Science departments, colleges can help teach those who aspire to become scientists to improve their writing. Many scientists lack basic writing skills that all who study English come to take for granted, which then impedes them from effectively communicating their findings. Through the use of teaching methods, which include more writing components in classes, students can both learn the material better and also gain valuable writing skills that can then be transferred to their real world careers.

Science textbooks and journal articles tend to exhibit a third person past tense writing style that also makes heavy use of the passive voice. The author is as far detached as possible from the writing itself. This makes the reading very boring and many times this style makes the writing harder to follow. The lack of the author's personal voice in the work also tends to hamper its clarity. This is the defacto, "acceptable" convention for most scientific journal writing because the idea is to present an unbiased, objective, account of the work being presented. However, as we will see, the more famous scientists, such as Charles Darwin, James Watson and Francis Crick stepped outside of these conventions. They made their writing more personal, which, in turn, got them noticed above all others, namely due to their writing being accessible to

the lay person (Halloran). Also, by putting their own voice into their papers they were able to tell the audience how important their work was above all the other similar papers and have a sense of authority not present in other works, therein making their arguments stronger. A major point of contention in this paper is that while it may be important to follow established convention to some level, this is not the be all end all for being published and recognized for one's work. Creativity will always stand out above everything, especially when the research amounts to an extraordinary finding and can speak for itself. As we will see later on, even though Oswald Avery *et. al.* published a very important paper on the findings of DNA nine years before Watson and Crick, the latter authors, according to Halloran, were given credit due to the much more creative and authoritative writing they produced, which broke standard convention.

Taken together in all their forms, science writing itself can also be considered a form of literature. Many associate scientific writing with the bland, drab nature that has become characteristic of writing throughout the science fields. Poorly written science textbooks contribute greatly to students' misinterpreting of just how interesting and exciting science texts can be, because the standard writing style presents the material in a manner that bores them and makes them uninterested in wanting to read and understand the material. This, in turn, gives the students a much more difficult time in understanding the subject matter. However, when someone reads the work of Charles Darwin's <u>The Origin of Species</u>, it becomes surprising to see just how exciting science writing can be and also how accessible to the public it can be made through its understandable simplicity. The irony of Darwin's work is that while he tones down the jargon he does not do it at the expense of sacrificing the theory by being forced to dumb it down. He was able to put his theory into a manner that was just as detailed but also accessible to

the general public while also acceptable to the scientific community. As with all groundbreaking scientific work, the findings were of course debated by scientists, and eventually accepted.

In today's world, science writing is a genre of literature that is increasingly becoming a greater part of today's social structure. Science and technology permeates society more than ever, and a working knowledge of scientific principles is becoming more of a requirement for mere survival in today's world.

What is the problem?

If a person cannot convey his or her ideas well, nobody is going to want to read them nor will their ideas make sense. The problem with most current scientific papers is that since there are increasing amounts of discoveries every day, more and more works are being published. Science cares so much about the facts, to the point that as long as the facts are at least somewhat intelligible, they have a good chance of being published in a journal. Regardless, more and more scientists are being produced in today's increasingly scientifically advanced society, and with this emphasis we tend to brush writing quality aside because the facts and the scientific details are considered the most important. The problem we are faced with is that the quality of writing seems to be decreasing in an age of massive new discoveries where the facts are severely overshadowing writing quality, and most importantly, clarity. However, well-written and textually engaging writing is always appreciated by the scientific community due to these sorts of papers being more interesting to read, much more intelligible and the work more easily

reproducible. While bad writing may, most of the time, come out as an eyesore, in science it can mean the difference between truly understanding what the author accomplished in his or her experiments or even whether or not the experimental procedure is written well enough that another scientist can follow it and reproduce the work.

As a scientific community, there needs to be a change from the "just the facts are important" mantra to the idea that the quality of the writing is just as important as the facts. If one cannot interpret the facts because they are not clearly written out and understandable, then the facts do not mean much. A major problem comes in interpretation of the literature.

While the facts may be written out on the page, their interpretation might differ from the author's intention if they are not clear. For example, an experimental procedure in an inorganic chemistry synthesis I once followed had a significant problem in this respect. In inorganic chemistry, most chemical reactions are carried out in an inert atmosphere, meaning there can be no oxygen present, so nitrogen is instead used. However, for this one step in the procedure, it was necessary to expose the reaction to oxygen. However, the procedure said something like "the reaction mixture was exposed to air five times by putting the mixture under vacuum and then opening the stopcock. Then the reaction was stirred under air for 3 hours." While this may seem clear at first glance, to a chemist this can bring out questions. It was unclear whether the reaction mixture needed to be closed after brief exposure to oxygen so that only the amount of oxygen in the mixture would be allowed to stay, or if the mixture was supposed to stay fully open and exposed to air. With syntheses like these, one has to be very specific with all aspects, especially when it comes to oxygen exposure because long-term exposure to oxygen, by keeping the mixture fully open to the atmosphere, could cause the entire compound to decompose. In science

as opposed to English, as will be addressed later, only one method out of a few possible ones is usually correct and if the scientist interprets the information incorrectly it could cause a tremendously different experimental result to occur than what is trying to be attained. Especially when trying to reproduce someone else's work, simple questions such as this can cause major problems that can take a very long time to figure out, even if it is something simple. Because many possible interpretations may exist, finding the one correct method can be very painstaking. This is why attention to detail and clarity is extremely important when it comes to scientific writing. Even trying to reproduce work that was previously done in the same laboratory by former students is challenging since the writing has to be extremely clear in what needs to be done because even the slightest lack of clarity or error can cause a dramatically different result.

Along with the issue of clarity also comes another problem. My major issue, along with most everybody else's, was not a lack of understanding of the scientific theory or of the assignment itself, but the inability to write clearly and sustain an effective argument. When explaining the facts it is also important to argue one's point clearly as well as being specific in what occurred in the experiment and the analysis of the results. I lacked the basic fundamental writing skills required to produce a good paper as well as needing help in getting a better sense of detail. I always understood the importance of being able to write well, but after that first year of college I realized that I needed to become a better writer if I wanted to not only make it through college and in the work force, but also if I ever wanted to be published. Writing has many facets to it; understanding all of the different aspects and having a firm grasp on them produces clearer, stronger and more fine-tuned works. Scientists possessing these qualities are rare these days, which offers a distinct advantage to those few over the rest of the scientific

community in terms of attracting people who are willing to read one's work as well as people who are *able* to understand that it. While many papers are field-specific, there are also papers that could be understood by the public if they were only written intelligibly enough to be understood by mainstream society! What I am looking to examine is how to get more scientists to improve all aspects of their writing skills so that the scientific community as a whole, as well as the lay person, can benefit from more people who can convey their work and arguments more clearly and effectively. The best time to improve these skills is while students are in college, namely as undergraduates, as they are learning their specific field. It is important that students learn writing techniques through professors of both the scientist's discipline and also through the school's mainstream writing program. However, the roles of these two departments are significantly different.

It is the responsibility of English professors to teach students transferable writing skills. Exposing them to scientific writing would show that these papers are not really so different from what they would write for an English class. While the format may be a bit different, science writing still encompasses many of the same characteristics, just presented in a different manner. For example, they contain a thesis statement in the form of a hypothesis, with the main body of the paper arguing either for or against the hypothesis based on an analysis of the data collected and what the authors claim to have discovered. They also contain a conclusion that sums up the entire paper. And just as in analyzing a piece of literature, other scientific texts are cited to support their argument and to explain relevant experimental data.

A major reason why students have so much trouble with science writing is that they only know how to write in the one style acceptable throughout high school: in the third person past

tense in order to keep themselves as far detached from the work as possible. They likely pick up this detached, impersonal, writing style from a few sources: textbooks, lab report writing and the characteristic five-paragraph essay writing format learned in high school. They are instilled in them from when they are young that this is the only acceptable academic writing style. In college English courses, students learn that this is not the case and that in real world writing strong works are ones that embody the author's presence and voice. Most students I see always say the only correct way to write scientific papers is to strictly stay in the third person passive voice. This is strictly enforced in laboratory classes because professors are concerned with the students getting the facts and details correct and not allowing anything else to get in the way or make these reports biased in any way. However, what the professors do not tell the students is that these reports are merely exercises to ensure good laboratory practice and non-bias in the experiments themselves. The laboratory report writing style is strictly meant for the academic setting and not that of the real world because the author's conclusions and their interpretation of the data are essentially their own. Many students get caught up in the idea that this one style of writing is the only true acceptable form at the professional level. Clearly, this is not the case. It is a common misconception that is likely a major cause for the writing problems seen on such a massive scale within the scientific community today.

In this paper, I examine mainly higher order concerns, which focus on writing style and argumentation. While lower order concerns that encompass such aspects as proper grammar are still very important, higher order problems mainly plague writers in the scientific genre. Here, I will look to change the view on how scientific writing is perceived and taught to students. We will see examples of famous scientists who made their discoveries known to all through their

creative, unique and accessible styles of writing, such as Watson and Crick, Charles Darwin and Lewis Thomas and analyze why their work stood out from all the rest and they were given credit, although others came to similar conclusions at the same time. Also, we will see some examples of methodologies taught to aspiring scientists that are promising in helping them improve their writing abilities. From interdisciplinary classes, inter-departmental discussions and through writing in the science classes themselves to help students better learn the material while also improving writing skills. By getting students to think in new ways, by instilling in them more creative and novel practices, this will help them learn to write better for the scientific community as well as for real world audiences.

Why Does Good Science Writing Matter?

Incorporating more science writing into undergraduate classes would be invaluable to many students who aspire to go into scientific fields because they can see that while the conventions may be a bit different, the concept for the writing itself remains the same. This will also show students the importance of writing in a manner appropriate for a specific audience, in terms of both writing style and conventions, especially since scientific papers are strict in the high degree of formality they usually require. This can be helpful for future science majors in understanding that scientific papers do not just require a presentation of the facts because the facts are used to argue a specific point, just as in English writing. When students understand that scientific writing format is just a variation of what they are used to in English class, with all of

the writing fundamentals remaining the same, they will be better able to apply and transfer the skills they learn in English class to not only scientific audiences but also to audiences they write to in other genres, as well.

Another, more prominent, factor that mars many scientists' writing is their lack of writing training, altogether. In college, students do not get much opportunity to write scientific papers, or even papers in general, as most science classes are test-based and barely include any type of writing component, with the exception of a few assignments usually in the form of the traditional "lab report." This takes on a very different, much more standardized and structured form in terms of acceptable convention. These are somewhat analogous to the five-paragraph essay form that the New York State Regents Exam is concerned with, except here there is much less room for deviation without the risk of a penalty. Students are not given a suggested convention; they are required to follow it. The assessment of these assignments is very formalist in nature, where students strictly following convention and proper format in arguing their points are at the forefront in the determination of a grade. The focus becomes more of giving the teacher what he or she wants rather than gaining valuable writing practice. However, the problem with this lies in many students not having a good knowledge of the actual writing process, and furthermore how to utilize it in order to accomplish this goal. What many students lack is that they are unable to or have a difficult time making a successful argument for or against their original hypotheses. Many beginning scientists do not understand that they need to argue for or against something in their writing, so most students do not even formulate an argument! Many times, the students cannot be (but usually are) faulted because they are not made aware of this, especially since writing is not their specialty. Most undergraduate laboratory reports usually consist of a very basic summary of

what was done in the experiment and a short discussion of why their initial hypothesis was either right or wrong.

This leads to problems at the college level because students do not realize that although the lab reports still take on a strict and standardized form, much more is expected of them in terms of analyzing their data, utilizing theory and most importantly, arguing how and why their hypothesis was correct or incorrect. The attention to detail that professors look for, especially in introductory courses, is very overwhelming for students since most have never written papers that required sophisticated arguments. For the students who can argue a point fairly well, even though they may see the connections between the data and what they are trying to argue, most do not understand how to express their ideas clearly and effectively, due to their lack of practice. However, this needs to change, both within the science classes themselves and through the help of English teachers.

Models of Scientists who are also Good Writers

Not all scientists are bad writers, but only some realize that it is important to have at least a good knowledge of the craft, so they make sure to get it. Most scientists dismiss writing training as unimportant because they emphasize their experimental data as the definitive mark of a published paper. While good data is very important in a scientific paper, it is not the only important aspect, as most fail to realize. A good paper that will draw the attention of the

scientific community is also one that is engaging and makes potential audiences *want* to read it because the paper is written in such a way that makes people want to learn more about the topic.

Scientists who are not so well trained in writing may be unable to grasp the reader's interest because they simply do not know how or may not think that it is important for writing in the sciences. This is an important skill a writer learns in English class early on but then discards it when writing scientific papers because students are never taught in science classes that in the real world reader interest is everything. The teachers grading the lab report in college are looking for the correct facts and are unconcerned with how interesting or engaging the paper is. They care solely about the science, and this is where students tend to forget the importance of writing style. In the real world of writing, outside of class, this factor becomes extremely important for getting people to be interested in one's work.

Charles Darwin: An example of an effective and engaging writer

Charles Darwin is a very famous scientist because of his breakthrough theory of evolution through natural selection. Even though this article is directed toward teachers in the field of English, most, if not all, of the people reading this have at least a general understanding of this concept. Why is this? It is because it was not only Darwin's data that caused him to stand out with his theory, but also his effective and engaging writing style in his book, The Origin of Species, which brought his ideas out much more effectively than if done in the drab, traditional and formal manner that most scientific texts do. For example, he states:

> [w]hen a variation is of the slightest use to a being, we cannot tell how much of it to attribute to the accumulative action of natural selection, and how much to the conditions of life. Thus, it is well known to furriers that animals of the same species have thicker and better fur the more severe the climate is under which they have lived; but who can tell how much of this difference may be due to the warmest-clad individuals having been favoured and preserved during many generations, and how much to the direct action of the severe climate? For it would appear that climate has some direct action on the hair of our domestic quadrupeds (Darwin).

While his massive amount of hard data collected over the years gives him a strong basis for his argument of evolution through natural selection, he is able to communicate these ideas in such a way that most regular people can understand the concept without difficulty, and are also interested in reading the book. Darwin writes in a clear and concise manner that does not necessitate the use of obscure scientific jargon. He mainly uses simple scientific terms. The benefits of doing this are two-fold: he can effectively communicate his ideas to other scientists in an acceptable manner while also allowing the lay person to understand his ideas.

Lewis Thomas: An Example of Utilizing Creativity to Explain and Relate Biological Principles to Everyday Society.

Lewis Thomas, in his book, The Lives of a Cell, does an excellent job of relating biological concepts to real life by educating the reader on some aspects of biology (with an emphasis on medicine) and relating these concepts to society's behavior in a work that is presented in a very informal manner. He uses a tone where he speaks directly to the audience and not down to them. He does this in order to speak on mainstream society's level while not bombarding them with scientific terms that are too difficult for the lay person to comprehend. When he must use biology terms he makes sure to explain them. For example, in a chapter entitled *Germs*, he seeks to explain why people are so afraid of bacterial disease. He discusses that "[w]e explode clouds of aerosol, mixed for good luck with deodorants, into our noses, mouths, underarms, privileged crannies—even into the intimate insides of our telephones" (Thomas 75) because of the societal impression there is about 'germs' and how we need to defend ourselves at every opportunity. However, he goes on to say that "[t]hese are paranoid delusions on a societal scale, explainable in part by our need for enemies, and in part by our memory of what things used to be like" (75-76). Thomas starts the chapter with a creative approach, to interest the reader in the coming discussion and then goes on to say why this behavior of wanting to clean everything and anything occurs, which is due to a manufactured, rather than a real concern. What is fascinating is how he blends medical science into the discussion to help show that this is more a manufactured concern, rather than a real one. He goes a bit into the science of bacterial infection and how far we have come in destroying this threat, but also explains that the vast majority of the many microbial organisms in existence are not even infectious and scientifically explains why this is so in an easy to follow manner. His blend

of creativity and scientific fact truly gives the reader a balanced overall picture of both science and societal perspectives, showing how society relates to science in the many issues he tackles. What is most important to note, however, is that not only is the book eye opening and easily understandable, but it is also something that many would be interested in reading due to its unique style.

Thomas shows that writing about science fact can be just as poetic and engaging as could be a novel of classic literature. By blending creativity along with scientific fact, Thomas likens scientific principles to real life society and puts the facts in terms that both scientists and the lay person can understand, while also being truly engrossed in what they are reading. This is the key to successful science writing; to be able to maintain an audience that encompasses the lay person all the way through the top scientists of one's specific field shows an excellent command of the craft. As was stated earlier, it is not just the cold hard facts that matter with science writing, but also the manner in which it is presented and the stylistic choices. The choices one makes in writing a paper either make or break the effectiveness and reader interest for the work.

Watson and Crick – Discoverers of the Structure of DNA and Excellent Writers

James Watson and Francis Crick are most widely known as the two people who discovered the structure of DNA (Deoxyribonucleic acid). This discovery has led to widespread research into how the molecule works and how to manipulate it. If not for these two individuals, the structure of DNA may not have been discovered until long after, right? This is absolutely

false because there were quite a few other scientists who discovered its structure; Watson and Crick's notoriety was due to how the paper was written. That was what caught the attention of both the public and the scientific community, alike (Halloran).

The paper itself if only one page long and is not very technically detailed. It is also, like Charles Darwin's The Origin of Species, not marred by massive amounts of scientific jargon. What it does accomplish, however, is to convey the main point that the discovery is a very big deal as well as divulging the discovery in the shortest amount of words so that people do not have to read through pages of unnecessary work as well as avoiding the passive voice The paper is simple in that it tells what the structure of the molecule is by giving the basic details of how it is put together and does not go into any unnecessary detail. Anybody, regardless of their background can, for the most part, understand what the paper is trying to say (Halloran 80). This is extremely important because in order to make a large impact on both the public as well as the scientific community one has to be able to convey one's thoughts clearly and concisely so that anyone can read the paper and understand just how great the discovery is, as well as why it is significant. However, it was the unconventional style of their paper that was published in Nature that is what truly made them win out over everyone else. Now, let us take a more detailed look into the paper itself to try and understand why going outside of normal convention is what truly made Watson and Crick stand out from the rest of those looking to be recognized as the discoverers and why they were the ones who were given credit.

From the first sentence, Watson and Crick's paper breaks a major rule in terms of acceptable scientific convention by saying "[w]e wish to suggest a structure for the salt of deoxyribose nucleic acid (D.N.A.)" (Watson and Crick). By using the word "we" they break the

ideal that scientists should always write in the third person past tense in order to keep the work objective and the scientist as detached as possible from it. They continually break this convention throughout the paper in order to

> put forward a strong proprietary claim to the double helix. What they offer is not *the* structure of DNA or *a* model of DNA, but Watson and Crick's structure or model . . . The paper articulates a recognizable public persona, an *ethos* . . . By contrast, the Wilkins et al. paper that appears immediately following Watson-Crick the April 1953 *Nature* were bloodless and impersonal in the manner more typical of scientific prose: 'The purpose of this communication is …' 'It may be shown that . . .'" (Halloran 75)

This ethos put forth by Watson and Crick is extremely important because it gives the scientist a voice, rather than the scientist being an impersonal observer and only objectively reporting findings. When the author has a voice in his or her paper it gives the writing a sense of personality and by doing so catches more people's attention because the author is essentially telling the reader to listen and that he or she has something interesting to say. While objectivity in a scientific laboratory is important in ensuring an unbiased scientific result, in writing this does not apply and this is where many get the approach to writing wrong. While it is not wrong to write at an objective, impersonal, level, authors are more noticed when their writing has something of the author's ethos present in the writing itself. Unlike scientific research, writing is not an unbiased experiment. It is, indeed, very personal and should not be approached with

detachment. Another important point, however, is that people are more inclined to read something that has some personality and is interesting rather than something that sounds boring and detached, even though the information may be of great importance. It is not always the person who makes the first discovery who wins out, but rather the person who makes the claim that stands out the most. For example, another major paper that is associated with early works in DNA, was authored by *Avery et. al.* in the *Journal of Experimental Medicine* in 1944.

The paper is very long and goes into great detail about how DNA was isolated. However, his main argumentative flaw was that they treat it as an analysis and lay no claims to their work throughout the entire paper. In fact, DNA is not even mentioned until "roughly half-way through its 7500 word length. They make no strong claims about the importance of their discovery, and in fact introduce the paper as simply a "more detailed analysis . . . events transpire in the passive voice, data suggest conclusions without human assistance" (Halloran 76) and the authors use the term "the writers" when referring to themselves. This created a very impersonal paper that lacks that confident ethos the Watson and Crick paper employs in that while Avery just seems to be reporting results, he sometimes seems unsure of himself, Watson and Crick are very sure of their work, and where certain aspects are unclear, they state that it is unclear. Their argument is much stronger because they are not afraid to tell discuss their findings in a more personal way and with no holding back and no fear of sticking to the established conventions. In their case, it paid off.

What is also interesting about Watson and Crick is that while the work of many other scientists is key to helping them to reach their discovery, they, in their initial papers, downplay these other scientists' importance. For example, "the slight they offer to Erwin Chargaff by downplaying his priority for establishing the chemical ratios in DNA that form such an important

part of their argument" (Miller and Halloran) is a big deal because if not for Chargaff, Watson and Crick would be missing key components to figuring out how the DNA molecule is put together. However, this downplay seems to be a result of What Miller and Halloran call the "Max Planck Effect." They go on to explain that the relationship is the "Oedipal one, in which the younger generation finds it necessary to kill its fathers by rejecting a prevailing paradigm and replacing it with its own, revolutionary one" (107). By downplaying Chargaff they make themselves look as if they came up with something totally new and novel and expanded upon Chargaff's work without ever mentioning his name (except in the references). By doing this, Watson and Crick make themselves look like they accomplished much more than they actually did.

However, one can ask what the logic behind publishing a one-page paper, no matter how unique, could possibly give Watson and Crick the credit if it does not go into the type of scientific detail necessary to convince the scientific community that their results are, indeed, correct? The answer is that their intention behind the paper was for it to be only an "initial move in a rhetorical strategy aimed at gaining and holding the attention of an audience" (Halloran 77). Later on, Crick published a much longer essay addressed to the scientific community in *Scientific American* that furthered his and Crick's claim on the discovery of DNA's structure. "The essay does not yet speak of the double-helical model of DNA as one of the established facts of biology; the model is still in effect the private property of Watson and Crick." (Halloran 78). Their rhetorical strategy in writing papers played a tremendous role. By employing this writing strategy they further expanded their claim to DNA belonging to them and continue to further

their argument in that the discovery is very important, which helped them immensely in being credited and becoming famous for their discovery.

Watson and Crick provide a great model for scientists who wish to learn to write effectively because their ethos came to be extremely important for not only the adoption of their structure of DNA as the canonical model, but also as a great way of getting their writing noticed above others. Their ability to be unafraid to go outside of convention in order to grasp more attention by using their ethos as a rhetorical strategy was a truly remarkable idea. Unfortunately, not many scientists tend to adopt their strategy when reporting findings. While others reported similar findings, the fact that it was Watson and Crick's unique writing strategy for that of those in the genre of scientific writing, shows that the facts do not always stand for themselves, no matter how great the discovery. However, the fact that this discovery was such a milestone in biological research also made Watson and Crick stand out even more because not only did they use a unique rhetorical strategy, but they also made it clear to say this discovery was very important and that it was *their* own.

What are possible solutions?

As with anything, the best way to begin an undertaking of interdisciplinary writing is to start small. Writing for fields such as physics and math in a college setting may prove to be troublesome for both teachers and students. However, writing papers in the field of biology seems like a good place to start, as it is not so heavily concerned with complicated equations as

are math, physics or chemistry and data is usually in the form of more easily interpretable charts and graphs. Also, much of elementary theory in biology is not very difficult to understand and write about. There likely many different ways to go about this: discussions with the science departments to help science teachers teach their students how to write better, and also creating cross-listed biology/English classes where both an English professor and a science professor can team teach the class, bringing in elements from both disciplines. However, a very important way in which we can go about teaching students good science writing practices is to expose them to examples of good science writing and have active class discussions about why these works set themselves apart from the others. Examples of these works include the works of Charles Darwin, Watson and Crick, the more creative ventures of Lewis Thomas as well as the many examples of good writing present in today's literature. In essence, well-written literature is easier to follow and thus be more easily reproducible since the results and procedures will be more easily understood.

One solution: Inter-Disciplinary Discussions

In the article *Writing in Biology: a Seminar,* an inter-disciplinary seminar was attempted between English and biology teachers, and was a great success. The point of this was for English professors to help Biology professors gain an understanding of how to go about properly fixing their students' writing problems. At first, when the Biology professors were asked to generate a list of the most problematic parts of student writing, the most common aspects came out to be

"immature or undeveloped thinking habits" and "inability to read texts critically or efficiently" (Fulwiler). While grammatical and organizational problems were deemed less important, the fact that the aforementioned aspects topped the list showed that while students did have problems with lower order concerns, the higher order ones were more deficient, overall. Without teachers effectively communicating these higher order skills to their students, especially in a discipline where formal writing classes are few and far between, students do not end up learning to effectively utilize these core writing skills. The issue with many laboratory classes is that writing and revising strategy is never spelled out for the students when it really needs to be, so they are relying mainly on the skills learned from high school English and science classes. This may be why they lack the ability to read critically at what college professors expect and do not have mature thinking habits when it comes to arguing a point.

Open communication between the English and science departments is one way to help improve their students' writing, just through this exchange of ideas. This is because while many science professors have issues with their students' writing, they may not know how to address them properly. The English teachers, in this case, helped guide the science teachers in helping their students by showing them how to find the solutions to their problems themselves.

Going a Step Further – Inter-Disciplinary Classes

To help students who specialize in other disciplines, we can come up with a way to incorporate writing in the disciplines through developing joint English/Science classes geared

toward students who are science majors, or for those who are otherwise interested in learning to write for other disciplines. While the major focus would be in science, this can be applied to other subjects, as well. For example, instead of, or in addition to freshman composition, students in the sciences could be given an option to take a writing course that is co-taught by a Science and an English professor, with the focus being on both learning scientific theory. At the same time they would learn to write and sustain an argument by utilizing that theory. For example, one possible assignment for a class like this would have students learning to analyze scientific journal articles, but then they would have to argue for or against something related to that article by utilizing the theory they learn in class along with that of the article. In this manner, both the Science and English professors would evaluate the papers over the aspects of the argument and the theory, and each would have specific feedback based on the writing and for the theory discussed. By promoting cross-departmental teaching, people in science majors can get some more writing training while also learning to write properly. It is important that students learn the difference between writing for these different audiences, but also to have a good background of transferable writing skills. They need to see that transferable writing skills are the key to success in writing papers for different audiences because many techniques can be applied in different ways depending on the interests of the readers. However, it will also show that writing for science is not that different from writing for English, aside from certain conventions and the type of information conveyed. Nevertheless, the writing itself does not greatly differ. While the formats and conventions of scientific writing may be different than what is seen is English, the papers in both disciplines set out to do the same thing: argue and support a point.

We can also integrate creative writing assignments through classes like this, possibly as classes themselves. For example, a joint English and science class could be offered that explores creative writing with the backing of scientific theory such as in the style of the book The Lives of a Cell, by Lewis Thomas. Overall, there are plenty of possibilities for joining English and science classes that have yet to be explored, which could truly open up the field of writing for many students, especially by showing them that it does not have to always be all boring, formal, writing, as many students perceive it.

Teaching Writing from Within the Science Classes

Turning away from joint English and Science classes, it is also important that the science courses themselves incorporate more writing as well. During 1992's Meeting of the Society for College Science Teachers, a Professor from Utica College of Syracuse University, Harold W. Pier came up with a novel idea for teaching Organic Chemistry. The programs and Abstracts for the presentations of that meeting detailed his idea for the idea to incorporate writing as a study tool for the class. Instead of a textbook, the students are instead given an outline of the lectures for the week. The students themselves then "write up the week's lectures, using the notes as a framework. The write-up is read by the professor or other students in the class and occasionally by students in an English composition class" (Pier 30). This is interesting because not only are the students responsible for writing up a set of notes but they also get feedback from the professor, their peers as well as sometimes from English students. This is great for the students

because not only do they get help from the professor in terms of how well they grasped the material, but also receive writing help from English students. Adding a writing component to an Organic Chemistry course is an excellent idea because, having been through Organic Chemistry myself, the writing would definitely help to reinforce much of the material because many of these concepts are quite difficult to grasp. By forcing them to read the material thoroughly several times in order to be able to write about it is truly a win-win situation for the students. Since most science classes consist of the student feverishly having to take notes as a professor lectures, with their grade almost solely based on exam scores, this is a nice departure from that routine. When the professor does finally lecture on the material, the student will already be very familiar with the subject matter and can focus more so on the lecture rather than on worrying about scribbling down every detail the professor discusses.

As was just shown, writing is a very good tool to utilize in order to get students to learn more effectively. Getting students to write about Organic Chemistry is a great way of getting them to understand the material. However, if we take this a step further, we can see that, as Randy Moore of Wright State University states, "[w]riting is thinking and that rewriting, the essence of effective writing, is rethinking" (Moore 39). He has come up with a program called "Writing to Learn Biology" that teaches students to write effectively through having students write in a variety of genres and for different audiences, which include "take a side" essays, letters to the editor, analyses of data and journal writing. Throughout his course, he also teaches students many different aspects of writing in general. He has found that students who take his course end up doing better in later courses. In addition, the students also show an improvement in their lower order concerns. Overall, courses like these are truly great to have and should be

promoted further. It would be safe to say that making these a requirement for students in the scientific fields would definitely benefit the students greatly. By helping students to improve their writing abilities, especially in the way they think about writing, this could change a student's entire career path.

An Interdisciplinary English/Science Class

David Hamilton, who has done great work in teaching writing to students of different disciplines, has instructed a class in which students in all fields of science how to write better, both in general and also specifically for their particular field by teaching them transferable writing skills. He dubs it a course in writing science. It is a special interest writing course that is aimed at upperclassmen and also graduate students. He begins the class by having students bring in an article from their own field that students believe is a good piece of writing. He then has the students evaluate the work and by doing so is able to gain enough information to break the students into study groups of people who have similar interests. This is great for grouping students together with similar interests and goals for the types of scientific genres and audiences the students look to write for.

However, a great assignment in the class has the science students writing for both the professor and the other students writing about their research, but they do it as if they are writing for a lay person who knows nothing of their research nor understands the scientific jargon. As Hamilton states, "[t]heir problem is to bring you from nowhere to an understanding of what they

do" (Hamilton 784). However, what I find really powerful is in how Hamilton contrasts this assignment against a paper on a literary work. Here, he compares physics research to Hamlet. He goes on to say that when writing a paper on Hamlet, "you allow for gaps in the immature argument because you can fill out so many possibilities for yourself, the fact that the physicist forgets a detail or offers an inept example hurts. Suddenly you're lost. He'll have you go back and get it straight" (784). This shows a huge contrast between scientific writing and English writing. Scientific writing allows for much less speculation and one's own personal interpretation than a paper on a Shakespearian work where there is so much room for speculation. This is not to say that science is not creative; it is just that it is much more difficult to interpret a physics text that does not explain itself clearly and has only one correct interpretation rather than a Shakespearian text, which can have a seemingly endless amount of possible meanings. This is a key difference between English and Science writing, and I agree with Hamilton's idea that when one writes scientific texts for the lay person, this is when once can truly see where major revisions are necessary. This is because when explaining scientific principles in everyday terms, examples must be clear so that anyone can understand and also every important detail must be present so that there are no real gaps in the theory. With a paper on Hamlet, for example, it is assumed the reader knows and understands the text so plot details can be omitted to allow for more theorizing and explanation, but if there are gaps in the theory or details the audience is more likely to be able to fill in the gaps. With physics, especially when scientists are presenting new findings, any slight holes in the theory behind the research would cause major questions to be asked because the reader is unable to fill in the gaps due to their being no other existing text backing up the newfound work.

Conclusion

For the many students in college who could use this writing instruction, the inclusion of classes that seek to help students with their writing ability, but tailored more toward writing to scientific audiences, could be a truly invaluable help to aspiring scientists and for those who would like to experience writing in a different discipline. The first step to students in scientific disciplines becoming better writers is to admitting to the problem and taking steps themselves to do something about it by taking classes that can improve their writing, whether they are within or outside of the science department they are studying. While getting help within a department is ideal for learning key scientific writing strategies it is also beneficial to take writing classes offered outside of their field of study, in order to gain new perspectives in writing. Experiencing writing for many different audiences and learning other styles are extremely valuable for furthering a student's overall perspective on writing, and improving their skills as a whole. While practice does not make perfect, it can enable dramatic improvement in writing ability just by experiencing many different takes on the writing process.

Good science writing is important to everyone, especially for the scientific community. Clarity goes a long way in helping the audience to better understand the work that is under discussion, both for the lay person from another field reading the paper, as well as for people in that field attempting to reproduce or fully understand the work in question. When a scientist who researches specifically in the field being written for may has a difficult time understanding the literature, this causes many problems in attempting to further the research or take it in other directions if one cannot fully understand the fundamental basis for the work. Good science

writing goes a long way and if the writing issue can be tackled both through college English and Science departments, the clarity and overall quality of writing being produced from future scientists can potentially increase dramatically.

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