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Implementing a New Senior Thesis Science Writing Course

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Abstract

Scientific writing presents a unique set of challenges. Communicating scientific research methodologies, results, and implications is often impeded by poor writing. Natural Science (NS) Professors at International Christian University (ICU) have long recognised this problem and have expressed their concerns to the Director of the English for Liberal Arts Program (ELA). A series of meetings between professors from the NS Department and the ELA Program led to two science writing workshops being held for science majors who are required to write their senior thesis in English. Following the success of these workshops, a new science writing course was proposed to the curriculum committee. The proposal was accepted, and a new course entitled "Senior Thesis Science Writing" was offered for the first time in Fall AY2017. This paper describes the background, workshops, and new course design, and concludes with a reflection on difficulties faced, and suggestions for how the course may develop in the future.

Background

The ability to clearly communicate the results and implications of experiments is essential for scientists. However, many journal editors have complained about the recent standard, going so far as to say it "has reached an all-time low, in terms of grammar and imprecise communication" (Heatwole, 2008, p. 159). This can hinder understanding both within the scientific community and between the scientific community and the general public. Greene (2013) argues that as scientific fields develop and scientific writing becomes more complex, it has become harder for scientists to understand ideas from different fields (p. 2). Furthermore, when a Pew Research Center poll in the U.S. reveals that about half of respondents believe human activity is not a factor in global climate change, and a third do not believe in human evolution, it seems there is also a communication problem between scientists and the general public (Greene, 2013). In order to reduce this gap and help produce science-literate societies, the president of the American Association for the Advancement of Science called for all scientists to "make their work both beneficial and understandable" to everyone (as cited in Lempinen, 2010, p. 1591).

One reason for poor communication skills amongst scientists is often their lack of training. Despite its importance, many undergraduates are not taught scientific writing, often because class time is devoted to learning the scientific concepts of their field (Turbek et al., 2016). This often applies to ICU students in the Natural Science (NS) Department. While they have a professor supervising their senior thesis research at every step, the professors perhaps do not have the time to sufficiently instruct the students in how to write up their final paper. This is especially problematic now that all NS majors are required to submit their senior thesis in English. Although ICU students receive intensive academic writing instruction

through the ELA program, writing in the sciences is very different from writing in the humanities. Indeed, in a needs analysis conducted with NS majors, students rated themselves much higher in their academic writing skills than their scientific writing skills. For these reasons, the ELA has collaborated with the NS Department to create the Senior Thesis Science Writing course commencing from Fall semester 2017.

Science Writing Workshops

In spring 2015, meetings were held between members of the Natural Science department and members of the ELA to discuss ways to improve the level of scientific writing at ICU, more specifically, to improve science majors' ability to write their senior thesis in English. It was agreed that science writing workshops would be held in December 2015, to support senior students to write their senior thesis in English. Prior to the workshops, we interviewed four NS majors from the Chemistry, Biology and Physics departments.

The students had taken science courses in their sophomore year in addition to junior and senior year classes since declaring their majors. A similar theme in the interviews was that students had written lab reports in both English and Japanese, but had not received specific instruction in scientific writing. They had received templates to follow, or previous students' work to examine and use as models. Furthermore, depending on their professor, the students had been given different structures to follow when writing the reports. For example, some requiring separate results and discussion sections, while others required these sections combined.

The students reported finding the discussion section the hardest part to write, followed by the introduction. Their main concern with the results section was dealing with data, and reading and describing graphs. They reported having little experience in describing data in English. For example, one student said she had only done this when studying for the IELTS test.

Another observation was the difference between scientific writing and the writing they have done in the ELA. They commented that there is no scientific writing in the ELA program. In ARW and RCA they learn to write persuasive, argumentative papers with an introduction, three body paragraphs, and a conclusion. They feel science writing has a very different structure and style, and that they have had little opportunity to learn how to write scientific reports.

Some said vocabulary and grammar was an issue. However, others reported that they had come to realise there is a lot of conventional vocabulary and grammar in scientific papers which actually makes this aspect somewhat easier than writing in other fields. They reported receiving instruction on using the passive voice, and hedging, for example, but wanted to see more examples of these skills in use.

In terms of feedback on their writing, the students suggested it focused on the content of the paper, rather than the style or structure. Furthermore, they explained that the Writing Support Desk is not staffed by any NS majors or graduates, making it difficult to get individual feedback on their writing. Some students reported reading more scientific papers in their senior year, rather than the textbooks they had used previously, and copying the structure of these papers for their senior thesis. We have strived to take these findings into account first when designing the workshops, and subsequently with the new Senior Thesis Science Writing course.

The two workshops were held in the winter term of AY2015, and were designed around the commonly used IMRaD (Introduction, Method, Results, and Discussion) scientific report writing structure. Workshops were open to all senior students, and were attended by around 20 students, faculty, and staff.

The first workshop covered the Introduction and Method sections. The second covered the Results and Discussion sections. In addition to the structural elements of scientific report writing, style elements such as voice and tense were mentioned, but time constraints prevented us from covering these topics in as much details as we would have liked. Following the workshops, students were asked to complete a feedback questionnaire.

This feedback indicated the students had appreciated going through model IMRaD sections sentence by sentence, analysing the function of each sentence and the logical order. They reported understanding more clearly the distinction between the results and discussion sections. All respondents said they strongly agreed that they felt more confident in writing their senior thesis after attending the workshops, and, as one respondent put it, **"**I feel that I need classes specialized in scientific writing whether in English or Japanese." As expected, students reported that the introduction and discussion sections are the most difficult to write, and likewise, NS professors reported that these sections tended to be the least well written.

Senior Thesis Science Writing Course

Further discussions with the ELA director led to a proposal for a new scientific report writing course. As well as improving the level of scientific writing, it was thought that the new course, taught exclusively in English, would contribute to the University's application to the Super Global 30 Program. The proposal was submitted to the curriculum committee, chaired by Dean Itoh, and it was agreed that a new course entitled, "Senior Thesis Science Writing" would commence in the fall term of AY2017. Seniors write their final thesis in the winter so a senior thesis writing course in fall will provide students with a timely opportunity to improve their science writing skills. The Senior Thesis Science Writing course comprises two classes and one tutorial each week. It is open to all junior and senior students who have declared their major and are studying experimental physics, chemistry, or biology.

Needs Analysis

In order to further inform the design of the syllabus, students enrolled on the course completed a Google Form as part of a needs analysis. Some of the key findings are highlighted here:

- Students rated themselves on a scale of 1 - 5, with 1 representing very low and 5 very high, in terms of how they rate their ability in academic writing, in scientific writing, and in representing the content of their scientific work in English.
- 64.7% of respondents answered 3 or 4 to describe their academic writing ability, while 35.3% chose 2.
- Conversely, for scientific writing, 29.4% answered 3 or 4, while 70.6% chose 1 or 2. The same results were recorded for their ability to represent the content of their scientific work in English.
- 76.5% of the students felt the discussion is the hardest section of a scientific paper to write. 17.6% said introduction and 5.9% results.

- Conversely, 82.4% said the Methodology section is the easiest section to write.
- Similar to the pre-workshop interviews done in 2015, most students said they had written some reports in both English and Japanese for laboratory classes. Some said they had not been taught how to write scientific papers, while others reported receiving templates to copy or scientific articles to read in order to gain familiarity with the format.

Course Design

One of the difficulties in designing a science report writing course lies in the fact that there are different conventions, styles and structural features in different science fields. Since students taking the course study different areas of science for their majors, our approach was to provide a generic IMRaD (Introduction, Methodology, Results, and Discussion) scientific report structure based on a model established by Glasman-Deal (2010) in her book, *Science Research Writing*.

In addition to structure, the course goal contains a style component designed to raise awareness and build competence in using different stylistic features and conventions, such as voice, hedging, and writing to a specific audience. Students are then asked to look at reports written in their specific field to ascertain which features and conventions are prevalent in their specific field. The course goals include being able to:

- Understand the IMRaD scientific writing structure.
- Write an example of each section of the IMRaD structure.
- Use appropriate vocabulary, grammar, and style for each section of a paper.
- Describe visual data expressed in graphs and charts.
- Understand the features of a well-written abstract.
- Analyse a paper within their own field for features covered during the course.

Successful completion of this course requires students to write and submit four written assignments, one for each of the four sections. Writing a scientific report requires students to undertake an extensive review of other similar research and obtain empirical research data. In the fall semester, students may not be in a position to begin writing about their own specific research project, so students are given the option of writing about one of four fictitious, but realistic scientific problems. Using fictitious problems means that students have to invent references to other studies, imagine a realistic methodology, and invent empirical data. Of course fabricating an experiment is one of the greatest sins a scientific researcher can commit, but for the purpose of this course, this approach gives students a practical way to practice using the structural model, and build competence using grammar and style conventions. The four fictitious research problems are:

1. Many cyclists are concerned about breathing polluted air. There are some filter masks available that prevent cyclists breathing in large particles of soot, but a mask has not yet been designed that can filter out small harmful chemical compounds without severely hindering the cyclist's ability to breath. Your research aims to solve this problem.
2. People like to have bird feeders in their gardens to attract small birds like finches, but larger unwanted species of birds, like pigeons are attracted too. Nobody has yet come

up with a bird feeder design that can attract small birds but prevent larger ones from feeding. You believe your research may be able to solve this problem.
3. Dicotyledonous plants such as sugarbeet, sunflower, soybean, dry bean, canola are very vulnerable to frost damage. Farmers have used expensive heating systems or cloth covers to protect their crops. More recently cheaper chemical sprays have been used to prevent the formation of frost, but they are bad for the environment. You are testing a chemical spray made from a plant extract XXA which could be an environmentally sound alternative.
4. A chemical reaction known as the Williams reaction is widely used in industry. It uses a chemical catalyst called RBX, which reduces the activation energy by 25%. There has been research looking for a better catalyst, and although some have been found to reduce the activation energy further, they are either too expensive, or very dangerous and bad for the environment. You are testing several promising new catalysts.

IMRaD Structure

Introduction The introduction is one of the most difficult sections of the IMRaD structure, partly because significant background knowledge and an awareness of similar research in the field is required. A well-written introduction justifies the research in the context of other studies in the field. Students are asked to follow a four component model adapted from the model presented by Glasman-Deal (2010, p. 24):

1. Establish the importance of the topic (background, key terms, and problems).
2. Summarise previous and / or current research in the field.
3. Identify a gap in the current research, and describe the problem to be addressed.
4. Introduce the paper.

Students are given three articles published in *Nature* and asked to identify each of the four components in the introduction. Students are then asked to write an introduction based on their own research area or one of the four fictitious problems described previously.

Method The title of this section varies in different journals and across different disciplines. *Procedure, Experimental,* and *Methodology* are common alternative section headings. The Method section provides readers with details of the procedure, equipment, type and quantity of material used. A well-written methodology will allow readers to follow and replicate the work and obtain similar results. Using an adapted version of Glasman-Deal's (2010) four component method structure (p. 67), students are asked to identify each of the four components of the methods section of an article taken from a scientific journal:

1. Provide an overview of the method, equipment and materials and necessary background information.
2. Provide specific details about materials and methods (e.g. sequence, duration, sizes, quantities, temperatures).
3. Compare to other similar studies.
4. Indicate any problems or limitations.

A successful methodology section requires students to express procedural sequence and the physical arrangement of apparatus clearly. Students are asked to write a methodology section

based on their own experimental research if possible, or use an imagined methodology based on one of the fictitious problems stated previously.

Results In this section writers report the outcome of their experiment in the form of data expressed in visual form. Graphs, charts, and tables are commonly used to present the results of observations made, or measurements taken. The written element of the results section provides a summary of the results and highlights key findings with reference to the aim of the research project. Problems or limitations of the results are acknowledged, and a brief overview of implications can be mentioned, to be expanded on further in the discussion section. Using an adapted version of Glasman-Deal's (2010) four component model (p. 123), students are asked to write a results section based on the following four components:

1. General summary or overview of results.
2. Highlighting key results in reference to the aim, and other similar studies.
3. Acknowledgment of any problems.
4. Possible implications of results.

The vocabulary required to write an effective results section is based on describing visual data. Students must be able to describe general trends, anomalies, highlight key results, and comment on whether they support or contradict any hypothesised outcome. Students are asked to write their own results section, complete with visual data, based on their own research findings if possible, or use invented data based on of the four fictitious scientific problems described previously.

Discussion Some journals combine the results and discussion sections and end with a short conclusion which usually comprises a summary of the discussion section and a revisiting of key results. The classic IMRaD structure ends with a discussion section in which findings are interpreted and their implications are speculated upon. Using an adapted version of Glassman-Deal's (2010) four component model (p. 155), students are asked to write a discussion section based on the following four components:

1. Revisit key results in comparison with expected results.
2. Relate key results to other significant research in the field.
3. Interpret and describe implications of results. Speculate on possible applications.
4. Acknowledge limitations. Suggest further research.

In order to produce a well-written discussion section, writers must be able to use hedging techniques in order to express their interpretation with appropriate caution. The use of modal verbs is a particular feature of the discussion section. Students are asked to write a discussion section based on their own research if possible, and if not, on one of the fictitious scientific problems described previously.

Reading analysis After students have studied and practiced writing each of the four parts of the IMRaD structure, they are asked to find a scientific report published in a quality academic journal, on a subject closely related to their research interest. Students are asked to analyse their chosen article, and the style guide for that particular journal, and write a short report commenting on its structure and style.

Style

In addition to analyzing models and examples of each of the IMRaD sections, aspects of style are also introduced to help students write more clearly and comprehensively. Some of the elements incorporated into the syllabus are described below:

Audience Before addressing the different components of the IMRaD structure itself, students are asked to reflect on who they are writing for, i.e. the audience. A science journalist may be writing to the general public and therefore need to explain technical terms and provide important background information. On the other hand, a scientific report is likely to only be read by people with some expertise in the field, and it can be assumed that they will understand technical terms, and already be aware of necessary background information. Students are encouraged to write to an audience with a similar level of expertise to themselves, and only explain technical terms and provide background information when there is doubt that the reader already has the necessary knowledge.

IMRaD Section specific grammar and vocabulary In addition to analysing a model for each IMRaD section, the students are also made aware of conventional grammar and vocabulary incorporated into each section. Taking the Introduction section as an example, students look at the type of grammar used in each of the four components of the introduction. For example, using the present simple tense to introduce background information, present perfect tense for past to present day approaches to the research topic, and past simple tense for briefly introducing the results. Vocabulary common to each of the four components is also studied. The students then use the introduction sections from the *Nature* articles they have used previously to study the introduction model, to find examples of the section specific grammar and vocabulary.

Voice The active voice is recommended for scientific writing as it is generally clearer, more concise and has a more direct character-action-goal order. For instance, *Nature* favours the active voice "as experience has shown that readers find concepts and results to be conveyed more clearly if written directly." (Nature, 2009). The main exception to this is the methodology section, which is usually written in the past simple tense using the passive form. The students are also shown other examples when the passive is useful, such as in order to keep a consistent subject within a paragraph, or to put emphasis on certain words by placing them at strategic parts of a sentence.

Brevity We encourage students to think of the reader at all times. It is not necessary to use long, complicated words over short, simple ones. Similarly, shorter sentences will also result in clearer messages with more impact. Breaking up long sentences will reduce the chance of being misunderstood and make the paper more readable (Wallwork, 2011). We ask the students to be as concise as possible in their writing. This is not only for the reader's sake, but many science journals have strict restrictions on word counts.

Hedging Judicious use of hedging strategies is essential for good scientific writing. Expressing appropriate caution, and confidence helps readers establish a good relationship with the readers, and therefore helps to build their reputation as a scientific researcher. Students are taught the importance of hedging, given different hedging strategies, and given opportunities to practice both using them and recognizing them in published scientific papers.

Further Development

The Senior Thesis Science Writing course is now in its first semester, so there will inevitably be areas in which we can improve the course as we proceed. We were hoping to conduct an experiment with the students which they could use to write up a full paper. However, this proved difficult due to the mixed scientific background of the students, the lack of an appropriate laboratory and equipment, and the short length of the course. We plan to work closely with the NS professors to see if we can introduce an experimental component to the class in the future. For now, we require students to write an IMRaD portfolio and finally analyse two papers in their field and highlight the structure and the style used throughout the paper.

We would also like to implement a system for senior NS students to get more individual support with their theses. This could be done through the Writing Support Helpdesk, or creating a separate writing center in the NS department staffed by graduate students. Finally, along with the NS professors, we would like to see more scientific papers in the ELA program and we are continuing to investigate how this can be achieved in an appropriate way.

Conclusion

Writing scientific papers is very different from the writing ICU students undertake in the ELA program. It may seem like an intimidating process for NS majors. However, by analysing each IMRaD section during the Senior Thesis Science Writing course, we hope to show the students that it is not such a daunting prospect. By understanding the conventions and model each section typically follows, the students can understand what to include in each section and in what order to include it. Furthermore, they will be aware of vocabulary and grammar that frequently appears not only within each section of the paper, but at each stage of each section.

The small class sizes within the NS department allows the students to benefit from close relationships and guidance from their professors during lessons and with their senior thesis experiments. We hope that this course will add to this by giving students the opportunity to understand the writing process more clearly. Carrying out experiments is not enough for scientists, the “ability to effectively communicate research findings is crucial for success.” (Turbek et al., 2016, p. 417).

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