Teaching Scientific Writing in a First-Year Chemistry Laboratory

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***Abstract*—The dominant way that chemistry undergraduate students develop their scientific writing skills is in the preparation of laboratory reports. We integrated writing instruction into a first-year chemistry lab course to teach students how to write substantial, formal lab reports, rather than the previously required short lab reports, and to prepare them for upper levels of study in chemistry, where they will be required to write reports in the style of a scientific publication. This writing instruction initiative uses teaching assistants as the major players, and focuses on training these teaching assistants effectively so that they can provide valuable and consistent feedback to students.**

***Index Terms*—First-year chemistry laboratory, teaching assistants, writing instruction, undergraduate teaching.**

I. Introduction

CHEMISTRY students enrolled in first-year university courses are normally just finished high school, and typically have a dualistic [1] way of thinking. That is, they believe that there are "right" answers and "wrong" answers to all questions, their instructors will provide them with the "truth", and any uncertainty is only temporary [2]. However, university-level assignments often expect students to engage in a multiplistic/relativistic, more sophisticated kind of critical thinking and to extrapolate class material into new circumstances.

A. Writing Instruction for TAs Program Description

Unlike first-year students at many American universities, students at U of T (and most other Canadian universities) do not take a first-year composition course. Instead, individual departments and programs are responsible for teaching students to write within their discipline. The Writing Instruction for TAs (WIT) program is a teaching initiative that was launched in 2008, to address need for better integration of writing instruction into programs of study in the Faculty of Arts and Science. Specifically, this project aimed to provide "support and training for instructors to develop appropriate program-specific writing instruction, and [to train] teaching assistants (TAs) to assist appropriately in this process" [3]. This program places particular focus on the role of TAs[1] in undergraduate writing instruction [4]. In WIT, participating departments receive additional funding from the faculty to hire one senior graduate student (usually in their third year or later) to work as the Lead Writing TA (LWTA). The entire sum of funding that a participating unit receives goes to pay TAs. The LWTA participates in a weeklong training session in June (before planning for the upcoming academic term begins) to learn best practices of teaching and evaluating writing, building and managing teaching teams, dealing with language proficiency challenges (both in students and in TAs), and training TAs to implement good writing instruction. Working together with the departmental WIT coordinator and participating course instructors, the LWTA facilitates and supports the ongoing development, implementation, and evaluation of writing instruction in participating courses. Typically, these courses already have a significant amount of writing, and the WIT support is used to develop or redevelop writing assignments. At the end of the year, the LWTA produces a report of the department's WIT activities. If there is mutual agreement, the LWTA can hold consecutive appointments.

B. WIT in the Department of Chemistry

The Department of Chemistry received WIT funding for the first time in 2009. The departmental writing goals stipulate that every Chemistry program student should be able to:

1. Write at least one laboratory report (minors) or several (majors/specialists) in the format of an academic chemical journal.
2. Include applicable content within the prescribed format, in terms of correct scientific language and writing style (such as using short, declarative sentences rather than the passive voice)
3. Search and reference the primary literature appropriately, including proper use of online chemical databases
4. Write original material and be aware of academic integrity issues

After two years of targeting third-year laboratory courses, we decided to introduce some writing instruction into the

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[1] At U of T, most graduate students are required to work as TAs, running workshops, tutorials, and laboratories, and grading student work. In the Department of Chemistry, all graduate students are required to TA unless they hold a major scholarship (many of which prohibit TAing).

first year level. We selected a small full-year course (~120 students) called CHM151 *Chemistry: The Molecular Science*. The course description clearly states that it is more demanding than the other first-year option (two complementary half-year courses, CHM138 and CHM139), and that students are expected to have an understanding of introductory organic chemistry when they begin the course. Students choose to enrol in this course rather than taking the less demanding general chemistry offerings. In this paper, we describe the development, implementation, and qualitative evaluation of a writing instruction program in this first-year chemistry course.

II. Developing WIT in CHM151

This course is well established in the department and the lab schedule is carefully balanced. We examined the existing structure of the course, and used the LWTA's previous experience as a CHM151 lab demonstrator to identify key areas for improvement and goals for WIT in the course.

A. Assessment of the Existing Structure

We identified four key areas where WIT interventions could improve the existing course.

Instruction on writing laboratory reports: Students were expected to read the lab manual independently, and use this information to prepare properly formatted short lab reports. This was not an ideal arrangement, as it required students to engage in too much self-study in order to successfully complete the basic course work.

The lab report format: Students work in partners in the lab but prepare individual lab reports. Lab reports included brief introduction, methods, tabulated results, and discussion sections, but the overall length was limited to two pages and the writing was consequently very limited. Short, data-analysis-only reports that omit elements of a complete lab report (or scientific article) do not engage the students in understanding the experiment as a whole, and the result can be that comprehension is actually reduced [5].

Assessment criteria and feedback to students: Lab reports were graded using a correct/incorrect grading scheme that was not made available to students. This was not ideal because unstated criteria, assumptions about commonly understood expectations, and assessment standards can create problems for students [6]. TAs checked lab reports for the required content and assigned part marks for different sections. Feedback on the writing itself was normally minimal because the amount of time the TAs are allotted for grading lab reports is quite limited.[2]

Schedule for returning laboratory reports: Students in CHM151 complete five labs per term, doing one lab every other week, for a total of 10 experiments over the full academic year (September–April). Students submitted their lab reports in the next lab (i.e. two weeks after completing the experiment), and TAs returned their graded reports the following lab (again, two weeks later). This normally meant that TAs only finished grading in time for the next lab. Although this was the most logistically convenient, it was highly problematic: students were writing two reports before receiving *any* feedback (whether grades or comments), and this feedback was returned a full month after they had completed the actual experiment.

[2] Laboratory courses are very expensive to run, and the budgets for these courses are always very tight. TAs are an expensive part of this budget because they spend long hours in the lab with the students, and one consequence is that there is limited time available for grading.

B. Goals for WIT in CHM151

We identified four main goals for the writing instruction in CHM151, all of which are based in the foundational idea that good writing develops through specific and targeted instruction, multiple writing opportunities, and timely and focused feedback [7].

Create a level playing field: U of T has a very diverse student population, which means that students entering first year come from a wide variety of cultural and educational backgrounds. This has implications for their level of preparedness for first-year chemistry, and means that not all students will be equally capable of completing course work. Even within the cohort of students entering U of T from Ontario high schools (which all use the same curriculum), an in-house study found that there was a statistically very significant difference in how prepared these students were for university-level chemistry [8]. These differences have implications in student abilities to read and write at the university level, and clearly indicate that first-year writing instruction plays an important role in bringing *all* students to the required level of preparation.

Use writing to enhance learning: Writing-to-learn is an established method for enhancing student learning. Lab report assignments should help students develop their understanding of the course material by asking them to synthesize their observations/results and relevant readings.

Make grading policies transparent and understandable: It is not sufficient to give a student a number grade. If a student is to *learn*, they need to clearly understand where their areas of weakness are and what criteria were used in assessment. Helping students understand how they are assessed by making grading criteria transparent also prepares them for navigating diverse expectations from future course instructors.

Return graded lab reports more quickly: This is very simple, but very important. Giving students feedback quickly after they submit an assignment, and when it is relevant for current work, increases the chances of students making good use of it.

III. Implementing WIT in CHM151

We took a two-stage approach in integrating writing instruction into CHM151. This decision was motivated by a desire to support the self-efficacy of first-year chemistry students. By planning for students to experience initial success, it is possible to help them develop better self-efficacy in a progressive manner, which will in turn enable them to tackle more challenging tasks [9]. Because the students in this course are self-selected, they might have a generally higher level of chemistry self-efficacy than the average first year science student, but this would not necessarily mean their self-efficacy extended to *writing* in chemistry. Also, they were still transitioning into university and therefore still needed support. In the Fall term (Experiments 1 through 5), we chose to make small-scale changes to a system we already knew to be manageable for

the students [10], and in the Spring term (Experiments 6 through 10) we challenged the students with more significant tasks.

A. Fall Term WIT Activities

Experiment 1 is a computation lab that only takes half the lab period. Previously, the other half of the lab period was unused. During this free time, students were given an **introductory lecture** by the lab TAs that gave them information about the lab and the lab reports. Much of this information has always been available to students in the lab manual, but many students still struggle to meet expectations of punctuality, preparedness, and behaviour in the lab.

The lab report for Experiment 1 is a fill-in-the-blanks-type report. In the introductory presentation, we gave students the **option of writing a short discussion** for this report, for 1 bonus mark on a 20-mark report, based on simple instructions. This was meant to provide a low stakes opportunity for students to practice writing a short discussion and get some early feedback, and to give the TAs an opportunity to see writing samples from students before their first written report.

We elected to not change the format of the lab reports during the Fall term, to give the students an opportunity to become comfortable with the basic report before challenging them with more advanced tasks. For the whole term, the LWTA offered students the chance to **pick up graded lab reports the Friday before their next lab**. This gave them the chance to use feedback on one report in writing their next one. Approximately 75% of students took advantage of this opportunity.

B. Spring Term WIT Activities

We continued returning student reports on Fridays during the Spring term. In Experiment 6, which concerns spectroscopy, we introduced an **in-lab reading assignment** to be completed in pairs. The students were to use their reading to complete a worksheet with a series of carefully constructed questions (also in pairs), and then use their answers to **write a properly formatted introduction** in their individual lab reports.

In Experiment 7, we introduced a more **substantial assignment for the discussion** section of the lab report, giving students **specific questions** to guide their discussion. These questions were designed to guide the students in producing a focused, analytical discussion [10]. We also provided them with references to key sections of their textbook that they might use for more information.

In Experiments 8 and 9, students were required to write an **abstract** for their report.

In Experiment 10, where the students prepared a Grätzel-type dye-sensitized solar cell, they were required to write a **formal lab report**. They were provided with **two journal articles to use as references** in the introduction and discussion sections: one from *J. Chem. Ed.* that describes the design of the experiment they performed [11], and the original *Nature* paper on the Grätzel cell [12]. The first source was required reading, while the second was optional for students who felt able to tackle the language.

For all experiments in the Spring term, we also provided students with **writing guides** for the relevant new section of their lab report. These writing guides gave concise, general advice on writing sections of the lab report, and provided specific information about the requirements for CHM151.

Also for all experiments in the Spring term, we prepared **one-page grading sheets** that clearly indicated the main criteria and mark value for each section of each lab report. These grading sheets also had large comment boxes where the TAs wrote comments. This was intended to reduce the marking time for each lab report by eliminating the need for marginal comments.

C. TA Training and Collaboration

The LWTA met regularly with the TAs throughout the year. During these meetings, the LWTA presented TAs with **relevant support and training** in teaching and evaluating writing. **Benchmarking sessions** were held for key lab reports in order to ensure consistency across all TAs. All instructional materials in the Fall term and all assessment materials in the Spring term were developed in collaboration with the TAs.

D. Refinements in 2012–2013

Student response in 2011–2012 indicated that that they would have liked to have the writing guides and associated instruction in the Fall term. So, the LWTA (LJE) provided the students with instruction on writing a university lab report during a course tutorial (students have tutorial on weeks they do not have lab), and the students were given the option to write a formal lab report for Experiment 3 for bonus marks, and assigned a mandatory formal lab report for Experiment 6. This gave them **three opportunities to write a formal lab report**, with good spacing between them.

E. Refinements in 2013–2014

Over two years of WIT in this course, student response indicated that they wanted to see samples of student work. In a tutorial early in the Fall term, the LWTA (LH) gave a presentation on writing a university lab report, and then students worked on assessing a **"bad" sample report** that the teaching team had prepared. This report contained many of the commonly seen errors in student writing in previous years, and students were asked to identify and suggest corrections for these errors. This task was taken up in the tutorial groups. Afterward, an answer key with feedback was made available to all students.

Students were given the option of writing an introduction and abstract for their lab report for Experiment 3, and results, discussion, and conclusion sections in their lab report for Experiment 4; 75% of the class chose to do this writing. For Experiment 7, students were given a short piece of text with references removed, and asked to indicate where they thought references belonged and why.

IV. Evaluation of WIT in CHM151

We surveyed students at the end of April to get their feedback on elements of the writing instruction in CHM151. Comparing the survey results for the key summative questions from 2012 and 2014 (Table 1) we see that student response was and continues to be positive overall. This serves as a good indication that students are receiving the message that writing is important in learning chemistry. Student comments also indicate that the program is having a positive impact on their learning, and that students recognize the role that writing plays in their studies:

TABLE I
RESULTS FROM SUMMATIVE QUESTIONS ON STUDENT SURVEYS IN 2012 AND 2014

Question	2012 Responses	2014 Responses
How much did writing laboratory reports in CHM151Y increase your understanding of the course material in the laboratory?	Very much/Somewhat: 86% Neutral: 8% Not really/not at all: 6%	Very much/Somewhat: 82% Neutral: 12% Not really/Not at all: 6%
How helpful were the writing guides in understanding how to properly complete each section of a scientific lab report?	Very helpful/Helpful: 86% Neutral: 14% Unhelpfu/Very unhelpful: 2%	Very helpful/Helpful: 78% Neutral: 16% Unhelpful/Very unhelpful: 6%
How helpful was the writing instruction in this course for learning how to properly write a university-level scientific lab report?	Very helpful/Helpful: 89% Neutral: 5% Unhelpful/Very unhelpful: 6%	Very helpful/Helpful: 78% Neutral: 13% Unhelpful/Very unhelpful: 9%
Overall, how helpful was the writing instruction and feedback you received in this course in improving your writing skills during this academic year?	Very helpful/Helpful: 75% Neutral: 22% Unhelpful/Very unhelpful: 3%	Very helpful/Helpful: 71% Neutral: 20% Unhelpful/Very unhelpful: 9%

"I have talked to friends in both CHM138 and CHM139 and have found that these courses do not have a significant amount of writing for lab reports. Writing, for me, was one of the most advantageous attributes of the CHM151 labs." (2012)

"I felt that the writing instruction was an important part of my learning experience." (2012)

"Writing full lab reports was very time consuming, but it did further my understanding." (2014)

"Overall the writing instruction is CHM 151 was well done and helped provide us with an introduction to how labs should be written in upper years." (2014)

Of course, there are still aspects of this program that could be more effective. Some key areas of note are:

Optional vs. required writing: Students have sometimes expressed confusion or uncertainty about this. The use of bonus marks for optional writing is a good way to encourage participation, but requires caution because some students have demonstrated the attitude that *all* writing should be for bonus marks. This can undermine the role of writing in learning.

Sample reports: Students want more of these, but we need to be aware of the possible disadvantages of priming them too much with "perfect" examples to copy (which is a reality for students who are still dualistic in thinking). In third year courses, students are instead given the opportunity to prepare a draft report and receive feedback before submitting it for marks. In contrast to the temptation to simply copy the sections of a sample, students generate their own content and then improve it.

The lab manual: While the report assignments have been updated, the lab manual has not received the same attention. While the descriptions of the experiments themselves require no revision, the introductory sections of the lab manual are a persistent weakness that needs to be addressed. This problem predates WIT in CHM151, but has become more pronounced with the introduction of WIT.

Balancing support and challenge: Some students have commented that the writing instruction they received was just a repeat from high school. One student in 2014 commented that they "put many 'neutrals' [on their survey] as these skills were taught in high school." While we have been very conscious of supporting those students who were underprepared for first year, we need to also be aware of those students who were very well prepared. If these students do not feel challenged by the course, there is a risk that they will lose interest.

SAMPLE MATERIALS

Sample assignments, writing guides, grading sheets, and TA training material are available from JEL upon request.

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