LANGUAGE AS AN ENGINEERING LEARNING TOOL: INTEGRATION OF LANGUAGE AND ENGINEERING EDUCATION FOR FIRST-YEAR STUDENTS TO IMPROVE BOTH TECHNICAL LEARNING OUTCOMES AND COMMUNICATION SKILLS

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Abstract – *Vantage College (VC) at UBC offers innovative specialized first-year programs for international students that integrate core content courses with complementary language education to allow participants to hone their communication skills while meeting their regular academic requirements. In the Applied Science stream of VC, each engineering course is linked to a complementary language course and the instructors collaborate closely. In this paper, three examples of writing tasks are presented that deal with the intersection of language training and technical engineering content, all in the context of writing lab reports for two engineering chemistry courses. A description of each task is provided, and the benefits to students both in terms of improved communication skills and enhanced understanding of technical content is provided from the perspective of language and engineering instructors, as well as from students based on feedback on each activity collected through surveys. The integrated approach was found to be quite effective in improving learning outcomes.*

Keywords: First-Year Education, International Students, Content Integration, Technical Communication

1. INTRODUCTION

The rapidly growing prosperity of key international markets and the resulting increase in student mobility continue to fuel a growing demand for North-American Applied Science post-secondary education. Many international students, however, are faced with language and cultural barriers that present obstacles to their academic success and that can prevent them from fully integrating into the academic and engineering communities at their institutions. Universities across North-America have adopted a variety of academic

models to attract and serve these international students, with varied degrees of success [2], but the need for novel pedagogical approaches that address these challenges remains pressing.

In response to this need, Vantage College (VC) at the University of British Columbia (UBC) was established with a mandate to offer innovative interdisciplinary first-year programs to international students that integrate core content courses with discipline-specific language training and support programs to allow participants to hone their communication skills while meeting the academic requirements of their respective academic disciplines. These programs are offered to international students who have an outstanding academic standing and have a strong foundation in English, but whose level of language proficiency is just below that set forth by UBC for entry into its programs. Participants take all of their first year courses with their Vantage cohort, and, upon successful completion of the program, join their “direct-entry” counterparts in second year for the remainder of their undergraduate studies. In the Applied Science stream of VC, each engineering course is associated with a dedicated language course, with the engineering and language instructors working closely together to develop and deliver their respective curricula and accomplish mutual learning objectives. The engineering courses in VC follow the curriculum for first-year Applied Science at UBC. The language courses draw on the school of linguistic theory known as Systemic Functional Linguistics (SFL), which emphasizes the relationship between language form and functional meaning, i.e. how the particular vocabulary and grammar choices that communicators make contribute to the achievement of given communicative functions. SFL serves as a lens, in this context, through which engineering-specific language for achieving engineering-specific communicative functions can be brought into sharp focus for learners [3]. The integration of communication training and technical content has previously been shown to be effective [1], and

more specifically, the nature, logistics, and effectiveness of this type of partnership within VC between the two engineering chemistry courses and associated language courses that are the subject of this paper were described in previous work [6].

One of the important objectives of engineering programs is the development of communication and critical thinking skills, which are crucial for student success after graduation but remain some of the most challenging skills to comprehensively develop and assess. In engineering curricula, communication skills are often taught in dedicated courses or modules on technical communication with subsequent assessment generally limited to minor components of engineering deliverables such as lab or technical reports. This tendency minimizes incentives for students to improve their communication skills and limits opportunities to receive comprehensive feedback. As an alternative approach, language training can be integrated with all aspects of technical content, with benefits not only to communicative proficiency but also to the development of analytical skills and technical mastery.

This paper describes the interaction of the two aforementioned first-year engineering chemistry courses with their associated language courses, using three examples of intersections of language and technical content that are particularly challenging for students, in the context of writing lab reports. These examples are part of a wider curriculum that relates to other deliverables and language skills, but given that lab reports represent one of the key engineering deliverables, and present multiple opportunities to reach the learning objectives of both courses, the effectiveness of this approach is discussed here in that particular context.

Assessment by both the engineering and language instructors, as well as feedback obtained from student surveys on the tasks described in this paper, suggest that the language-focused interventions in the adjunct course are helping students not only to develop their English-language communication skills, but also their technical lab report writing abilities, and improve their understanding of the technical engineering content underpinning their assigned tasks and the critical thinking abilities needed to analyze and discuss observations and measured data. Students reported that these activities were useful in helping them develop their language skills, but also in understanding what information to include in lab reports, and how to critically analyze results to appropriate depth.

Although this approach was quite effective as part of this first-year VC program, the need for the development of technical communication skills and critical thinking is not limited to first-year courses, and this integrated approach may prove quite useful (if more labour-intensive than conventional approaches) in upper-year laboratory courses, which is currently the subject of ongoing work.

2. ASSESSING LAB REPORTS TO IMPROVE LANGUAGE AND TECHNICAL SKILLS

Based on instructor assessments and student feedback collected from the first year of the Applied Science stream of VC, the governing aim of the language course, now in its second year, became developing student ability to write lab reports, the key communication-related deliverable in the associated engineering chemistry courses. Of the five lab reports that students had to submit in the engineering courses during each of the Fall 2016 and Winter 2017 terms, three were also collected by the language instructor to evaluate the quality of writing. On six of the ten lab reports that they prepared over the two terms students therefore received both technical feedback from the disciplinary TAs, and communication-focused feedback from the language instructor.

One important consequence of having students ‘double-submit’ their lab reports in this way was that it created a much greater marks-based incentive for students to work towards the improvement of their writing, as the quality of language was only given a weight of 5% in the disciplinary lab report evaluation rubric, a typical weighting in engineering courses. The language course was also ‘for-credit’ and students were required to pass it in order to graduate from VC and progress into second-year engineering at UBC. As such, using the course to assess language use in lab reports sent the message to students that quality of writing is a key factor in whether a lab report succeeds or fails. In addition to requiring students to submit their lab reports to him for language assessment and feedback, the English instructor also required them to use this feedback to produce a second, revised version of each report in which they addressed as best they could the language issues that he had noted. As an aside, in order to understand the technical content of the labs well enough to evaluate how well student reports communicated their authors’ intended meanings, the language instructor performed each lab himself and wrote up his own reports, on which he received detailed feedback from the engineering instructor. Excerpts from these language-instructor-prepared reports were then used in language training activities in the adjunct course.

Having students engage in this process of ‘double-submitting’ their lab reports and then re-submitting (to the language teacher only) allowed for the identification of important opportunities to simultaneously strengthen lab-report writing skills and scientific understanding. Indeed, it was found that focusing students’ attention on the language of lab reports might lead not only to improved English composition skills but also to an enriched understanding of (a) empiricism as the epistemological foundation of engineering studies and (b) the specific scientific concepts made manifest in the particular

experiments that students were reporting on. Three examples of such specific intersections of language and technical content that became the subject of student training are described below.

2.1. Self-Mention and Objectivity

The greater-than-usual focus on language use in lab reports seemed to help students perceive the close relationship between how lab report writers position themselves in their texts and key questions of subjectivity and objectivity in the production of scientific knowledge. In early lab reports, many students used the language of “self-mention” — i.e. first-person pronouns (*I, we*) or possessive adjectives (*my, our*)—when recounting their lab work, as in the following excerpts:

*“After **we** made some adjustments on the pinion, the expected curve showed on the computer interface.”*

*“Furthermore, the top and end of the metal tube isn’t covered by insulation sleeves because they are not the length **we** need to calculate in the experiment.”*

As the engineering professor had instructed students that self-mention should be avoided in the lab reports and technical writing in general, the English instructor in his feedback suggested that these sentences be recast in the passive voice to eliminate the first-person pronoun. For example, a successful revision by the author of the first excerpt would be

*“After adjustments **were** made to the pinion...”*

Since the use of self-mention was a common mistake, students were shown how to use the linguistic resource of passivization to eliminate it and given practice in the formation of passive structures, which a good number of students had not mastered before entering the course. This focus on particular language forms—eliminating first person pronouns, forming the passive voice correctly—was accompanied by careful consideration of a key communicative function that passivization allows lab report writers to fulfill: downplaying for readers their own identity as observers or experimenters and emphasizing instead the phenomena that they observed in the lab. Thus, by analyzing and practicing a particular language feature of lab reports, students were able to see that academic language use is not simply a matter of the correctness/incorrectness of forms but also—and more importantly—an expression of fundamental disciplinary principles: in this case, the empiricist tenet that the object of inquiry, and not the inquirer, should be the focal point. This then allowed for the engineering instructor to

broaden the discussion on the purpose of lab reports, and the reasoning behind the concepts of experimental controls and experimental design, which are technical manifestations of the same objectives, in a context that was more relevant than if covered without the greater discussion.

2.2. Hedging and Adjusting Claim Strength to Match Evidence

The second area of interest relates to the drawing of conclusions that are appropriately supported by data, a topic that is somewhat challenging to reinforce effectively using conventional evaluation rubrics. Focusing on the writing in lab reports allowed students to develop facility with the language of “hedging” and to also see its close connection to the obligation that scientists are under to draw conclusions that do not overstate the strength of their empirical data, and that are appropriately supported by the nature and quantity of their observations. Hedges are instances in a text in which the writer “withhold[s] complete commitment to a proposition” and are realized linguistically by means of modal verbs such as *may* and *might*, as well as adjectives and adverbs such as *possible* and *probably* [5]. As part of the first lab that students performed, they had to experimentally determine the density of two unknown substances and then, based on the measured density values and the physical appearance of the substances (e.g. colour, luster), make an educated guess as to the identity of the substances. Due to limitations in the type of data collected and in the experimental methodology available, few students were able to correctly identify the unknown substances, at least with any kind of certainty, but many nevertheless used language in their lab reports that implied total confidence in their claims about the identity of the substances, as in these examples:

“Comparing [experimental and literature values], the two metals are iron and polyethylene terephthalate.”

“The dark grey Sample 1 is magnesium and the shiny silver-coloured Sample 2 is aluminum.”

In feedback on such examples, both the language and engineering instructors indicated that the writers needed to use hedges to better reflect the level of confidence with which they could justifiably make their claims. A successful revision of the first excerpt would therefore be, for example

*“... the two metals **could** be iron and polyethylene terephthalate.”*

Like passivization, then, hedging became a focal point for the teaching and learning of the language of lab reports. Through classroom activities, students were able to see how the use of particular language forms (modal verbs and certain kinds of adjectives and adverbs) was inextricably linked to a fundamental principle of scientific inquiry—that inferences must be carefully made and say no more than what is clearly justified by the data.

In the engineering course, the instructor followed up on this concept when discussing the critical analysis of results and the identification of sources of error. In this context again, many students, attempting to explain discrepancies between measured results and expected values, categorically stated possible phenomena as the main/only reasons for these differences, in comments such as:

“The unintended escape of gas from the [improperly sealed] suction flask occurred and resulted in an inaccurately low value for the molar volume of N_2 ”

Conspicuously absent was any discussion of the likelihood of this phenomenon or suggestions of modifications to the experimental protocol or further experimental work that could eliminate or at least verify these sources of error. An emphasis on the language of hedging prompts questions such as “Did this really happen?”; “How likely was this to have happened?”; “How big of an impact would this have had on experimental results?”; and “Does this really explain the observed discrepancies between observed and expected results?”, all of which are crucial questions to ask during the critical analysis of results in the discussion part of a lab report. Many students at all levels struggle with these concepts, leading to superficial discussions or analysis of results, and the focus on language provided a context in which to explore this issue. The concept of critical analysis is further explored in section 3 of this paper through peer-feedback activities related to the discussion section of reports.

2.3. Student Feedback on Language-Focused Interventions

In order to gauge the effectiveness of the language-focused lab report feedback, a survey measuring student perceptions of its impact on their learning was conducted toward the end of the course. Of primary interest was whether, and to what degree, students perceived their language-centered lab report work in the adjunct course as beneficial to (a) the development of their communication skills and (b) their understanding of the scientific concepts and principles around which their lab experiments were designed.

Figure 1 summarizes students’ perception of the impact of the language course work related to their lab reports on

their composition skills. Over 30% of respondents ‘strongly agreed’ and nearly 40% of respondents ‘agreed’ that the language feedback and revisions process had contributed to the improvement of their ability to write lab reports in English, which represents an aggregated 71.6% of responding students finding the feedback useful. Only 9% of students chose either ‘disagree’ or ‘strongly disagree’—and 19.4% responded ‘neutral’ or that the intervention had no impact on their writing skills.

Fig. 1. Student responses to the Likert-scale survey item “Getting written feedback from the English instructor and revising my lab reports have helped me improve my English-language lab report writing skills.” ($n=67/81$).

While it is not particularly surprising that a majority of students reported the language-focused lab report work to be beneficial to their English writing development, the results obtained for a survey item about the effect of the language interventions on technical and scientific understanding, shown in Fig. 2, were more unexpected. Approximately 30% ‘strongly agreed’ and 45% ‘agreed’ that these language activities helped them deepen their understanding of the scientific concepts involved in their labs. By comparison, only 10.5% of students selected ‘disagree’ or ‘strongly disagree’ for this item, with 14.9% neither agreeing nor disagreeing with the statement.

Fig. 2. Student responses to the Likert-scale survey item “Language-focused instruction, assignments, and feedback on lab reports in [the language course] have enhanced my understanding of the scientific concepts involved in the labs.” ($n=67/81$).

In addition to the aforementioned Likert-scale items, the survey also included open-ended questions seeking general commentary on the strengths and weaknesses of the language course. In terms of perceived strengths, one important theme that emerged from the student comments was an appreciation for the amount of feedback that was being provided. As one respondent wrote,

“[The instructor] gives us a feedback of our lab reports. This means that we can see where we are mistaken and we can fix that errors for future assignments.”

Another perceived strength was that the adjunct course focused for the most part on the particular texts that the students were producing in the disciplinary course, rather than on generic examples of lab reports. Indeed, several students mentioned specifically that receiving ample feedback on the particular reports they were writing was quite helpful, as was the instructor sharing a model report that he had prepared for the first lab of the term. One student cited the fact that the instructor

“used the lab reports that we gave to him as examples to work with”

as a notable strength.

As to the themes that emerged from student comments on areas for improvement, a noticeable number of respondents stated they would have benefitted from more in-class lab report writing practice. Addressing this important concern will likely necessitate creative classroom time management strategies on the instructor’s part, since the language course meets for only one 50-minute session each week. Another key theme was that students wanted additional exemplary model lab reports to use as guides for their own writing; as one wrote,

“I prefer having more good examples and can learn from them.”

Although providing *post-hoc* models of the lab reports that students write seems to have important benefits for their writing development, it may be wiser to limit the number of such models provided to minimize possible plagiarism by students in subsequent years, and to satisfy the demand for additional models with exemplary reports for labs that students will not do themselves.

3. PEER REVIEW ASSIGNMENT TO PROMOTE CRITICAL THINKING IN LAB REPORTS

Having students work directly on lab reports in the language adjunct course presents the opportunity to

introduce or reinforce technical concepts and analytical skills while working on student writing skills. As previously discussed, a common weakness in lab reports, at all levels, is a lack of depth of analysis. While engineering students become quite adept at performing calculations, drawing and describing trends in graphs, and listing sources of error, many have difficulty taking the next step of critically analyzing or explaining their results. This can involve the following, all of which are the elements of real value in the discussion section of a report: suggesting physical phenomena or mechanisms that could explain the results observed; analyzing the likelihood and impact of sources of error, qualifying those sources of error, or discussing whether or not they could, in fact, account for any observed discrepancies in results; and designing and suggesting future work to clarify or confirm underlying phenomena. Although superficial analysis is prevalent (and understandable) in the reports of first year students, the problem often persists even as students move on to the upper years of engineering programs. This superficiality is not always due to a lack of technical understanding on the part of the students, but is often a matter of limited communication skills or awareness of *what* to write in a discussion (i.e. of reader expectations).

To help prompt the questions that would lead to a deeper analysis of results, a peer-review activity based on the Discussion section of a lab report was designed. Peer review activities have been shown to improve learning and to develop an appreciation for what counts as high quality work in particular fields [4,7], making them well-suited for this particular application. In this assignment, after having written a lab report themselves, students received anonymized versions of some of their peers’ discussion sections from reports for the same experiment, and were tasked with evaluating various elements of language, including those discussed previously, as well as critiquing the discussion for its structure, the writer’s understanding of technical content, and its depth of analysis. The objective of this assessment was for the reader to identify areas for improvement and provide helpful feedback that would be passed on to the writer, as well as reflect on whether particular elements might be missing from his or her own writing. Students were evaluated on the quality of their evaluation of their peers’ work.

3.1 Student Performance on the Peer Review Assignment

Overall, students were quite adept at identifying problems with their peers’ work and providing relevant, valuable feedback, through statements like:

“[...] the writer gives three sources of error that may affect the accuracy of data without explaining them. The

writer also doesn't mention what other experiments can be performed to improve the accuracy of data and to determine whether the identified errors are really significant."

The act of evaluating others' work also made them reflect on their own writing and how to improve it, as corroborated by the survey results discussed in section 3.2.

It is interesting to note that, without being explicitly prompted to do so, several students commented in the peer review activity on language features as they relate to the technical content in lab reports, as in the following example:

"[...] various errors were noted, but are they significant enough to affect the results? [...] when stating errors, hedges should be used as you are not sure you are 100% correct"

This suggests that certain students are internalizing this connection between language choices and technical objectives.

3.2 Student Feedback for the Peer Review Activity

As shown in Fig. 3, when asked whether the peer review activity helped them improve their understanding of how language was used in the discussion sections of lab reports, over 75% "agreed" or "strongly agreed" that it had, 13% neither agreed nor disagreed and the remaining students "disagreed" or "strongly disagreed" with the statement, which mirrors the results shown in Figs. 1 and 2.

Fig. 3. Student responses to the Likert-scale survey item "The peer feedback assignment helped me improve my understanding of how to use language effectively in the Results and Discussion section of a lab report." (n=38/81)

The survey also asked students whether the activity helped improve their understanding of the elements that

should be included in the discussion section of a report. As shown in Fig. 4, over 75% of the students agreed with the statement, suggesting that this type of activity was quite helpful. It should be noted that the response rate for the surveys providing the results in Figs. 3 and 4 (47%) is significantly lower than that for the other surveys described here. This is likely due to the timing of this survey, which was much nearer to the end of the term when student participation in optional activities is generally reduced. It is also important to note that the survey results reflect the perception of students on their performance and the role of these activities in helping them improve their writing skills, and not a formal evaluation of the quality of their work. Anecdotally, however, it is the opinion of the language and engineering instructors that the students made tremendous progress in their lab report writing skills over the course of the academic year, both in terms of language and technical merit, and the results presented here appear reliable. A more comprehensive and systematic evaluation of student progress is warranted, however, and will be the subject of future work.

Fig. 4. Students responses to the Likert-scale survey item "The peer feedback assignment helped me improve my understanding of what I should write about when interpreting my data in the Results and Discussion section of a lab report." (n=38/81)

A strong theme that emerged from the open-ended responses to this survey was the students' valuing of the opportunity to reflect on their own writing in relation to that of their peers. For instance, to the question of what was most useful in this activity, one student wrote:

"I think that it helped me look at the way that I write discussion sections from a different perspective and therefore it will help me write better in the future, especially to evaluate sources of error better"

When asked what was least helpful, several students indicated something along the following lines:

“I find other students' lab report somewhere I cannot understand. I think I may have the same problem.”

Although such comments speak to the limitations of the peer review assignment, they are at the same time heartening in that they suggest a developing awareness on the commenter's part of his/her own lab report writing weaknesses and of the importance of language in communicating technical information effectively.

4. CONCLUSIONS AND FUTURE WORK

This paper outlined three examples of the intersection of technical and language instruction that arose from the association of two adjunct language courses with two first-year engineering courses as part of the Vantage College Applied Science program. These examples are part of a larger curriculum that aims to both develop the English-language communication skills of international students and support their learning of technical engineering material. Given the effectiveness of the approaches presented, as assessed by both the course instructors and the students themselves, this collaboration will continue.

Given perceived benefits of the peer review activity, this type of task will be expanded and implemented for other sections of the lab report in the future. A digital assessment system is also under development, which will allow for the efficient cataloguing of student work and identification/categorization of errors, making a much more comprehensive and systematic analysis of student performance possible.

Every science and engineering lab instructor can provide examples of language-related difficulties such as those discussed in this paper. Given that the integrated approach described here seems effective at training first-year students, it would be interesting to try to implement some of these above-mentioned strategies in upper-year engineering courses and to evaluate their impact on the writing and technical analysis of those students.

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