INTEGRATING WRITING AND ENGINEERING INSTRUCTION TO BUILD A FOUNDATION FOR STUDENT SUCCESS IN THEIR ENGINEERING DISCIPLINE

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Abstract – The importance of communication skills cannot be over-emphasized in the context of 21st-century global engineering. Writing is an important skill to learn, but it can be difficult to make the writing assignment meaningful and relevant for engineering students. To meet the challenge of global demand for engineering education and increase in enrollment and to motivate students to learn communication and writing skills, writing instruction is integrated with engineering courses in various UBC engineering programs. Integration helps students to transform their technical knowledge into problem-solving solutions for case studies grounded in their discipline. The ongoing research project’s theoretical framework includes principles from genre theory, situated learning, case-study approach and student-centred learning. Three models of integration have emerged: project-based full integration, course-based partial integration, and topic-based thematic integration. The pedagogical experiment on integration moves from disciplinary-specific and situated writing to “open” and “global” learning of writing where knowledge of the discipline is learned, applied, created, and transformed across disciplines and cultures.

Keywords: Second-Year Engineering Education, Integration, Writing Instruction, Genre, WID/CID, Student-Centred Learning, Transformation, Global Citizen

1. INTRODUCTION

The importance of communication skills cannot be over-emphasized in 21st-century global engineering. The Canadian Engineering Accreditation Board (CEAB) presents communication skills as important graduate attributes, which include the “ability to communicate complex engineering concepts within the profession and with society at large.” Specifically, students should be able to “read, write, speak, and listen; they should be able to comprehend and write effective reports and design documentation, and to give and effectively respond to clear instructions” [14]. Growing global demand for engineering education has increased enrollment, and average class size in our technical communication courses has increased from 20 to 50 over the last 25 years. A full-time teaching load has increased from 120 to 300 students per annum, which is a daily challenge both for the instructors and students. Our paper describes how we deal with this challenge.

We make writing assignments meaningful to engineering students by integrating writing instruction in engineering courses either directly or indirectly through collaborative and complementary assignments. Students learn how to transform technical knowledge into problem-solving solutions for contemporary engineering case studies, which is necessary for them to develop the critical thinking skills required in their careers as global engineers. Integration started a decade ago in the departments of Mechanical, Chemical and Biological, Geological, Mining, Electrical, and Integrated Engineering at the UBC Faculty of Applied Science. Our paper presents the results of integrating writing instruction with engineering courses in these departments.

2. THEORY AND METHODOLOGY

Our theoretical framework is based on principles from genre theory, situated learning, the case-study approach, and student-centred learning.

2.1 Genre theory and multi-dimensional methodology

Following Bazerman, we regard writing as “a complex activity” that involves the interplay of “texts, language, materialities, society, minds and histories” in the acts of reading and writing [5]. The complexity of writing allows for a combination of diverse multidisciplinary approaches. Understanding genre as social action allows us to explore the intersection of writing and engineering. In Martha D. Patton’s Darwinian analogy for writing-in-the disciplines,
genre is viewed as “a field-specific-activity” mediating
change and stability to develop disciplinary knowledge
through selection and replication [31]. We assess context
from a rhetorical perspective based on the pedagogical
principles of engineering education, genre analysis,
activity theory and writing studies [41].

Integrating writing instruction in engineering courses is
not a novel idea [33]. It is based on an established tradition
of integrating writing instruction and professional
competencies in engineering education [4, 11, 39].
However, integration sometimes lacks clear exposition for
systematic implementation. Applying writing as a tool
focuses on situatedness and a discipline-specific approach
but leaves out broader social and global engagement as an
important objective of writing instruction [26]. Learning
the genres in a “closed” discourse community may work in
vocational education (e.g., for nurses and technicians who
learn exactly how to perform a task), but not in the
academic environment of engineering education. An
interdisciplinary instead of an intra-disciplinary approach
is likely to be the best pedagogical practice. Writing
facilitates this knowledge-transformation process.

Genre is also seen as cultural artifacts representing
ideological and disciplinary beliefs and knowledge [9].
Teaching students not only “how” to follow the
conventions but also “why” the conventions are enforced
enables them to interrogate their own understanding of the
conventions. These conventions signal the “norms,
epistemology, ideology, and social ontology” of the
discourse community of engineering [8]. Instead of
learning a template to fill in the content, they learn how to
apply their skills in different situations.

2.2 Situated learning and the case approach

Writing is called upon to respond to a situation or
exigence that is made up of three constituents: exigence or
problem, audience, and constraints, which are the basic
elements of a case [12]. The case study approach engages
students in the interplay between purpose, context and
audience and forces them to inspect the inventories of their
genre knowledge and mobilize “all of the available means
of persuasion” and communication skills to find the most
appropriate strategy and solution.

2.3 Student-centred learning, teamwork and peer-
review

There is no better illustration of the saying “knowledge
is power” than the power held by genre in education [10].
Genre theory implicates the shifting of power in the
student-teacher relationship. Involving students in the
social action of WID/CID, the “generic power” empowers
them to construct knowledge through engagement and
social interaction [32, 43].

The move to interactive learning and learner-centered
teaching has redefined the roles of teachers, the purposes
of teaching and learning, the function of content, and the
purpose and processes of assessment. Student-led
classroom activities, collaborative learning and problem-
solving or integration in research groups and projects give
students the opportunity to participate in professional work
similar to the real-world workplace, which stimulates
deeper learning [2, 17].

Power shifts from instructors to students who are no
longer “empty vessels.” Students learn by asking questions
and discovering solutions. They learn from one another as
they share their approaches to problems and solutions in
design assignments and class activities [13, 44]. Students are
positioned as engineers-in-training, active and
interactive learners, and the instructor is their supervisor,
mentor, designer and facilitator of learning experience,
resource provider, and co-learner.

Peer-review in writing instruction helps students read and
respond to one another’s writing. There are three
approaches: open-ended; guided – with a list of general
questions; directed – with a checklist [35]. Building peer-
reviews into writing instruction and course assessment
hands students the power of genre knowledge so they
become masters of their own learning and “insiders” of the
engineering discourse community.

2.4 Writing instruction beyond WID/CID: Educating
21-century global engineers/citizens

Technical communication courses are important for
educating professional engineers. Integrated courses
address the following Canadian Engineering Accreditation
Board graduate attributes: problem analysis, individual
and teamwork skills, communication skills, professionalism, ethics and equity, and life-long learning
[14]. Students are encouraged to practice EGBC’s code of
ethics in the classroom and observe Canadian copyright
and IEEE documentation in research. These expectations
and class activities reinforce the pledge they make at the
UBC Engineering Iron Pin Ceremony: the UBC
Engineering Code of Ethics “adapted from the
EGBC Code of Ethics” for students and their time
as a UBC Engineer.”
3. THREE MODELS OF INTEGRATION

We have developed three models of integration: project-based full integration, course-based partial integration, and topic-based thematic integration.

3.1 Full integration in the Department of Mechanical Engineering

Mech 226/227 is a technical communication course for 2nd-year mechanical engineering students within the integrated Mech 2 program. In 2003 the technical communication instructors and engineering professors started designing a course centred on topics and readings that reflect fundamental competencies for engineers. The goal was to promote a more inclusive use of writing that would enable engineering students to draw upon their interest in engineering and their own rhetorical resources. New case studies set out in the engineering context were developed for the courses. Inspired by research in engineering education [16, 19], our pedagogical approach incorporated project-based learning and team-based activities.

The development of Mech 2 required collaboration among 17 instructors teaching various disciplines: technical communication, mechanical and electrical engineering, robotics, mathematics [30]. The design-related activity system of Mech 2 involves design, prototype development, competition, documentation, assessment as well as attendant ethical issues, teamwork, and communication. Learning activities have many elements related to team dynamics and community knowledge-building. The writing component was integrated with engineering assignments in the areas of content, delivery, and assessment.

Our integrated approach borrows from an established tradition of integrating writing instruction and professional competencies in engineering education [4, 11, 39], which however has not been commonly practiced in US and Canadian engineering programs. We created rhetorical situations that promoted the use of genres linked to the activity system of Mech 2 [36, 37]. We used genre theory to decide which genres to assign and teach in Mech 2 in order to meet the requirements of Mech 226/227, Mech 2, the Faculty, and CEAB graduate attributes.

Assignments are based on projects that students are undertaking concurrently. Intensive teamwork replicates teamwork that is paramount in the engineering workplace. Collaborative writing, as noted by Ingram and Parker [25], requires a lot of shared interaction, decision-making and responsibility, so it fits the program well. A considerable amount of communication is digitally mediated and occurs online in the Learning Management System site of the Mech 2 program.

We observed the following positive outcomes of this integration:

- Increased motivation, increased enrolment, and higher caliber students [30].
- More ambitious and inspiring report topics.
- Zero plagiarism. Project assignments are always new and the design is original.
- A dramatic reduction in the percentage of students failing the technical communication course.

Mech 2 has been recognized as one of the best curriculum innovations to foster collaboration in university teaching. It has won three important awards. In 2005 the Mech 2 program was an ASME Curriculum Innovation Prize Winner from the American Society of Mechanical Engineers. In 2006 it received the Alfred Scow Award from UBC Campus Advisory Board on Student Development. The program later received The Alan Blizzard Award which is administered by the Society for Teaching and Learning in Higher Education (STLHE). We have also observed some negative outcomes over the years:

1. An increased level of stress [30] that is high both for students and instructors due to a huge workload and “just-in-time production” mode.
2. An insular nature of discipline-specific writing within the Mech 2 community. It is permeated with jargon and technical terms that only insiders understand.
3. Less class time devoted for writing instruction. Similar to the findings reported by Shwom and Hirsch [38], the intensity of learning in Mech 2 tends to de-emphasize the writing component of the course. Design projects received most of the classroom time and focus, diluting or diminishing the value of writing instruction, as outlined by Reave [34].

3.1. Partial integration in the Department of Chemical and Biological Engineering

We began to integrate APSC 201: Technical Communication with CHBE 262: Chemical Engineering and Applied Chemistry Laboratory in 2011. APSC 201 was later renamed as CHBE 201: Integrated Technical Communication and extended to an 8-month duration to match CHBE 262, the 2nd-year foundational lab course. Between 2013 and 2016, 30% of CHBE 201’s assignments were integrated with CHBE 262’s and 70 % had content
related to their chemical engineering labs. In 2017, we started integrating CHBE 201 with CHBE 241: Material and Energy Balances, along with CHBE 262. All these courses are informed by team-based learning and problem-based learning protocols.

CHBE 201 is taught in a “flipped” classroom model [7], and learning is student-centred [1], with 50% of student grades determined by individually-tested assignments and 50% by team-based assignments. Pre-class readings and chapter tests, as well as group discussions, have replaced long lectures. Class time is for working on assignments. Students are introduced to problems in class, which they discuss in groups and solve either working individually, in pairs, or teams following rubrics. Peer calibrated review teaches them to evaluate the work of their colleagues. They learn from their mistakes, as well as from the mistakes of others.

Assignments are genre-based using case studies related to chemical and biological engineering processes and applications. Each assignment has an instructional rubric and an evaluative rubric. Critical questions guide students in their readings of the case study to search for appropriate responses and solutions to the problems. Practice assignments are peer-reviewed following the rubrics to calibrate their marking before assignments are graded by student teams for marks. The instructor checks the student-marked assignments afterwards for quality assurance and adds comments, corrects mistakes and adjusts the grade. Students also evaluate the contribution of their peers for team assignments based on 5 questions tied to a 4-point Linkert scale.

Integration with CHBE 262: Three of the lab reports submitted to CHBE 262 are workshopped, peer-reviewed, and revised in CHBE 201 classes before they are submitted to both courses. At the end of the academic year, students prepare a poster proposing a new lab or demonstrating an industrial application for one of their labs and present it in the lab course as well as their technical communication course. Thirty percent of their final course grade in technical communication is based on assignments that have a similar value in CHBE 262. Ancillary assignments, such as process descriptions, reinforce their theoretical understanding of their labs in water and sewerage treatment, catalysis, and transesterification of biodiesel.

From CHBE 262 to CHBE 241: In 2017 we started to also integrate CHBE 201 with CHBE 241. Case studies situated in British Columbia’s paper and pulp industry, a major contributor to the province’s economy and the government’s revenue, were developed to help students understand energy consumption and cost efficiency in a competitive, global market. Topics include description of High Consistency and Low Consistency pulping, implementing chemical pre-treatments to increase fiber strength and resistance to fiber cutting, and comparing the effects of chemical pre-treatments on energy consumption and pulp parameters. Students learned how to mediate information between multiple audiences, including operation managers, consultants, the plant manager, and R&D head and corporate head office.

CHBE 201 now has 100% of its assignments integrated directly or indirectly with CHBE 262 and 241 to help students learn and understand more clearly the content of their engineering courses. Figure 1 below shows the percentage of CHBE 201’s assignments integrated with CHBE 262 and 241 respectively.

![Fig. 1. CHBE 201 integrated assignments](image)

### 3.3 Topic-based, thematic integration

MINE 201 and GEO 201 are 2nd-year technical communication courses. They use a thematic approach with case studies for assignments revolving around one main topic each term. The assignments include the proposal, report and oral presentation for the course project; they also include the portfolio assignments, technical description, the midterm, and final exam. These assignments either complement work in other engineering courses students are taking concurrently or provide background pertaining to courses they will take in the following semester. The topic in 2017 is the failure of the Mount Polley Tailings Pond dam, its retrofit and Long-term Water Management Plan [24, 20, 21]. Students responded to criticisms in the report “Post Mount Polley Dam Safety in Transboundary Mines in British Columbia” written by David Chambers on behalf of many First Nations, environmental groups and NGOs [15]. The report suggests best practices are not being followed at both Mount Polley and Red Chris mines [15], which are owned and operated by Imperial Metals [24]. Documentation for the case study is extensive and consists of various technical
Mount Polley mine is an open pit copper/gold mine with an underground component in the Cariboo region of central British Columbia [24, 40]. On August 4, 2014, the breach of the Tailings Storage Facility (TSF) of the mine released 24 million cubic metres of water and tailings into Polley Lake and its neighbouring waterways. It was one of the most serious tailing pond dam failures in BC history [18, 27]. Much of the damage from the spill at Mount Polley has been remediated and the mine re-opened at reduced capacity in 2016 [24]. Red Chris mine opened in Fall 2014 and is processing 30,000 tpd of copper ore [24].

The report “Post-Mount Polley Tailings Dam Safety in Transboundary Mines in British Columbia” [15] cites several core recommendations which are excerpted from “The Independent Expert Engineering Investigation and Review Panel” [29]. Their core recommendation is to implement dry tailings operations in new mines in BC which doesn’t apply to either Mount Polley or Red Chris mines since they were already in operation as wet tailings mines before the report was written.

Two of three additional recommendations by the review panel have been implemented at both Mount Polley and Red Chris [24]. But the author of the report “Post Mount Polley Dam Safety in Transboundary Mines in British Columbia” is disingenuous in drawing their conclusion that both Mount Polley and Red Chris tailing pond dams do not comply with the recommendations and are at high-risk of failure [15]. Students respond to a number of case studies addressing this situation and various audiences. They are required to counter the conclusions of the report in memoranda to the Board of Directors and letters to shareholders of Imperial Metals, in a manner that is non-confrontational and not litigious.

A portfolio assignment requires students to assess the long-term water management plan [3, 20] for the retrofitted Mount Polley Mine proposed by Imperial Metals [24, 28] and to present a report on the assessment to a stakeholder advisory board comprised of First Nations, community leaders, and local environmental groups that is chaired by the BC Ministry of Mines. The assessment is written from the perspective of a committee member who is a mining engineer or geological engineer (depending on the class) representing the BC Ministry of Environment. This is the real-world situation for the process of approval of long-term water management plans for mines in British Columbia.

Through the iterative process of revisiting the documentation necessary to answer these assignments, engineering knowledge is transformed and crystallized by students. The case studies are examined from various perspectives in the memoranda, letter reports, and process descriptions that comprise the portfolio, midterm, final exam, formal report, and oral presentation assignments of the course. Upon completion of the final exam students have a good understanding of the tailing pond dams profiled in the case study and the genre approaches necessary to present information relevant to their audiences.

4. CONCLUSION

This paper describes the three models for integrating writing and engineering instruction at the University of British Columbia: Project-based full integration, course-based partial integration, and topic-based thematic integration. Principles of genre studies and learning theories in engineering education and research on writing instruction support these integration models. Student-centred learning, genre analysis, situated writing and case-study approach, as well as the practice of flipped class and peer-review, have made writing instruction more meaningful and relevant. They have changed the teacher-student relationship. Students have power of learning and assessment, which engages them in the learning experience and improves learning outcomes. The objectives of these models are to promote student learning and educate global engineers. Students learn writing competence and problem-solving skills and take leadership roles in interdisciplinary and multicultural work environments. They explore complex social problems in case studies which raises their awareness of global issues.

While most engineering programs at UBC Applied Science have integrated writing instruction with engineering courses, not all of them have transitioned. Quantitative and qualitative data need to be collected to review the impact of integration on students’ learning experience; learning outcomes need to be analyzed and evaluated and the models improved. Integration of writing and engineering instruction remains to be further researched, explored and implemented.

Writing instruction is becoming more important as the number of international students surges and enrollment in engineering increases. Good writing and technical communication skills are must-have for a global engineer. Integration of writing and engineering instruction points to the direction for meeting the challenge.
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