A FRAMEWORK FOR SECOND LANGUAGE, COMMUNICATION AND ENGINEERING LEARNING OUTCOMES

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ABSTRACT

Teaching and learning of engineering courses and programmes in a second language (L2) or for non-native speakers (NNS) has become increasingly common in recent years as international connections between institutions grow, industries globalise, and markets and the workforce become more fluid. The role that a L2 plays in engineering education varies depending on context, but there is no doubt that L2 and NNS involvement add an additional level of complexity to the teaching and learning environment. Study abroad students are tasked with developing technical engineering, communication and language skills simultaneously. Research suggests that providing additional instruction in the L2 aimed at the *specific* needs of a course, programme, or professional trade is beneficial. However, this instruction has seldom been taught in tandem with, much less integrated into a project-based engineering programme that focuses on both oral and written communication skills. To integrate second language, communication and engineering content outcomes into a project, we need to develop assessments that meet multiple learning outcomes across these areas, and to monitor the degree to which L2 impacts on the ability of NNS to perform engineering and communication outcomes. In this paper, we report on how a L2 (in our case English) is being integrated into projects, and how communication and language progress and learning outcomes can be assessed within the engineering project framework. Ultimately, we attempt to provide a new project framework that can help coordinate the engineering, communication and language learning outcomes with engineering graduate attributes in a project-based, study abroad programme.

KEYWORDS

Second language learning outcomes; Communication and teamwork skills; Project-based Learning; Integrated project framework for Language, Communication and Engineering Content; CDIO Standards 1,2,3,5,7,8,11

INTRODUCTION

One of the essential features of a CDIO approach to engineering education includes embedding interpersonal and communication skills into a program. Communication skills are important for any discipline, and engineers must be able to communicate technical information accurately and clearly to both technical experts and non-technicians alike. Engineering requires working in teams, as well as communicating through written reports, presentations and correspondence, and involves the use of language, visual and numerical information. These skills and attributes which the engineering students must acquire at the completion of an engineering program are described within the CDIO syllabus, and, along with a solid foundation in engineering principles, are believed to be the essential tools needed to handle the demands and the challenges of a dynamic world (Armstrong 2008).

As engineering courses and jobs have become more globalised, there has been more focus on how to help non-native speakers acquire the language skills needed for engineering communication. CDIO is an international initiative, and the CDIO syllabus 2.0 includes an item recognising the potential importance of second language learning within the CDIO framework. There is little detail, however, on how second language learning could or should be integrated with other aspects of the CDIO initiative, nor how second language learning outcomes or attributes can be incorporated into, or affect the outcomes of, project-based learning. In this paper, we explore how both second language and interpersonal skills can interact with engineering knowledge and technical skills in a project-based curriculum.

Course Structure

The Otago Polytechnic (OP) and Kanazawa Technical College (KTC) joint program (CEE) lasts for 32 full teaching weeks. The students in the program study Mechanical, Electrical and Information Technology (IT) courses. Weerakoon, Dunbar & Findlay (2014) and Weerakoon and Dunbar (2017) describe in detail the development and content of projects for the Mechanical Engineering course, which constitutes about 10% of the study load. English language skills account for about 50% of the program credit.

Engineering English

While the CDIO syllabus describes language features in general, there is little detail on the nature of engineering genre, and how genre can aid students in achieving successful communication goals. The best-known approach to analysis and teaching of professional and academic discourse is Swale's (1990) exploration of genre and move structures of a text. While significant research has been carried out on aspects of engineering English including technical vocabulary (Mudraya, 2006; Ward, 1999), grammar (Conrad 2017), and rhetoric (e.g. Artemeva, 2005; Flowerdew, 2000; Parkinson, 2017), these studies focus on how language classes can help students do better in their content classes, rather than using the language in the content class as an integrated component of the course.

Initiating students into the engineering genre is one goal of engineering courses. Flowerdew (2000) examined the genre and move structure of final-year engineering project reports. Dannels (2009) found that key factors differentiating successful engineering design presentations were the use of explanatory rhetoric to justify designs, creating a proximity to the audience, use of oral fluency, adoption of a professional language approach, and the use of cohesive devises to link ideas, sections, designs and solutions together.

Common moves that have been identified in engineering reports and presentations include: establishing relevance of topic; listing materials; describing procedures; describing a design; justifying a design decision; identifying a problem; evaluating a design solution; announcing results; interpreting results.

In recent research, some attempt has been made to more closely connect language and engineering content teaching. Tatzl et.al (2012) describe the development of a project-based technical writing model, which aims to integrate the teaching of report writing with a first-year engineering project. They argue that shared assignments in content and language classes raise the relevance for students. They conclude that collaboration between content and ESP instructors increases task authenticity, relevance and significance for students, and that student motivation can be fostered by integrating the project process into both language and content courses. Nekrasova-Beker and Beker (2017) describe the integration of project-based learning into language instruction in a foundation course at university. Rather than focusing only on report writing, this study assesses language through presentations and final reports. This "project" was not a technical engineering project, however, but rather preparation for an "engineering job interview".

INTEGRATION OF ENGLISH INTO ENGINEERING PBL

Learning outcomes for language courses generally involve some iteration of the following (based on NZCEL Level 4/5; equivalent to CEFR mid-upper B2 range). The learner

- understands the main ideas of complex speech (of professional relevance)
- is adapted to style and register
- is adapted to context, audience and purpose
- has a good range of lower frequency vocabulary relevant to topic
- writes well-constructed sentences including complex structure
- can express ideas orally in a spontaneous and fluent manner

In our course developed for an engineering context, these outcomes are realised as follows:

- Identify and accurately describe an engineering "problem"
- Describe engineering designs using accurate and precise terms
- Explain and justify engineering design / modelling decisions
- Identify and be able to use the problem-solution pattern common to engineering communication
- Identify and use cohesive devices to link parts of reports and presentations together
- Demonstrate an awareness of audience and the importance of tailoring communication to the level and interest of the audience
- Demonstrate techniques for developing and maintaining team / group relations

We believe these learning outcomes can be integrated and demonstrated within a project framework, especially one that involves the completion of a project report and presentation.

Based on our understanding of engineering genre and communication described above, we have developed an approach where some language skills are built directly into the project curriculum, while other aspects that require a more linguistic approach are taught in supplementary tutorials. We adopt the approach that technical vocabulary is best taught through the content matter in context, but we use language tutorials to further explore the language of measurement and accuracy of expression. This is to help students avoid the trap of using imprecise terms such as 'a lot', 'a few' etc. which are often inappropriate in an engineering context (Conrad, 2017).

Oral fluency depends on coordination of several skills including pronunciation, intonation, vocabulary and spoken grammar. While we have tutorials to deal with pronunciation and intonation, the project group work provides the ideal context for the practice and development of oral fluency skills, in a less threatening environment than a formal presentation, which we reserve for later in the course.

We teach engineering genre as an integrated part of project work, through the use of a progress “workbook”, final project reports and final project group presentation. This provides an authentic task that students become engaged in and can be given formative feedback on as the course progresses. Finally, we provide students with a discussion on the importance of understanding and tailoring a report or presentation to the audience.

Table 1. The course timeline for both language and engineering content knowledge

Week	Engineering Tasks	Language-focused tasks
1-5	Analyse theory and principle of forces in mechanics	Technical accuracy
5	Test 1 weighting 10%	
6-7	Project 1: Team building weighting 10%	Oral fluency Identify and describe a problem
8-11	Analyse forces and motion, work energy and friction	Oral / written explanatory rhetoric
11	Test 2 weighting 10%	
12-14	Project 2: Multidisciplinary weighting 20%	Engineering report - structure
15-16	Sustainability, energy resources and resource management	technical language
16-32	Project 3 Main project weighting 50%	Engineering genre – report and presentation Audience

TEAMWORK AND COMMUNICATION SKILLS

Language skills provide the fundamental foundation that students need to be able to communicate effectively on engineering tasks and support broader communication skills in a project-based learning environment. The CDIO initiative encourages the use of groupwork and communication skills, and PBL provides the ideal environment to integrate language, teamwork and content-based skills. However, PBL also brings considerable potential for interpersonal conflicts and unequal distribution of the workload amongst team members during the project cycle. We have found that the success of PBL depends on the flexibility and adaptability to challenging conditions during the CDIO process, and that, in addition to development of language and negotiation skills, early awareness of the diversity of student capability is essential in forming effective teams for PBL.

Team formation

Prior to the first project groupwork, we provide engineering content sessions that give students the foundation theory and the principle of forces in mechanics, the correct use of analysing forces in mechanical systems and their relationships to engineering applications. This engineering knowledge is sufficiently addressed to provide an insight into the basic underlying physics needed to develop a systematic approach to solving a small engineering problem.

Observations of English oral fluency, the general character and attitude of the learners during these early weeks, as well as the assessment of the first engineering test provide the basis for determining team leaders. We identify students who are disciplined, motivated and ready to solve problems in a self-directed way. This analysis is important to ensure all teams consist of even strength, especially in situations where the resilience of the team harmony and coherent decision-making process are tested as teams encounter design or implementation problems.

Each team consists of at least four members. Because of the multi-disciplinary background of the learners, we ensure that mechanical stream students are distributed evenly. As far as possible, we also attempt to achieve a gender balance. To achieve this, the engineering and English language instructors consult to choose team leaders, and these team leaders then pick the composition of the teams. We have found this model to work well with our Japanese students, as it helps to reduce interpersonal conflicts while maintaining team diversity. In cases where conflicts with team composition do occur, they are monitored during the initial project by the instructors and team adjustments can be made for subsequent projects.

Language and Communication skills development

Skills gained through group project work include an insight into group dynamics, collective decision making and exposure to viewpoints of others. Learners are also learning to solve a technical problem in an unfamiliar environment and apply theory into a working example. These attributes are used for formative assessment in the preliminary project, which helps to build on initial engineering language knowledge and oral fluency and familiarises learners with interpersonal communication skills.

After the completion of the first project, which consists only 10% of the overall weighting, a reflective session asks the learners to discuss team processes, and composition.

The second project provides learners greater freedom in decision making to arrive at a novel solution, as the solution to the technical problem increases in complexity and the project is open-ended. This project is also multi-disciplinary, so there is a greater level of knowledge transfer from other disciplines. Learners need to combine skills from two engineering disciplines synchronously to achieve a successful outcome. Consequently, there is a greater potential for interpersonal conflict amongst team members. Although interpersonal conflicts are often looked upon negatively in PBL, these projects are a good springboard to examine how learners navigate through the complex layers of language and interpersonal skills when they encounter conflicts of interest. This is quite common when teams find that their original design does not deliver the desired results. This model of learning through doing helps learners reinforce their engineering knowledge, but also gain essential oral language skills and communication attributes without having to provide separate lessons on teamwork theory.

ASSESSMENT

While integration of language and communication skills into PBL has been shown to be both possible and potentially effective, it is important that we build into our projects a system of assessment that both accurately and fairly represents the diverse learning outcomes, as well as meets the requirements of evidence of learning for any course moderation or audit.
The mechanical engineering course consists of three projects, and the project outcomes, complexity and the weighting are raised systematically as language fluency and accuracy improve and the students adapt to working within a PBL environment.

The project workbook

At the outset, students are encouraged to record evidence of their complete design lifecycle in a workbook or portfolio. These workbooks are both a record, and a resource for helping learners develop their technical language skills. Quite often in the initial stages, learners fail to demonstrate good record keeping practice and they are vague in describing their design decisions. Where learners simply record a design graphically, they can be prompted to add a brief description in words, and then to list advantages and drawbacks of their design. They may be prompted to calculate the forces and estimate number and size of screws needed, or precise measurements required. This also serves to introduce learners to the use of more technical terms used in designs. If these deficiencies are addressed regularly in the primary project, they are less likely to be repeated in the final project. Since Project 1 only accounts for 10%, the project provides the basis to develop this good practice.

In the second project, the members need to exercise a greater level of coordination, resilience, and more fluent communication skills to execute and complete all the project outcomes. This project has no clear formulae for a successful design, nor a calculation model for achieving the project outcomes. At this stage, learners need to ensure that the workbook is updated with all the evidence of design selections, and the design errors and weak decisions are not repeated. Earlier work on accurate description of designs and listing advantages and disadvantages can now be developed so that learners more explicitly justify their design selection using the evidence recorded in the workbook. This also offers an opportunity to examine the precise wording used, so that learners develop the habit of using expressions such as "the *preferred* option for…is…because…" (see Conrad, 2017).

Further, at this stage the evidence in the workbook should show the contribution from each member of the team and their involvement and task assignment. Growing oral fluency can be monitored by joining group discussions and ensuring design selections are based on collective group negotiations rather than the personal work of one member. The evidence recorded in the workbook is the basis to establish the contribution to design lifecycle from individual members. The workbook also reduces burden on both the facilitators and the students from having to conduct various forms of individual assessments to determine their contribution to the total project.

Final project report and presentation

The main project is multi-disciplinary and offers integration across other disciplines including CAD and Electrical Engineering. This project also allows the students a considerable length of time to identify and assess the problem, transfer knowledge from other disciplines and advance deep thinking for creative problem solving. Students now have both the technical, communication and language skills to work on a fuller project report and presentation. At this stage, the workbook provides a record that can be formed into a full report using guidance from engineering genre studies. Students can be familiarised with the moves associated with each section of a report, including moves that have not been covered in earlier projects such as establishing relevance of a topic, and following a sequence of problem-solution patterns of rhetoric. Finally, the testing of the project final product is conducted well before the submission of the final report. This enables the teams and individual learners time to reflect on the test outcomes and include an evaluation of their own design solutions and comparison of the effectiveness of their designs compared to other teams, and to include those conclusions in the final report along with the recommendations and/or suggested improvements.

The final report and presentation are summative assessments for both the mechanical engineering course and the English language course. The Engineering English learning outcomes can all be assessed through the report and presentation, which can provide adequate evidence for moderation.

ANALYSIS

Team Diversity and Performance

The largest proportion of students in our program come from an IT stream and, as a result, there is a diversity of student motivation towards mechanical engineering study. Figure 1 shows the result distribution for individual test component (20%) and team project 3 (50%). The graphs indicate that learners who perform well in individual assessments also do well in PBL. One surprising result from our case study is that highly motivated IT students can achieve high accomplishments in PBL in terms of innovation, novelty and success, despite no prior exposure to the mechanical engineering discipline. This may show that the multi-disciplinary nature of the projects can facilitate knowledge and skill transfer from other disciplines.

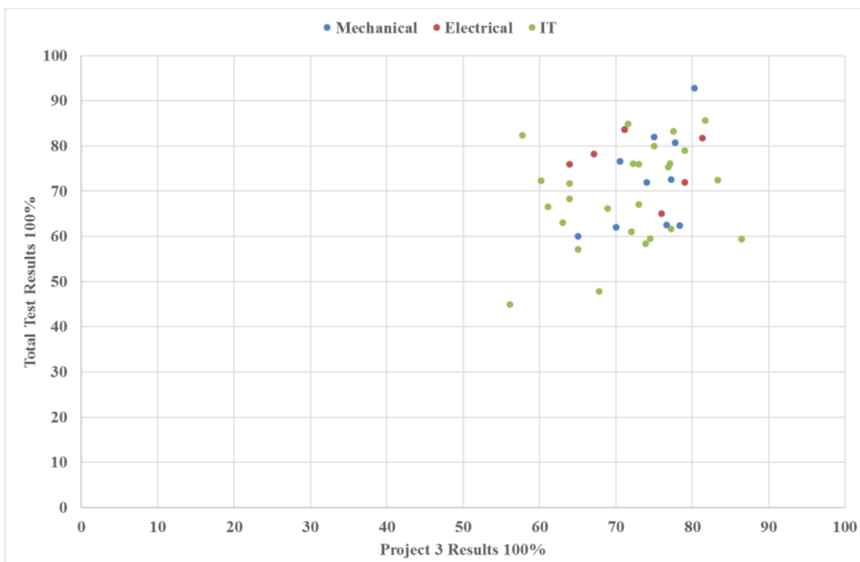


Figure 1. Tests vs Teamwork (Project 3)

Figure 1 also shows that learners who produce only poor to average scores in individual assessments can be motivated to perform well in PBL. In our experience, this relies on team composition, and is generally accomplished through combined effort of task allocation based on individual strengths and through peer support. Learners in the mid-range (between 60-75%) in individual assessments accomplished similar results with PBL.

English language results plotted against project scores (figure 2) also show similar trends. English language skills have also been measured through external TOEIC examinations after the completion of this programme. When these results are compared with indicative results from English tests before the programme, they show significant growth of 200-400 points, which would indicate that Engineering English and PBL provides a basis for growth in general English communicative ability as well. We are aware that the TOEIC test is not an ideal test for engineering English, nor does it necessarily reflect actual communicative ability. We would argue that it is likely our learners in fact improve more than is indicated by this test in terms of communicative ability due to the interactive group work they are involved in.

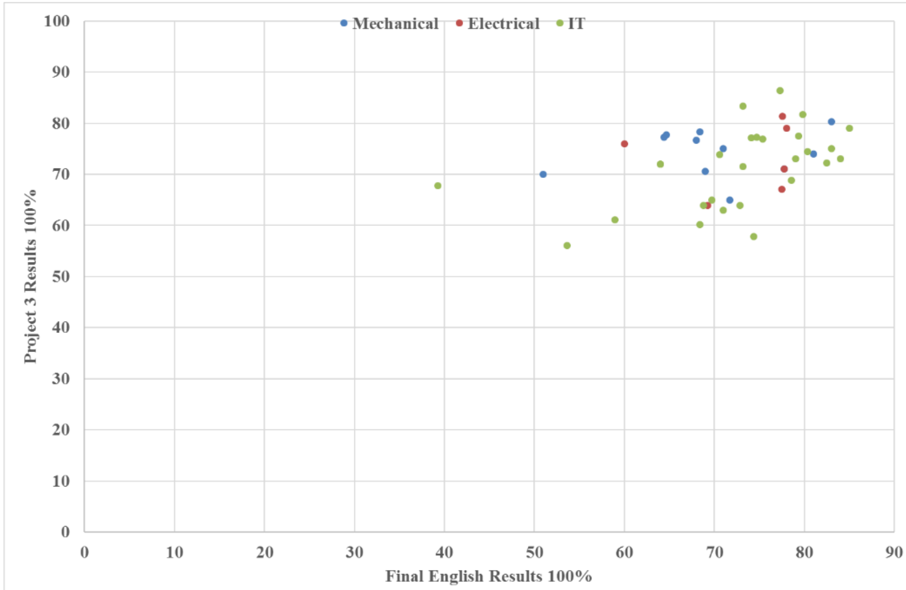


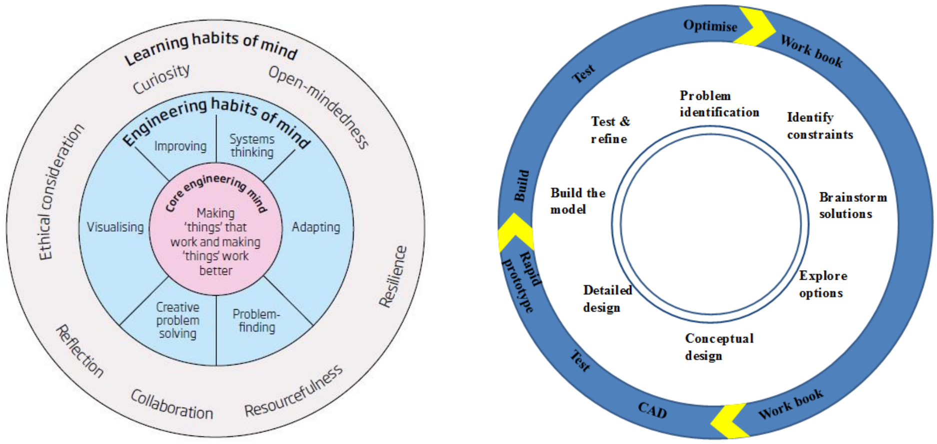
Figure 2: English final marks vs Project marks

Qualitative Feedback

With our most recent cohort we carried out a qualitative feedback analysis based on an initial questionnaire survey (n=15) and more in-depth follow-up interviews. The results suggests that about 80% of our learners agree that engineering project reports and presentations are useful, and 73% expect to use what they have learned from these courses in their future job. Most students (87%) enjoyed working in a team. Several also commented on the importance of teamwork to successful project-based learning, and one suggested more training in developing and maintaining team relations. This is a factor also noted by Neal, Ho, Fimbres-Weihs, Hussain, & Cinar (2011) in their feedback survey. 73% felt that writing reports and giving presentations in English was a difficult task, and 60% agreed that combining English with engineering projects helped them to understand the engineering concepts. Two learners commented that they had never written a comparable report in their L1, and that they needed more guidance in “how to write” and “what to write about”. One learner wrote that he or she didn’t “have words enough for writing”.

DISCUSSION & CONCLUSION

Lucas & Hanson (2014) argue that engineers think and act in a certain way (shown in figure 3a) and this is backed up by linguistic research into engineering genre (Parkinson, 2017). The model that we follow for the complete design lifecycle is shown in Figure 3b, and emphasizes the importance of evidence gathering and problem refinement. The thinking process for the design problem through the CDIO process is recorded in the workbook that each team maintains. The evaluation of team assessment for individual members is conducted using the information provided in the workbook. The workbook is expected to contain the aspects of engineering mind as established by Lucas & Hanson (2014).



a) Engineering mind b) Lifecycle of a product design

Figure 3 Engineering habits of mind (Lucas & Hanson, 2014) and Lifecycle of a product design *(Weerakoon, Dunbar, & Findlay, 2014)*

The intention of the engineering course is to primarily focus toward harnessing these characteristics, but these skills clearly depend on other essential skills and attributes, including communication and language skills. An integrated approach to teaching language, communication and engineering problem-solving skills through PBL as described in this paper can support the development of the engineering habits of mind.

The following diagram, based on a generic PBL model described in Beckett & Slater (2005) is a tentative effort to make these connections explicit.

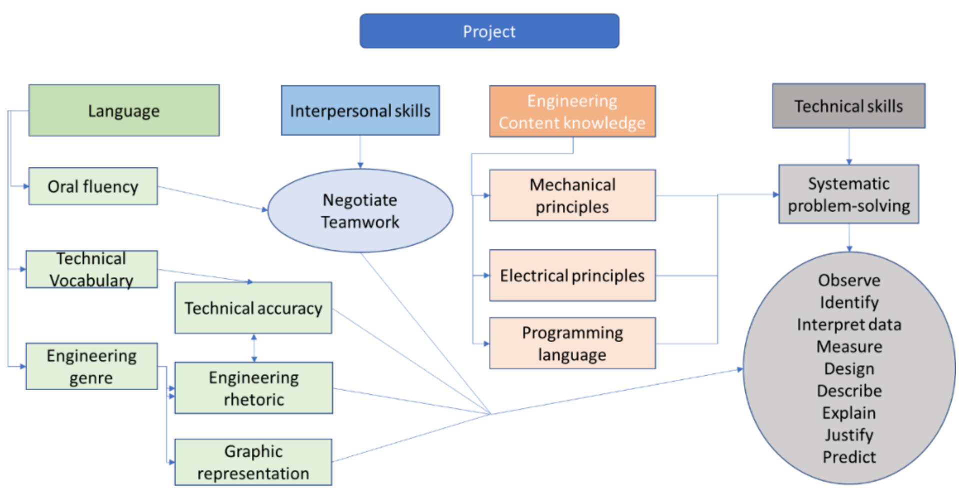


Figure 4. Framework for integration of Language, Interpersonal Skills and Content Knowledge for Engineering

Beckett and Slater (2005) call for the making of learning objectives of PBL activity transparent to the students to avoid differences in beliefs that may cause conflicts. The primary purpose of this diagram is to show students the connections between language, communication skills and content learning.

Our recommendations for the integration of L2 into a PBL course or program are necessarily tentative, but we believe using a workbook or similar approach to record team discussions, decisions and evidence of team progress can help initiate students into practices of the engineering mind and engineering language genre simultaneously, and that this process helps establish connections between content and communication skills. We believe that this approach is both practical and effective, and that the framework presented above can help make that those connections more explicit for students. We acknowledge that much further research needs to be done to show correlation between improvements in Engineering language skills, oral fluency, project work and engineering knowledge. We also need better measures of learner awareness of engineering genre prior to their study on our programme. The diagnostic test being developed by Fox & Artemova (2017) offers scope for improved measurements.

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