

INTEGRATING MULTI-DISCIPLINARY ENGINEERING PROJECTS WITH ENGLISH ON A STUDY-ABROAD PROGRAM

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ABSTRACT

This paper presents the development of an integrated approach to the teaching of mechanical engineering principles and English language communication skills on a study abroad program. In the current year we are implementing three projects. The main project consists of designing, implementing, and operating a complete wind turbine assembly to produce a minimum of 5 watts of electrical energy. This encompasses application of engineering principles and insights into conceiving, modelling and scaling appropriate solutions, before constructing and then operating the prototype. Coordination with other courses on the study abroad program ensures the projects also incorporate CAD and electrical engineering processes where appropriate, and that students can discuss and present their projects in English. A focal feature has been incorporating key concepts of sustainability, local environment, innovation, improvisation and resource management, whilst ensuring that engineering principles match as closely as possible those being taught in the corresponding institution in Japan.

The key factors that contribute to the success of these projects are

- Ensuring project outlines and assessments are clear and consistent, and teaching is focused primarily on meeting the project outcomes
- Creating an activity and inquiry-based learning environment to supplement the limited English language skills in the early stages
- Facilitating team building, project management and independent learning skills
- Ensuring student engagement through allocating tasks based on discipline strength, involving students in decision making processes, and encouraging collective responsibility.
- Coordinating between courses to ensure sufficient explanation and reinforcement of concepts across the curriculum
- Integrating English communication skills, including oral explanation, presentation skills and report writing into each stage of the projects.
- Combining engineering and English assessments to enhance authenticity and reduce student burden

KEYWORDS

activity-based teaching, project-based learning, intercultural communication skills, multi-disciplinary integration, study abroad, CDIO Standards 3,5,7,8,11

INTRODUCTION

Study-abroad programs in tertiary education are becoming more accepted as globally relevant education experiences. They are pathway programs where students commence studies for six to twelve months with a similar tertiary education provider outside the country. They are generally designed to lead to the completion of the course in the home tertiary institute without interruption to their program, whilst providing an opportunity for cultural interaction and contact with alternative traditions and approaches to life.

The Certificate in English and Engineering (CEE) is a 12 month study-abroad program operated by Otago Polytechnic in New Zealand for engineering students from Kanazawa Technical College in Japan, with the aim of creating engineers who are more capable of functioning in a global environment. The program is intended to have a balance between technical principles and application skills and work within a multi-disciplinary environment. The students in this program come from mechanical, electrical and IT disciplines. The typical distribution of the study load for the CEE program in their 12 months study is shown in Table 1

Table 1 Distribution of the study load for Certificate in English and Engineering

Subject	Study load
English	50%
Mechanical Engineering	10%
Computer Aided Design (CAD)	7%
Electrical Principles	7%
Mathematics	16%
Computer programing	10%

Assessment for these courses traditionally consists of short, well-defined problems that have one correct solution. The problems solved illustrate the principles governing the subjects; however they have only limited resemblance to practical situations. Assessments are focused on individual effort and ability rather than group work, and there is little emphasis on interpersonal relationships and communication, self- and team management as will be experienced in the workplace.

This paper presents our experience developing a project-based curriculum in the Mechanical Engineering course of the CEE program, providing students with learning outcomes that stress engineering principles and applications set in the context of the CDIO model.

PROJECT DEVELOPMENT

Students from the three CEE engineering streams study together. This means that both non-mechanical and mechanical students study the mechanical course. It was recognised from the outset that mechanical engineering theory would only be of real benefit to the mechanical students. Since non-mechanical majors do not require the academic strength and the consolidated knowledge from this course, it was felt that project-based engineering would broaden the knowledge of both mechanical and non-mechanical students, enabling students to:

- Look outside the boundaries of their own disciplines
- Develop interpersonal relationships and navigate comfortably in a multi-layer functional environment.
- Solve technical problems in engineering, and handle conflicts and differing opinions amongst the team members
- Experience project and time management
- Transfer other disciplinary knowledge to a working example
- Embed the habits of following sustainable practices through innovative low cost solutions
- Apply theoretical knowledge and application to working examples

From the planning stages, we decided to integrate projects across other engineering subjects as well as aspects of English language instruction. The integration of engineering and English assessments gives more authenticity to the language scenarios, and reduces the burden of assessment across the program. It also provides support to engineering faculty in the early stages of the programme when students have limited language skills. We began with one major design-build project but this has since been expanded to three projects.

Integrating English and Engineering

To create engineers who are capable of functioning in a global engineering environment, ability to communicate in English is essential. Integrating English and engineering offers advantages including increased support to students and faculty, more authentic communication opportunities, and reduced burden of assessment for staff and students.

Integration occurs throughout the curriculum, and includes English teaching staff being involved in teaching vocabulary and providing a more general social context for engineering terms, as well as being on hand to help and observe during engineering classes.

During project design and construction, students are interviewed in English about their progress, decisions and challenges, helping students to reflect on their own learning.

Integrating assessments makes the learning outcomes for the English courses more authentic, while early formative feedback on presentations and reports allows students to produce higher quality output that can be more easily understood by engineering lecturers, thus allowing engineering lecturers to focus on the engineering content, rather than being distracted by English language errors.

Interpersonal Relationships and Team building

We have found that different learning styles and team management practices across cultures need to be taken into consideration in project development. Japanese education still strongly favours rote learning and memorization, and is very teacher-centred. Self-study and interactive learning are not common in Japanese institutions (Dorji, 1997). This means that many Japanese have difficulty accepting an active part in learner-centred group activities, and this can inhibit the establishment of a cooperative atmosphere that is optimum for project work. In our first year we found Japanese students, faced with unfamiliar expectations, often sat around waiting to be told what to do.

Further, team formation and decision making processes vary across cultures, and this hindered our initial implementation of the projects. In Japanese (and other collectivist) culture more importance is placed on developing personal relationships and consensus decision-making, rather than the goal-focused teams more familiar in New Zealand culture (Davis, 1999). This meant that students struggled to work together, and in the first year a small number of students did the majority of the work with little consultation with their team.

Measures that were implemented to deal with this issue included:

- the addition of a small project first, during which team bonding was observed closely, and after which changes were made as deemed necessary.
- More information on and reinforcement of the expectations of student teams, their responsibilities, the role of the teacher as facilitator, and the expectations of self-directed study
- Allocating more time to the initial design stage, so that students were able to reach decisions with less pressure, and reminding students to keep accurate records of all discussions and ideas, including those later discarded
- Encouraging students to record their own decisions and reflect on their decision making processes, and monitoring and providing feedback where appropriate

Activity-based Learning

Engaging the diverse students' interest in learning the technical subject matter is important. Research has shown that implementing innovative teaching strategies in the classroom to engage students in critical thinking and problem solving can enhance learning (Young, 2005). Activity-based teaching has been shown to support an individual's path of learning and self-discovery. Therefore, the first step was to adopt teaching primarily focused on interactive activities to meet both the learning outcomes and prepare students for practical projects. Teaching emphasises the importance of transferring theory to solve practical problems.

Figures 1a and 1b illustrate two examples of interactive activity-based learning in the classroom to teach fundamentals governing mechanical engineering and their applications. This medium of instructions helps to seize and sustain attention and overcome limited English skills. The activity-based instructions also help students to grasp the English terminology used in engineering and improve their language and communication skills.

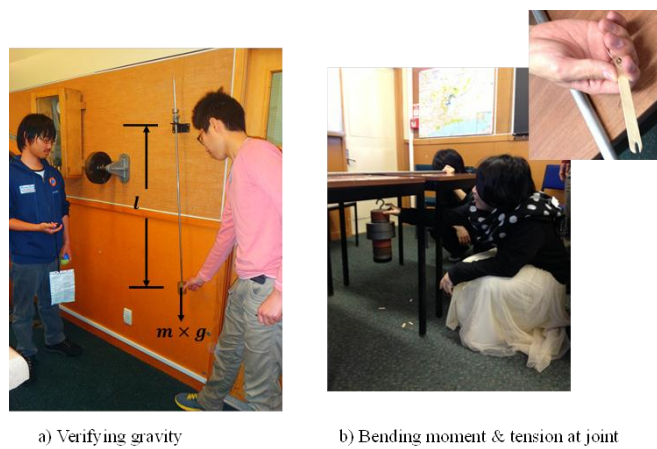


Figure 1 Classroom activity based learning

BASIC PROJECT STRUCTURE

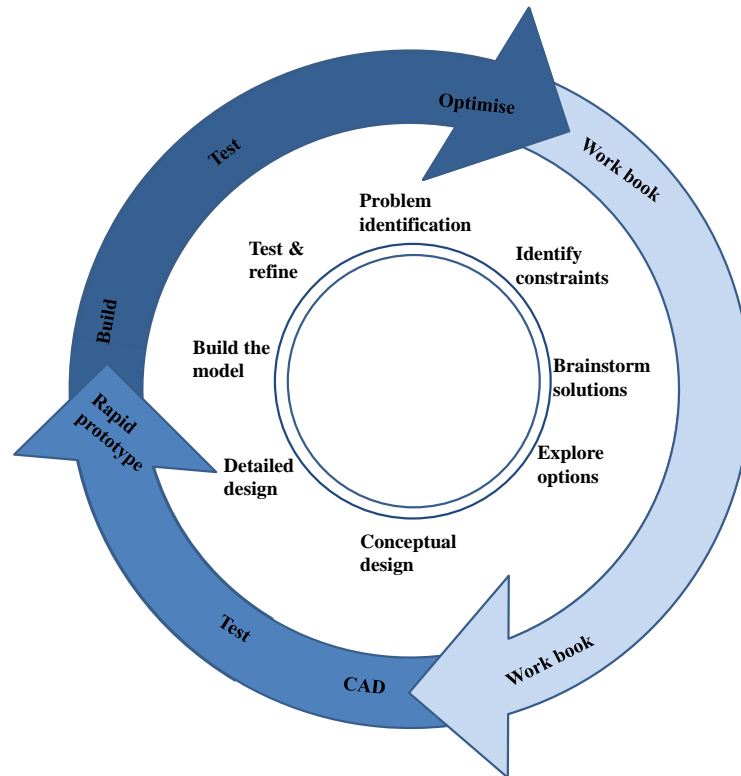


Figure 2 Life cycle of a Project

A project design is based upon customer requirements. It is imperative that this is communicated effectively during every step of the CDIO process. In the classroom, project requirements and anticipated outcomes, along with boundary limits must be communicated at the start of every project. Once the scope and the description of the project are provided, students can be guided by the cycle of steps shown in Figure 2 to meet the project outcome. This methodology encourages a team of very diverse students to explore potential design solutions that encompass the CDIO concept.

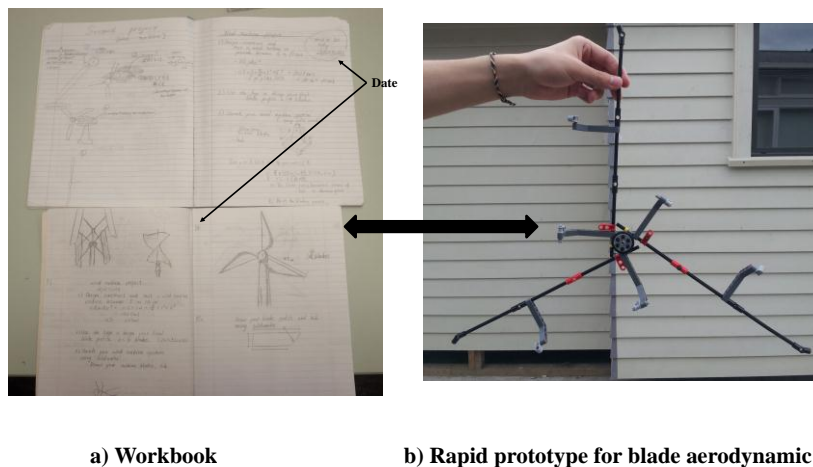


Figure 3 Workbook an important reference tool during conceive stage

Every team maintains a workbook during the engineering design process [Figure 3]. This resource is used to transfer classroom theory into practice, to undertake critical thinking and develop the analytical skills needed to conceive and develop solutions. It is also used to document and refine solutions researched through external resources such as the Internet, or deduce results through rapid prototyping and testing. This is an open-ended design space where interpersonal relationships, team and self-management skills combine with the ability to handle conflicts and differing opinions. An important feature of this process is the allocation of individual tasks to team members based on their strengths. The workbook also acts as a communication aid when students are called on to justify their decisions in English.

The team identifies the design configurations that appear to solve the problem best. The best solution is usually accompanied by a scaled model which features all important elements in the design, using Lego or other improvised components. This model will be tested and refined for performance improvements following the model shown in Figure 2.

The design will then be drawn using a CAD package detailing the profile and dimensions of all important components to be made, including the methods of attachment. The students learn the importance of technical drawing guidelines, since they need to take the drawing to the workshop to make certain parts as per drawing.

The construction and the assembly of all components of the full scale product and preliminary tests are carried out in the classroom until the final working product is built. Students are given incentives to arrive at the most optimum design. They also receive penalties for exceeding the boundary limits. Therefore, they are expected to review their design against the assessment criteria throughout the whole life-cycle of the design process.

The students become actively engaged and receive hands on experience during construction and assembly phases to work with light tools. They are strictly supervised when handling tools to ensure that they follow safety procedure. The types of tools they get to work with are drilling, grinding, roll forming, spanners, chisels, etc.

PROJECT DESCRIPTIONS

We currently have three group project assessments. Each group may consist of four to five students. All design project outcomes are of an explorative nature where conceive, design, implement, and operate processes are contextual learning experiences. The projects are:

Project 1: A compressive structural failure project [Figure 4]. This project consists of building a $150\text{ mm} \times 150\text{ mm}$ base and 250 mm tall structure using no more than 150 100 mm ice-block sticks. Each group is provided with 25 4 mm nuts and bolts, rubber bands and in-house made glue. The objective is to design the lightest structure that can hold the maximum compressive load. The compressive test for each structure is carried out using the Denison hydraulic test machine. The designs usually fail between 800 N to 1600 N compressive load. The main objective of this project is to introduce students to working in a team environment and designing solutions based on self-directed learning.

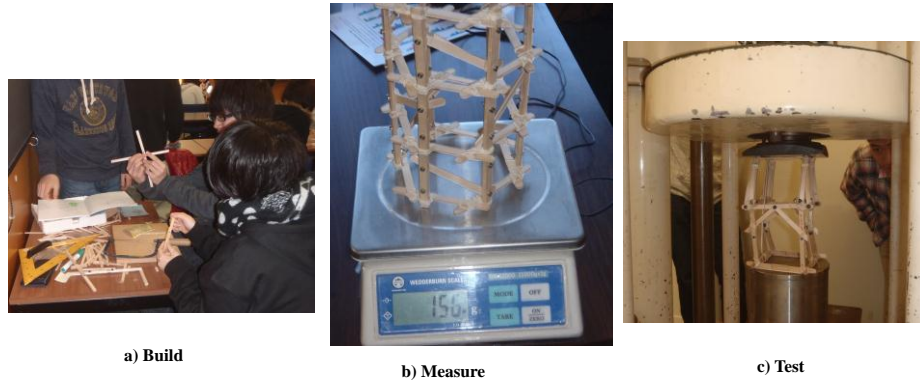


Figure 4 Build, measure, test

Project 2: A transport vehicle design project [Figure 5] where every team is provided with one Lego set to design a transport system that can travel 3m and deliver a ball into a 0.5 m tall hollow cylinder. The complexity of the objective is increased following the completion of the initial goal by confusing the program logic control for which they need to determine innovative solutions to overcome the time constant. This project was introduced to provide an opportunity for integration of IT skills with mechanical and electrical principles.



Figure 5 Design life cycle of transport vehicle project

Project 3: The wind turbine project is a major component of their work load in this course. This paper will describe the approach to meeting the assessment outcome in subsequent sections.

THE WIND TURBINE PROJECT

This project offers the potential to integrate across the mechanical engineering, CAD, electrical engineering and English courses. Figure 6 provides a sketch of the wind turbine assembly the students have to design. The main elements required for constructing the turbine assembly measure well with the learning outcomes of the mechanical course provided by KTC i.e. transfer mechanisms, loads on shafts, bearings and gears, gear ratios and bearing and gear theory, etc., while linking well with the local environment and potential industry links.

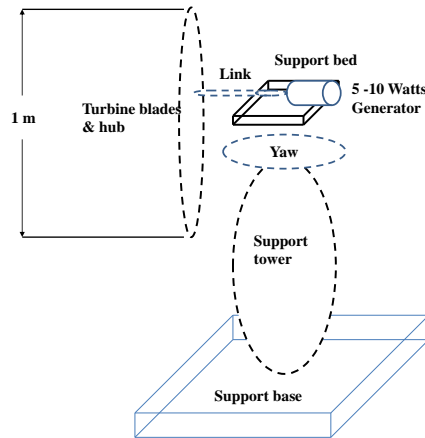
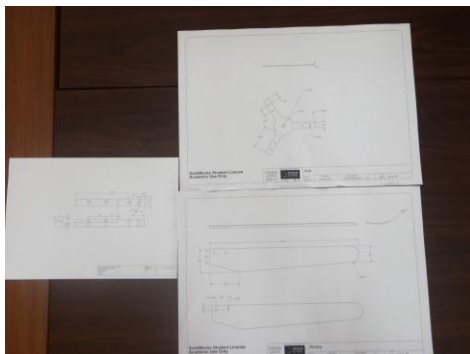


Figure 6 Scope of wind turbine design

CAD is used for detailed drawing of all elements of the turbine assembly including the components to be made in the workshop as per drawing [Figure 7]. Students are expected to communicate their design requirements to the workshop. This practice helps them recognise the importance of technical drawings, geometry, projected views, dimensioning, tolerances, materials, etc. All the procurement of ancillary parts such as nuts and bolts, bearings, and gear mechanisms required for making the final assembly are done by the students [Figure 7], who are encouraged to consider sustainable materials and resource management. The design, construction and operation of the wind turbine generator and electrical circuits are aligned with the curriculum of the electrical course. However, when conceiving the profile and the capacity of the generator, the wind blades and the hub assembly, the size and type of shaft and the support base play a dominant role.



a) Detailed drawing for workshop



b) Purchasing ancillaries for wind turbine

Figure 7 CAD and English communication

Teaching the Principles

In order to meet both the learning outcomes and project requirements, teaching is focused on activity-based learning developed within the classroom. This is illustrated in Figure 8, for teaching basic principles governing aerofoil design, gear ratios, torque vs. speed, and yaw mechanism.

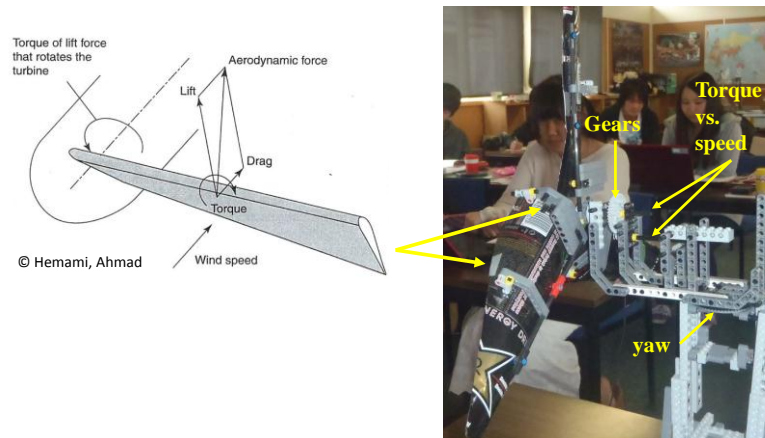


Figure 8 Classroom active teaching process i.e. aerofoil design

Design and Testing

The workbook is central to conceiving and designing the configuration for each feature and mechanism of the wind turbine assembly, from the selection of materials and design of simple elements to more complex aerofoil design and interface between mechanical and electrical elements.

At this stage, students recognise the connection between theory and its application and most of the learning is contextual. They become active learners and make decisions through increased engagement, research, debates, rapid prototype and tests. Various types of aerofoil designs and hub assembly need to be investigated to match the torque required to operate the generator. This is an open ended design space and the students are given the flexibility to select the best configuration.



a) Communicating design



b) Roll forming blades

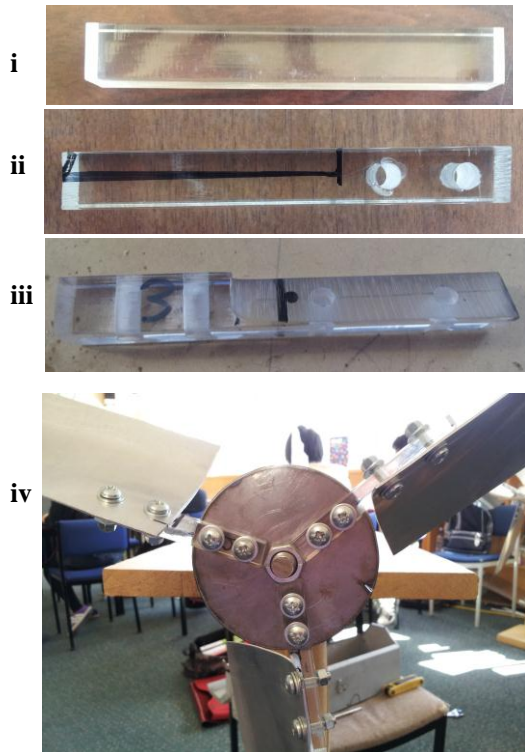


c) Hands on work

Figure 9 Student engagement in the workshop and in the class room

The size and profile of blades and hub assembly, and the form of moving mechanisms and the material selection will vary widely across all teams. Once the main components are

made in the workshop, students have a considerable load of hands on work, roll forming blade profile, grinding, drilling and the assembly of all components. Figure 10 illustrates the series of steps the students conduct before the final assembly. The wind turbine is then tested outdoors to further optimise the design features prior to attaching the generator.



a) Blade aerodynamics



i. Epicyclic gear for yaw



ii. Wind turbines

b) Complete turbine assembly

Figure 10: Wind Turbine Construction Process

Assessment Principles

The breakup of course assessment for the mechanical engineering is shows in Table 2

Table 2 Assessment activity and weighting for Mechanical Engineering Course

Assessment Activity	Weighting
Tests and Assignments	25%
Team Project 1	15%
Team Project 2	10%
Team Project 3	50%

Assessment of the project is based on the following criteria:

- 1) Workbook recording of learning processes
- 2) Successful completion of project objectives
- 3) Compliance to limits

- 4) Oral presentation
- 5) Written report with CAD drawings included

The oral presentation and written report are assessed for content as part of the Mechanical engineering course, and assessed for language as part of the English for Special Purposes (ESP) course. In addition, students are interviewed during the project building phase in English, and this is used as part of the ESP assessment.

FEEDBACK AND CONCLUSION

Initial feedback suggested that students found the hands-on experience motivating, but team management and self-directed learning were problematic. Based on this feedback, changes have been made as noted above, and recent feedback has reflected this. The following is from a student presentation at the end of the most recent year:

I think that from [this programme] we have developed responsibility for our actions. In the Japanese school, the teacher is the main focus in class. Therefore we study based on teacher's instruction and explanation. We aren't asked our opinion... the polytechnic education system is quite different... the learner is the centre of the class at polytechnic. In such classes, to manage ourselves was most important, especially in the mechanical projects... To put together our own thoughts and to execute our plan ourselves was hard. From this environment we were given the opportunity to think about "what should we do now". And we needed to have responsibility for ourselves.

From such feedback, we believe that we have been successful in our goal of raising awareness of working in a global environment, and enhancing students' personal and interpersonal skills, as well as giving them hands-on experience in the CDIO concepts.

At present, the CEE programme does not have CDIO standards as part of its programme document, but we believe it meets most of the requirements of a CDIO programme. These courses and projects are under constant review and development, and it is hoped that further integration across courses, including computer programming and mathematics will be possible in the near future, so that the whole programme becomes founded on the CDIO principles. A further goal is to integrate these courses with other Polytechnic courses. The experience that we have developed in this programme will be vital for integrating the students into multi-cultural groups.

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