CDIO DESIGN BUILD PROJECT: IMPLEMENTATION IN THE SINGAPORE POLYTECHNIC

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ABSTRACT

Projects are frequently used to promote integration of knowledge and skills. However, designing effective project based activities is a challenge as it entails many variables. From our experience, we realized that there are several important considerations that have to be addressed in order to develop an engaging project experience. Having a clear objective of introducing the project is critical as it translates to the knowledge, types of thinking and other process skills that will be incorporated. In addition, the design of task activities, assessment criteria, resources to be made available and also readiness of staff and students have to be carefully considered to ensure project success.

KEYWORDS

Design-Build Project, Active Learning, Integration, CDIO Skills

INTRODUCTION AND CONTEXT

A significant focus of the CDIO pedagogic approach is on integrated capstone and design-build projects. A particular challenge for designing pedagogically effective projects is identifying and managing the activities to enable students to find their learning both challenging and achievable.

Most engineering students in the Singapore Polytechnic are required to carry out a project yearly to practise their hands-on skills and to be exposed to some project skills. Students used to build a technical artifact that fulfilled some pre-determined objectives as defined by their lecturers in Year 1 and Year 2 projects. Very often, students needed to apply technical knowledge gleaned from their lessons and some thinking skills to solve these given problems. As the projects were usually specific in the requirements, many of the students ended up with similar answers at the end of the process. Activities carried out by the project students were focused on how to build the project work as shown in Figure 1.

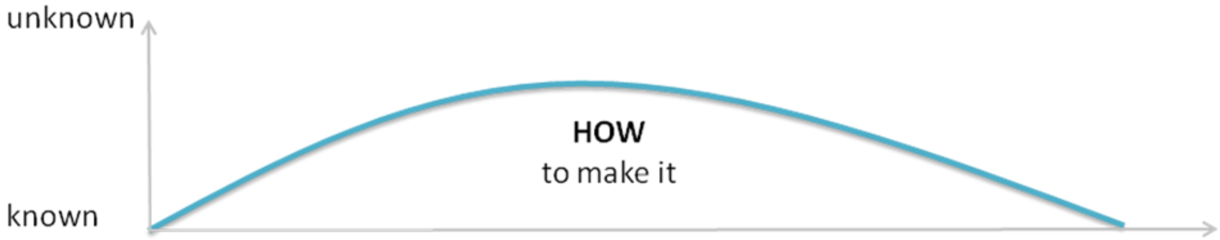

Figure 1 Project Focus

In 2007, we revamped all these projects in the School of Electrical and Electronic Engineering to include elements of conceive and design. As we do that, we introduced the dimension of “what to build” into the projects as shown in Figure 2. This new dimension brings about new activities and learning in the classroom which translates to new task activities, assessment criteria and resources development for the classroom. The remaining paper provides the details of how to design and implement a pedagogically effective project that promotes students’ learning.

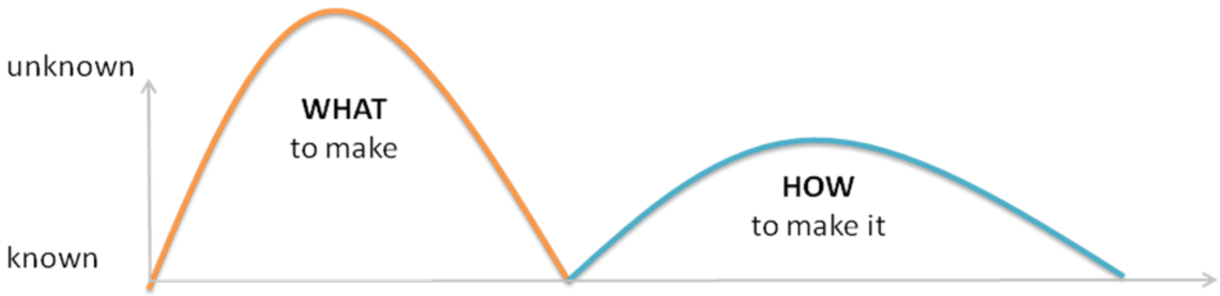

Figure 2 CDIO Project Focus

IMPLEMENTATION OF PROJECTS

To design projects that are fully calibrated to the course and module objectives, the four steps illustrated in Figure 3 have proved useful based on the experiences that our staff have gathered from the various projects that we had introduced in the Singapore Polytechnic.

This remaining section will first discuss the four steps and conclude with a case study of how these steps are applied to a project.

Figure 3 Steps in designing CDIO projects

Step 1: _Identify the knowledge, types of thinking and other process skills_

It is necessary to first identify the topic areas in the curriculum that will be utilised in the project. For example, what are the central concepts, principles and models that may be applied in the project. Besides the necessary knowledge, it is also important to identify the types of thinking which are important for promoting student's understanding and subsequent competence in this project eg. analysis, comparison, inference, evaluation, etc. In addition, other process skills that are required for promoting learning in the identified areas must also be identified. These may include skills in communication, searching for and organizing information, etc. A module such as 'Design and Innovation Project' in Year 2 may entail the knowledge and skills given in Table 1.

Table 1
Project Components of Design and Innovation Project

PROJECT COMPONENTS		
Subject Knowledge	Types of Thinking	Other Process Skills
- Microcontroller - Sensors and Instrumentation - Analog Systems - Biomedical Instrumentation	- Generating possibilities of project design - Analysis - part-whole relationships of a prototype design - Compare and contrast - previous solutions and new options generated - Making inferences and interpretations from data relating to market trends and prototype design - Evaluation of interesting options in relation to criteria	- Oral and written communication - Teamwork - Specific IT applications - Conceive-Design-Implement Product Cycle

Once the project is defined, we may then proceed to prepare the syllabus which should include the necessary activities and skill sets. For CDIO projects, there should be at least 3 components present in the syllabus; namely,

a) Technical knowledge and reasoning
b) Personal, interpersonal and professional skills and attributes
c) Conceive, design, implement and operate systems

After the project content is finalised, the supporting modules may need to be realigned to facilitate the smooth implementation of project which allow students to be exposed to the knowledge before using them in the project.

Step 2: Scope project

Project specifications may be very specific and constrained or it may be kept intentionally vague without a clearly described end deliverable as shown in Figure 4. Constrained problems are useful for early learning for students without any project experience. The other advantage is that projects may be designed closely to meet the curriculum requirements. In terms of administrative demands, this type of projects is likely to be less tedious as the all necessary logistics and preparation can be made ready before the project commences.

However, students working on such problems may not have the opportunity to find and frame problems which is an important skill set. Besides, students may not have the interest to work on assigned project that is given by the lecturer.

The Year 1 project at the School of Electrical and Electronic Engineering falls on this end of the spectrum where the task is specific and constrained. However, there is some flexibility that allows students to use their creativity to develop variations of the final project deliverable.

Figure 4 Continuum of projects

On the other hand, a different set of challenges arise if students do not have any constraints in their choices of projects. Students may decide to work on projects of interest that are out of the knowledge domain. Also, the scope of projects may be too wide that they have difficulty completing. This nature of projects inherently provides students the chance to frame and find interesting problems.

Instead of letting students work on either fully constrained projects or one without any constraint, the Year 2 Design and Innovation Project requires lecturers to supervise and guide students in finding problems. For this type of problems, the constraints could be broadly framed using project themes or they may be bounded by certain knowledge domains taught in the class. Lecturer who is setting the project has to carefully find a spot along the continuum shown in Figure 4 to find a level that is appropriate for students' learning at different stages of their learning. Guided problem finding satisfies the need for students to find personally relevant problems and at the same time allows students to work within the specified knowledge domains.

Some staff may opt for a totally "open" project instead of guided problem framing as they might feel that projects should not have constraints to promote students in pursuing their interests as much as possible. This is a valid argument that can only be answered by the readiness of staff and students in project work. In actual fact, there is unlikely a correct answer as it depends very much on staff and students working on the projects. However, even in the guided problem framing project, students are not working in a straight forward problem solving situation as there are many options and possibilities that students have to manage as they navigate in the problem and solution spaces as shown in Figure 5 which clearly depicts that students have to confront many possible and potential problems and possible solutions.

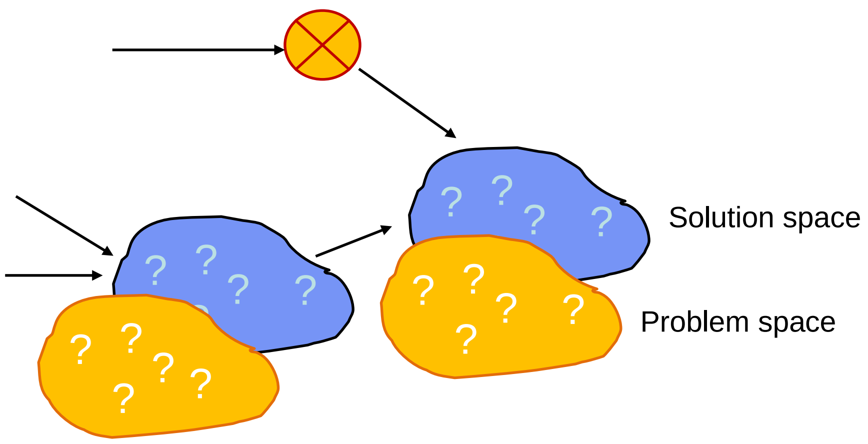

Figure 5 Problem and solution space

To ease the burden of supervising students, some lecturers may choose to assign students with very simple and easy projects. However, this will lead to undesirable students' responses such as boredom and relaxation. On the other hand, some lecturers may set very challenging projects to stretch their students. Again, we may not be able to achieve good project results as students may become unnecessarily stressed and worried all the time. Therefore, matching the right project to students' skill level is an important task that lecturers need to be good in. As can be seen in Figure 6, the lecturer has to align students' skills level to the right level of challenge so that students may operate in the flow region as suggested by Csikszentmihalyi [1].

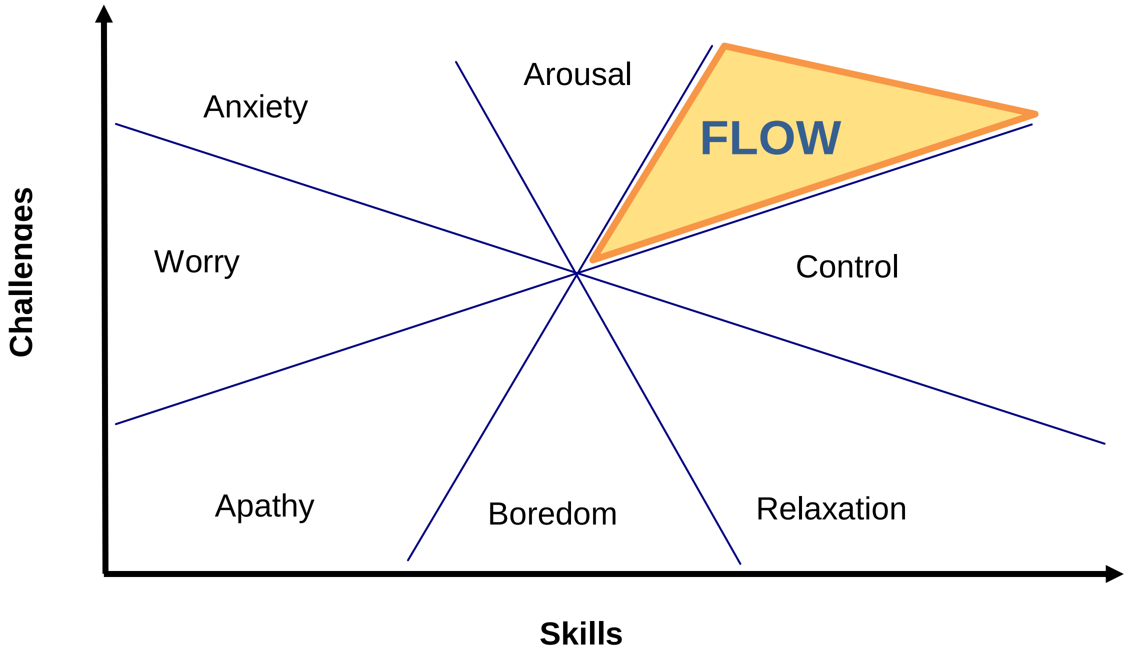

Figure 6 Csikszentmihalyi Flow

Step 3: Structure the project task activity

This stage involves constructing the project tasks. It is essential to ensure that the task incorporates the application of knowledge, skills and processes specified in Step 1. Also, it is important that the activities mirror, as far as possible, real world applications and it is sufficiently challenging, but realistically achievable in terms of student's prior competence, access to resources, and time frames allocated.

As far as possible, the project should be designed in such a way that successful completion involves more than one *correct answer* or there is more than one *correct way* of achieving the correct answer. This provides space for students to exercise their creativity.

Administratively, it is useful to provide clear notes which describe the products of the project task and specific formats of presentation that are acceptable in terms of written report, oral presentation and portfolio. It is also necessary to specify the parameters and scope of the activity e.g., time, length, areas to incorporate, individual/collaborative, choice is permitted, resource access, support provided, etc. While interacting with students, it is useful to cue their types of thinking and other desired process skills. As much as possible, all aspects of the assessment process and criteria should be spelled out at the start of the project.

As students work through the conceive – design – implement – operate stages, they will initially experience generative and problem structuring activities while the later stages are for problem solving activities. Thus, in relation to the skill sets, students start with soft skills such as thinking, problem framing and progress to hard skills such as CADD and other predominantly engineering related skills. Therefore, as students progress through their projects, the support and tools have to correspond accordingly.

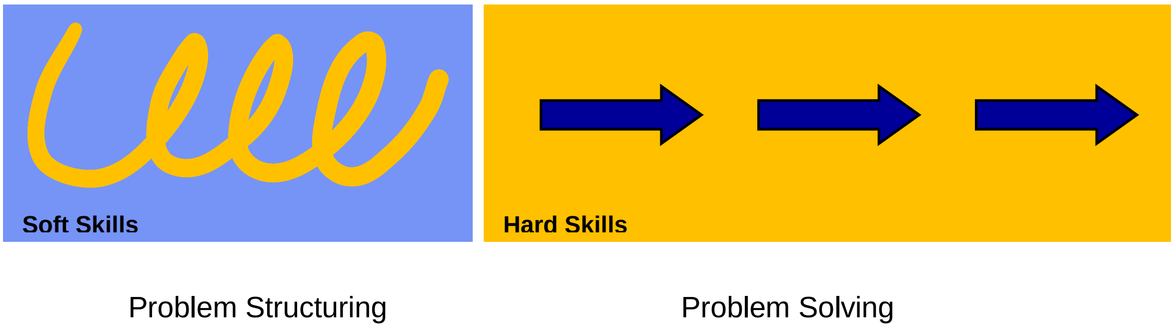

Figure 7 Stages in problem structuring

Step 4: Assessment

As projects provide good opportunities to assess types of thinking and the application of knowledge and skills, they are similarly the focus in the final assessment. Project assessment starts with the clarification of the exact performance areas that have to be assessed. These performance areas are essentially the knowledge and skills identified in Step 1.

Afterwhich, the criteria has to be established. These *performance criteria* define the key elements that underpin the performance - whether types of thinking, specific skills or knowledge applications. Performance criteria can then be organized into a marking scheme for the project. There are two formats frequently used as a marking scheme or scoring system; the checklist and the scoring-rubric.

a) Checklist

A checklist can vary in format, but essentially provides a breakdown of important procedures or operations in the activity being assessed. For each component of the checklist, there will be a statement or example of competent performance and, if marks are allocated, a weighting for that component is assigned.

Checklist are particularly well suited for assessing activities that can be divided into a series of clearly defined specific actions, e.g. conducting an experiment, math solutions, technical processes, etc.

b) Scoring rubric

A scoring rubric is a prepared scoring system for assessing student performance in activities where judgement is involved in the assessment decision. This is particularly the case with thinking and most skills, where assessment of a performance does not lend itself to a yes/no or competent/not competent type of judgement.

Each performance area can be assessed by way of a rating scale that defines the essential elements of performance (performance criteria) in that area. Such scales typically range from *very competent* (5 marks) to *not at all competent* (1 mark). Rubrics are used in the projects implemented in the School of Electrical and Electronic Engineering.

Irrespective of the format chosen, the marking scheme must ensure that the most important performance criteria which underpin competence in each performance area are identified. In addition, the marks allocated should reflect the cognitive activities and skills which the assessment activity requires the learner to demonstrate. As much as possible, adequate provision has to be made for acceptable alternative answers. Finally, it may be necessary for the marking scheme to be sufficiently broken down and organized to allow the marking to be as objective as possible.

c) Allocation of individual marks

Besides awarding marks to the group for completing the assigned project, it is often necessary to have an individual mark component so as to allow lecturers to reward good students while at the same time be able to give lower marks to students who are free-riders. In view of this requirement, the individual mark weightage should be substantial enough to reflect the individual contribution towards the project.

CASE STUDY: INTRODUCTION TO ENGINEERING

In this section, we will use a case study of how we developed the project module "Introduction to Engineering" using the steps given above. "Introduction to Engineering" is offered to Year 1 students from the School of Electrical and Electronic Engineering and it aims to equip students with relevant practical skills such as electronic components identification, correct wiring methods, prototyping, soldering and use of DC power supply and multi-meter. Students are expected to work in teams on exercises where they make use of sensors and electronic circuits to control simple operation. This module is designed to reinforce and integrate knowledge gleaned from other first year modules. Also, students will have opportunities to develop their thinking skills, problem solving skills and interpersonal skills such as teamwork and communications.

Step 1: *Identify the knowledge, types of thinking and other process skills*

Before the project is designed, the development team first identified the knowledge, types of thinking and other process skills as shown in Table 2. The subject knowledge is derived from the modules covered in the same period as when the project is taken. Step 2 further illustrates how the subject knowledge is applied in a project. The types of thinking and other skills are derived after consulting the CDIO syllabus developed by Crawley, E.F. et al [2] and also taking into consideration the students' competency.

Table 2
Project Components of Introduction to Engineering

Subject Knowledge	Types of Thinking	Other Skills
- Principles of Electrical & Electronic Engineering - Digital Electronics - IDEA (Innovation, Design and Enterprise in Action)	- Creative and Critical thinking	- Teamwork and Communication Skills - Electronic Prototyping skills - Focus on Design and Implementation skills. Some coverage of conceive skills.

Step 2: Scope project

As this is the first project that freshmen encounter in the polytechnic, it is designed to be constrained with clear deliverables. This project comprises two mini exercises; the first exercise is a 7 segment display which responds to different input settings while the second exercise is model car that maneuvers based on the conditions it encounters.

The underlying concept for both exercises is similar, students are required to complete a task that has somewhat similar outcome but at the same time is flexible enough to accommodate minor variations in the final solutions. We will use the model car exercise to elaborate how this is done.

For this exercise, students are required to build a model car that moves to a predetermined station before returning to the starting point. Groups are assigned different return points which provide for variations in the final answers. Figure 8 shows the circuits that students have to build and the blocks in white are standard functions that are similar for all groups. The gray block is different as it pertains to the return station and students have to make use of their thinking skills to design it. As mentioned in the previous step, the project requires an integration of different domain knowledge and they are indicated in the boxes in brackets.

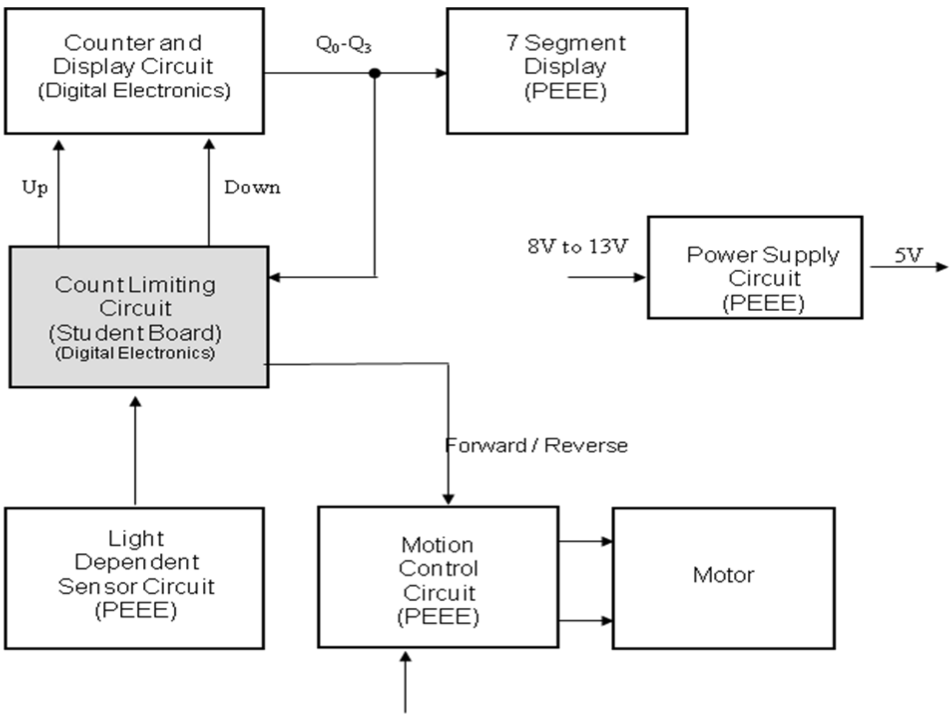

Figure 8 Schematic diagram of project

Step 3: Structure the project task activity

This project focuses on the hard skills such as electronic prototyping and simulation. Thus, students spend most of their time building and testing their circuits. Students will first discuss amongst themselves how they plan to construct the circuits. Afterwhich, they will simulate the circuits using Multisim software. Once they have designed the circuits correctly, some may proceed to using the breadboard to test the circuits while others may start to fabricate their stripboards.

As this project also allows some flexibility in the final solution, students will also make use of their creativity to generate interesting solutions. Thus, even though the stages appear to be in a linear fashion in Figure 9, the actual implementation tends to be a spiral that moves between hard and soft skills.

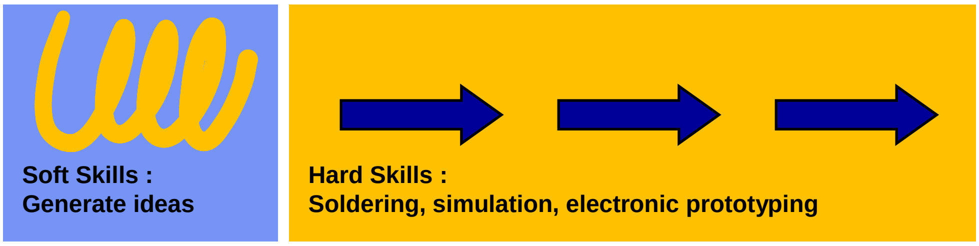

Figure 9 Project stages

Step 4: Assessment

A rubric as shown in figure 10 is used for marking this project. For every item, there is a range of marks that may be awarded based on the performance. Besides simplifying the marking process, this rubric also ensures that marks are more consistent among the different groups of students.

Workability of Counter and Display Circuit	Workability of Sensor Board	Workability of Motion Control Board	The car is able to move forward, display the station nos and stop after hitting the emergency switches	The car is able to reach the assigned station and reverse	The car is able to display the station appropriately as it reverses	Interview and Individual Competencies	Good Teamwork	Challenging Task - Marks to be awarded to the top 10 cars or less by external judges	Total SAS LAB3	Yr Long Total
10%	10%	10%	10%	10%	10%	10%	10%			

0-2 Not at All.
3-4 Limited Extent.
5-6 Moderated Extent.
7-8 Great Extent.
9-10 Very Great Extent.

Figure 10 Marking rubric

CONCLUSION

This paper has provided a systematic approach to develop design build projects based on experiences gleaned from staff at the Singapore Polytechnic. It also highlighted several important considerations such as effective assessment and design of task activities.

REFERENCES

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Biographical Information

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