INTRODUCTION TO ENGINEERING – THE NANYANG POLYTECHNIC EXPERIENCE

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ABSTRACT

Nanyang Polytechnic, Singapore has been a collaborator of the Worldwide CDIO Initiative since 2011. A working committee has since been formed to strategize and steer the CDIO implementation in the School of Engineering (SEG). This paper shares our experiences in adopting CDIO standard 4 - “Introduction to Engineering”; from raising awareness of the CDIO initiative, benchmarking our existing practices with the CDIO standards, sharing of success stories through pilot studies, to full implementation in 2013.

In the design of the “Introduction to Engineering” module, a general framework has been developed. This framework emphasizes on the relevance of knowledge covered in the first semester of study to the engineering disciplines, and the use of these integrated knowledge in engineering practices, as well as the essential personal and interpersonal skills. This framework can be adapted to various engineering disciplines and has been successfully implemented in all the 11 engineering courses offered in SEG. In particular, the use of such framework in two of the courses: Diploma in Aeronautical and Aerospace Technology and Diploma in Aerospace and System Management, and the challenges faced in the implementation are detailed in the paper.

Finally, the paper highlights that organizational cultures and values, systems and processes are important enabling factors for the success of large-scale implementation in an institution.

KEYWORDS

Introduction to Engineering, Course Design, Factors Enabling Success, Large Scale Implementation, Standard 4

Note – In the context of Nanyang Polytechnic, the term ‘course’ refers to a ‘program’ while the term ‘module’ refers to a ‘course’. For example, *Diploma in Aeronautical and Aerospace Technology* is a course; *Introduction to Engineering* is a module.

INTRODUCTION

Nanyang Polytechnic (NYP) started its endeavour to implement CDIO in 2011. Naturally, School of Engineering (SEG) in the polytechnic has been identified to pioneer the adoption of this initiative. In order to strategize and steer the CDIO implementation in the school, a working committee has since been formed. As a start, the committee organized several sharing sessions to raise the awareness of CDIO initiative among the management staff and faculty members to solicit their support and buy-in for the implementation. Through these sharing sessions, the concepts and benefits of CDIO framework were shared, and the relevance and importance of its implementation to train students to be industry-ready graduates were highlighted to the staff.

Concurrently, the course managers led their course management teams to kick off self-assessments on their respective diploma courses, based on the twelve CDIO standards. One common gap identified from the self-assessment exercises was the absence of an introductory module that matches the requirements as specified in CDIO Standard 4. That is, an introductory module that provides the framework for engineering practice in product, process, and system building, and introduces essential personal and interpersonal skills. The course managers and their teams believed that the introduction of such module in the first semester of students' first year of study will further stimulate students' interest in, and strengthen their motivation for, the practice of engineering through problem solving and design.

To gain the know-how in designing and implementing this introductory module, key members in the working committee visited institutions which had experiences in designing and implementing the "Introduction to Engineering" modules, and learn from collaborators during the CDIO International conferences and meetings. Eventually, the new introductory module had its pilot runs in two SEG courses after redesigning two existing modules for year-one students in 2012. The pilot runs had been a success, complementing with positive and encouraging feedback from the students.

With the extension of this introductory module to all SEG courses in plan, the staff members who were involved in the pilot runs were invited to share their experiences and the challenges they had faced through sharing sessions. Based on the feedback and evaluation of the pilot runs, the working committee has developed a general framework which emphasizes on the relevance of knowledge covered in the first semester of study to the engineering disciplines, and the use of these integrated knowledge in engineering practices, as well as the essential personal and interpersonal skills. This framework can be adapted to various engineering disciplines and has been successfully implemented in the "Introduction to Engineering" modules which were offered in all eleven SEG courses in April 2013.

GENERAL FRAMEWORK FOR IMPLEMENTING INTRODUCTION TO ENGINEERING MODULE

Module Design

SEG aims to achieve five objectives through the implementation of these "Introduction to Engineering" modules in students' first year of study:

- Motivate and excite students
- Demonstrate the relevance of disciplinary knowledge covered in Year 1 Semester 1, and show that it can be applied to real-world problems
- Begin the process of developing professional skills: creative & critical thinking, problem solving, team working, report writing & presentation skills, etc
- Introduce students to relevant core engineering disciplines, and clarify their understanding of the nature of engineering and what engineers do
- Raise students' awareness of CDIO program

These objectives were shared with the staff responsible for the module development (module coordinator) in order to ensure alignment across various courses.

The introductory module is designed to be a 60-hour module that lasts for 15 weeks of instruction (i.e. four instructional hours every week). In order to provide year-one students with a clearer picture on engineering and prepare them to work on hands-on projects in team setting, the first part of the instruction is designed to include various learning activities (e.g. case studies, videos, games, etc.) to introduce the students to the concepts of CDIO program, roles and responsibilities of engineers, the impact of engineering on society and environment, teamwork, thinking and problem-solving skills. After which, the students would be assigned in groups to work on their first project that gets them familiarised with the necessary tooling and experimentation skills. They would then continue to work on a second group project that integrates the application of CDIO skills and all relevant disciplinary knowledge they have learnt from other modules in the semester. To motivate and excite the students, they would compete in groups to demonstrate their achievements in the second project.

The abovementioned module design (as summarized in Table 1) serves as a general guideline; however, the respective module coordinators have the flexibility to design and incorporate various learning activities and project assignments on their own based on the needs of the respective courses.

Introduction to Engineering (60hr – 4 hours per week)	
Week 1 to 2	Topics to be covered in the first 8 hours: • Introduction to CDIO and purpose of Introduction to Engineering (~¼ hour) • Roles and Responsibility of Engineers (~¾ hour) • Impact of Engineering on Society and the Environment (~1 hour) • Teamwork (~2 hours) • Creative & Critical Thinking (~2 hours) • Problem Solving Skills (~2 hours)
Week 3 to 7	Group Project One – Familiarisation with Tooling & Experimentation
Week 8	Presentation for Group Project One
Week 9 to 14	Group Project Two – Integration of CDIO Skills
Week 15	Presentation for Group Project Two & Competition

Table 1. Module Design

Resources

To facilitate the instruction on introducing students to the concepts of roles and responsibilities of engineer, impact of engineering on society and the environment, teamwork, creative and critical thinking, and problem solving skills, a common pool of resources like training materials and ideas for designing learning activities on these areas were gathered, developed and shared among all module coordinators.

Regular meetings were also organised by the working committee to provide a platform for module coordinators to share, discuss and exchange ideas on best practices that were deployed in their classrooms. Peer observation of classes in action was also encouraged so that module coordinators could learn through collaboration, reflection and discussion.

Forming of such community of practice connected the module coordinators and allowed them to identify solutions to common problems, solve challenging problems, explore new possibilities, and create new, mutually beneficial opportunities.

Assessment

Module coordinators were encouraged to use rubrics as a standardized way of assessment by stating clearly the criteria and weightage for the different components of assessment. Through the use of rubrics, students would be clear on the expectations of quality for assignments and they would understand the reasoning behind a grade. Standard rubrics were developed to assess students' performance in individual contribution, teamwork, and presentation. The assessment criteria specified in these rubrics are listed in Table 2. The students are graded against the criteria on a scale of "Excellent", "Good", "Satisfactory" and "Need Improvement", which have marks assigned to them. However, module coordinators are allowed to assign different weightages for the criteria. They also have the option of not using all the assessment criteria but only choosing those appropriate for the delivery of their modules.

Assessment Criteria for Individual Contribution	Assessment Criteria for Teamwork	Assessment Criteria for Presentation
Attendance/promptness	Contribution to the team	Organization of information
Ability to describe a problem and develop a plan to solve the problem	Leadership	Delivery
Focus on tasks	Ability to work with others	Command of language
Critical thinking		Use of supporting materials/aids
Innovative thinking		Subject knowledge
Product and documentation		

Table 2. Assessment Criteria for Students' Performance

To facilitate the use of rubrics in the Introduction to Engineering modules, a flow chart on how rubrics could be implemented in the module was developed (see Figure 1). Two forms were created for the rubrics: Form A and Form B. Form A is for faculty use and they can input the actual marks for each criteria of the rubric. Form B is for faculty to discuss with students on areas that students had done well and areas that needed improvement.

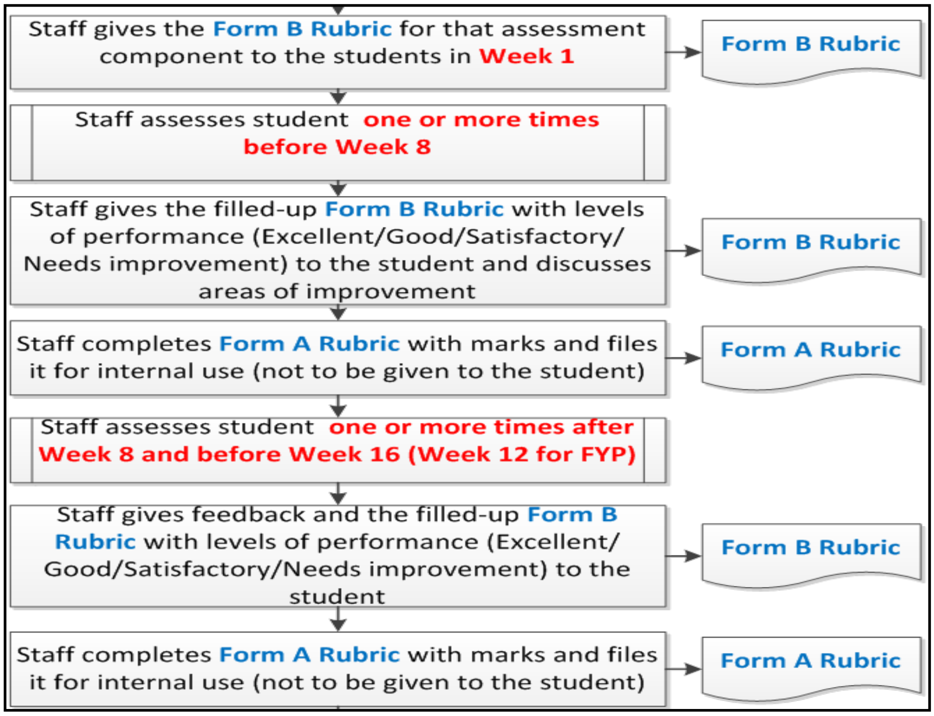

Figure 1. Flow chart for implementing rubrics in a module

ADOPTION OF THE GENERAL FRAMEWORK IN SEG

The following sections showcase the implementations of “Introduction to Engineering” modules in two SEG courses: Diploma in Aerospace and System Management (DASM) and Diploma in Aeronautical and Aerospace Technology (DAAT).

Adoption of the framework in DASM

The introductory module in DASM course aimed to promote students’ interest in engineering by providing a platform for students to build electronic engineering projects for aerospace application. The module has been designed to include the following projects.

Individual Project – My First Avionics

This project was designed for the students to get familiar with electronic components (such as resistors, capacitors, light-emitting diodes, switches and 555-timers), circuit diagrams, tooling, and learn experimentation skills by building an electronic board that demonstrated the functions of aircraft navigation lights and anti-collision lights. Each student was required to connect the circuit on the breadboard to understand the circuit connection and verify the circuit functions. They were then guided to prepare component layout diagram, and soldered the components onto the strip-board. They were expected to perform functional test for their project board.

At the end of the project, each student shared their learning experiences with the class for enhancing peer-learning in the class. Through this project, the students built up their technical capabilities and gained confidence for the group project.

Group Project – Let's Make It Fly

Groups of three to four students were formed by staff. Each group worked on a control board for the flying machine (Figure 2). The project integrated the application of CDIO skills and all relevant disciplinary knowledge they have learnt from other modules in the semester (e.g. Electrical Fundamentals and Computer Programming).

The project involved both hardware and software tasks. On one hand, the students were required to study and solder the circuit that controlled the rotor speed of the flying machine onto the strip-board. They were expected to verify the output waveform from the control board using oscilloscope. They were challenged to modify the given circuit to add new features such as ON/OFF control and indication lights. On the other hand, the students were required to develop the interface program (based on a sample C program code) that read and processed the sensor values (such as flying altitude and acceleration) from the flying machine, and output the relevant information to a display panel in their preferred format. The program was expected to control two indication light-emitting diodes on the flying machine too. Finally, the students were required to connect the control board to the flying machine, and upload the interface program to the flying machine controller before they performed testing to verify the functions and made changes if necessary.

To motivate and excite the students, they would compete in groups to demonstrate their achievements and to share their group learning experience to a panel of judges. Through this project, the students learned teamwork, enhanced their communication skills and practised problem-solving skills.

Most of the students commented that they enjoyed the learning activities and the module did stimulate their interest to learn more about Aerospace Systems.

Figure 2. Flying Machine Project

Adoption of the framework in DAAT

DAAT students were assigned interesting projects in their “Introduction to Engineering” module, in order to capture their interest for subsequent aeronautical-related modules. In addition to hands-on practical skill of producing work pieces using various machining processes, each group of students was tasked to design and build a hand-launched glider using compressed foams (Figure 3). As a group project, members within a group were tasked with different responsibilities in conducting research, designing and building the prototype, and presenting their project. The use of rubrics to feedback to students in this phase proved to be useful as students were aware on areas that they had been done well and areas that needed further improvements. The nature of the project had motivated the students to undergo several iterations of design improvements after initial failures, before completing a successful glider prototype.

The project provided a platform for the students to demonstrate practical application of their basic knowledge on airplane structures and theory of flight. At the end of the project assignment, the students competed for the glider that could fly the furthest linear distance. The competition had successfully created a lot of fun and excitement among the students.

In addition to the competition, each group of students prepared an after-competition presentation, with every member sharing their roles, challenges faced and how their design was conceived and improved on. The learning experience through this glider project has enabled the students to learn through self-discoveries and failures in a safe environment.

Figure 3. Glider Project

FEEDBACK FROM STUDENTS

At the end of the semester, surveys with a four-point scale (strongly agree, agree, disagree, strongly disagree) were conducted to gather feedback from 560 students on the “Introduction to Engineering” modules. The students were asked a series of questions that sought to validate the objectives and conduct of the introductory module, design-build experiences as well as the integrated curriculum. The results on the quantitative aspect of the surveys are as shown in Figure 4.

Do you agree?	Students’ Response n = 560
1. The learning objectives of this module are clear.	96% agreed
2. The module is well organized.	95% agreed
3. The pace is just right.	94% agreed
4. The module stimulates my interest to learn more about Engineering.	90% agreed
5. The module is relevant to other modules in the same semester.	88% agreed
6. Feedback provided by lecturers is helpful and timely.	96% agreed
7. Grading criteria are clear and fair.	94% agreed
8. Overall, the module is worthwhile.	94% agreed

Figure 4. Student Survey Results

From the surveys, majority of the students agreed that the learning objectives were clear and found the module to be well organized and conducted with the right pace. This indicated that they understood and knew the deliverables that were expected of them. Most students also found the module to be stimulating their interest to learn more about their respective engineering discipline. The results also indicated that majority of the students were able to apply knowledge learnt from different modules in the same semester. When it came to assessment, grading criteria were deemed clear and fair. Overall feedback from the students was positive.

On the qualitative aspect of the survey, comments from students were encouraging. In response to the question about the “best” part of the introductory module, the students reflected they liked the hands-on experience of developing projects in teams, which allowed them to learn more effectively through self-discoveries and to persevere through their failures.

FACULTY LEARNING EXPERIENCES

Module coordinators observed that students were much more engaged and motivated to learn more about engineering during the lessons. Students were enthusiastic in completing their projects and were excited in participating in the competitions. On the other hand, the module coordinators also face some challenges in the process of implementation which include: managing students with different capabilities in team setting (e.g. advising the students on proper problem-solving approaches, monitoring and ensuring the students were working as a team in carrying out the project works), synchronizing the delivery of related topics in various modules with that of the Introduction to Engineering module for better integration, etc. They also identified the need for more free-access workspace for students especially during the trouble-shooting phase of project development.

Going forward, the working committee will be working with the module coordinators to incorporate more activities within the introductory modules to enhance students' creative and problem-solving skills. One way is to inject more flexibilities and options into the project assignments for students to explore further on their own. The module coordinators will also look into how they can integrate with more modules that the students study in the same semester, so that the students apply the knowledge learnt in real-world problems. The school will be looking into designing and providing free-access workspace specifically for students to work on the Introduction to Engineering projects.

LESSONS LEARNT FOR LARGE SCALE IMPLEMENTATION

The "Introduction to Engineering" modules have been implemented in all the eleven SEG courses concurrently in the first semester of the academic year 2013. For such large-scale implementation to succeed, the working committee first had to obtain support from the course managers and department heads that were in positions of influence over the course and module curricula and the allocation of resources. The successful pilot runs in two SEG courses had convinced the faculty that the introductory module has been well-accepted by the students, and provided them with a positive learning experience.

NYP has long established a culture in which the staff shares a set of common organisational values, which include "the can-do spirit" and "borderless teamwork". This has facilitated the smooth implementation of this large-scale curriculum redesign, besides capabilities and efforts by individual staff member. The general framework for implementing "Introduction to Engineering" module and the various systems and processes that have been established have also enabled the staff to deliver the desired outcomes. The framework proves to be useful and flexible that allows the module coordinators to easily adapt and design various learning activities and project assignments for their respective engineering disciplines.

CONCLUSIONS

In summary, the curriculum redesign to implement "Introduction to Engineering" module in all eleven SEG courses has been a successful exercise. The organizational cultures and systems, as well as the individual efforts by the staff members, are crucial to the success. The learning objectives of this introductory module have been achieved in various courses of different engineering disciplines through adopting and adapting the general framework. Positive feedback from the students encouraged the faculty to fine-tune the processes and learning activities further to ensure that the implementation is sustainable, and the students will gain fruitful learning experience through the "Introduction to Engineering" modules. The CDIO approach of having practical introductory exposure to engineering activities coupled with built-in exercising of communication skills and teamwork was shown to be not only achievable but also rewarding.

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