ACTIVE LEARNING IN A SECOND YEAR MACHINE DESIGN PROGRAMME AT SINGAPORE POLYTECHNIC'S SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING

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ABSTRACT

In this economy of high demand for fast advancement of technology, engineering students are being tasked to learn and develop skill-sets that are readily called for in industry. This paper presents the development of a new course which was designed to equip students with the basic skills to design and build a working industrial machine through an active and experiential approach using CDIO.

In the first year of its programme, students were introduced to Engineering through a project that required them to design and fabricate model racing cars. Building on the knowledge and skills learnt in the first year, a new course, Design and Build 1, was developed through the integration of two existing courses, Engineering Design (ED) and Computer-Aided Design (CAD). This new course is to provide second year students an opportunity to design and build a working industrial machine. The course was taught in 15 weeks through the weekly 6 hour block a day lesson. The curriculum was redesigned to include the various stages of machine design such as conceptualization of ideas into drawing, designing, building and commissioning of the intended machine.

The learning activities were aligned with the CDIO framework to promote the acquisition of disciplinary knowledge/skills, personal and interpersonal skills, teamwork and product and system management, hence, providing students with a holistic training that prepares them for the real world of engineering.

The assessments adopted and management's support for the change will also be discussed in this paper.

INTRODUCTION

Previously, Engineering Design (ED) was taught without a working physical machine. The selection of machine elements was based on structured tutorial questions of different hypothetical scenarios. Students did not have the opportunity to relate the machine elements they were studying to a real machine.

Similarly, Computer-Aided Design (CAD) involved students modelling tutorial questions given at the end of each topic which again had no physical existence. Weaker students were not able to interpret the drawings and thus not able to model it readily on the computer. Students were proficient at solving well-defined problems in tutorials. However, in reality, most engineering problems are complex and open-ended and requires the synthesis of the knowledge across courses.

The CDIO framework was adopted to provide second year engineering students with an active and experiential learning journey in which they discovered a typical mechanical engineer's industrial encounters. Active learning has been defined as opportunities for students to engage with the subject matter of a course they are learning. Rather than passively receiving information, students are tasked to generate knowledge and the teacher takes the role a facilitator. Students in an active learning class environment solve problems, present solutions, apply their knowledge, brainstorm, debate, and create. With active learning, students develop a deeper understanding of the content they are learning. The integration of two existing courses, ED and CAD, and an addition of 7 new chapters, provided a seamless active learning environment for acquiring the knowledge/skills required for machine design.

The trimming machine, shown in figure 1, served as the learning platform to impart CDIO skills. This machine trimmed the leads of connectors to the dimensions specified in the machine specification. Six prototypes were manufactured to serve the cohorts' learning in this course. Each class was allocated a machine. The machine was sub-divided into 4 units, namely structure, escapement and component track, trimming 1 and trimming 2. Each class was similarly divided into 4 groups and each group would take up one of the 4 units.

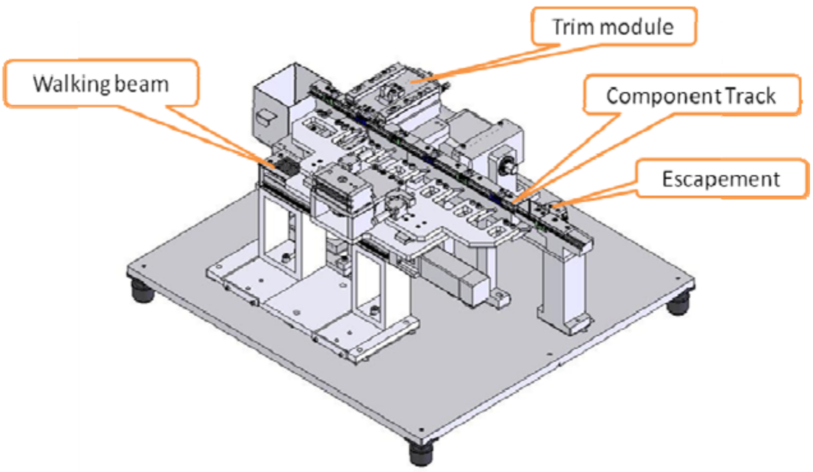

Figure 1 Trimming Machine

The objective of the course and deliverables were made clear to the students during the first lesson so that they could anticipate the vitality of the course. The deliverables, which included part and assembly drawings of the whole machine, fabricated missing part, purchase and requisition of standard parts, schedule and case-study were complied and presented in a portfolio submitted in the last lesson.

ACTIVE TEACHING AND LEARNING APPROACHES

Project Initialization

In this activity, students worked in groups to understand the Machine Specification and translated the information into the Project Information and Design Specification. Students were given about 30-40 minutes to discuss in their groups, items such as Machine Requirement, (e.g. size of machine, site limitation and etc), Quality Requirements (e.g. machine safety), Machine Qualification (involving First Article Approval), Delivery (e.g. maintenance manual, documentation of machine) and Shipping. Each group gave a 15 minute presentation to their classmates.

With the knowledge on the machine requirement, the groups proceeded to identify the activities to design and fabricate the machine. The first draft of the schedule was prepared and submitted for the lecturer's approval. The schedule listed the activities and indicated the corresponding time frame needed to finish an activity. As in any 'real' project, delay on the completion of certain task would be inevitable. Thus the lecturer would have to be consulted for advice when tasks were delayed.

Engineering Design

Formal ED lessons were conducted and followed by tutorial sessions where students attempt structured questions. Students selected machine components, such as gears, bearings, belt drives and motors based on the machine requirement and operation conditions. They had to first understand the design requirement and consideration in order to select suitable components, from manufacturers' catalogues, for the proper functioning of the machine. This activity developed both the discipline knowledge and critical thinking ability of students.

Seminar and Case-study

To make learning more interesting and engaging, a 2 hour seminar, presented by a Japanese company, THK, on the Linear Motion (LM) Guide was organised. Each group of students then applied the knowledge learnt to a given scenario in the case-study. The tasks involved understanding the machine requirement, function, on-line search for information on the features, characteristics and practices. Students used the on-line design calculation to select suitable LM guide. Each group presented their findings and recommendations of the case-study to their classmates and lecturers. They had to answer or defend the comment by other students in the class.

Reverse Engineering and Modelling

Skills on visualisation and interpretation of engineering drawing have always been difficult areas for students to learn. To enhance these skills, students disassembled the machine unit assigned to them, and identified each physical part by sketching the shapes and features. The dimensions of each part and feature were measured with vernier callipers and documented on the corresponding sketch as raw data. As each group only studied their own machine unit, they exchanged this raw data with other groups in order to cover the whole machine.

The part models and subsequently the part drawings with detailing on tolerances and surface finish were created in computer using CAD software. The process of studying the physical parts to get the part models and subsequently detailing the drawings improved the ability of students' skill on interpretation and visualization of engineering drawing. Students learnt and applied the common practices in drawing presentations, conventions and standards in their part drawings.

Critical thinking was practised as students searched standard parts such as gears and selected suitable ones to download the CAD model from the manufacturers' catalogue. Appropriate modification was done, such as modifying the bore diameter to suit the machine shaft, and the part drawing was subsequently created. On completion of the part modelling, students created the assembly model using CAD software. This process required students to look at the details of each part feature. They had to assign constraints to the part features to set up the sub-assembly of each unit and finally, created the whole machine assembly model. An assembly drawing showing the machine was created together with the bill of material (BOM).

The process of getting the assembly of the machine in computer had indeed brought the students to understand the functionality of each machine part and the makeup of the whole machine.

Design and Implementation

Design and fabrication activities were integrated into the course. From the disassembled machine, students identified a missing part in the unit under their charge. The group designed this missing part based on the features of other existing machine parts. The design of this missing part should enable it to be assembled or fitted onto the machine with other existing parts so that the machine functioned according to requirement. Design could involve the size, shape as well as other features such as hole and slots and its location. Once the design and modelling on computer were completed, the part was fabricated using knowledge learnt in another course, Computer-Aided Machining. Students assembled this fabricated part on to the machine during the hands-on assembly lesson.

Students were required to put up the purchase requisition of standard parts (e.g. fasteners, gears, etc.). This generated a lot of communication among students of different groups as they exchanged information on the standard parts with other groups handling other units. This activity simulated the purchasing process as would happen in the real working place.

The physical assembly of the machine was held on the second last lesson. Students reported to the workshop with their missing parts, purchase and requisition forms and schedules. These items were shown to the workshop staff for checking. With the duly completed purchase and requisition forms and missing parts, students were given the standard tools and parts to start the unit assembly. For missing parts that could not fit properly on the unit or machine, further machining was required. Students proceeded to the machining workshop to do the final machining. On completion of the unit assembly, the students assembled the whole machine excluding the wiring. The wiring was assisted by the workshop staff. Following that, students could see the commissioning of the machine. It was indeed a rare opportunity that students got to assemble a working machine. The workshop staff interviewed each group to assess their contributions.

Assessment of CDIO Skill Sets

Assessment weightages and methods were discussed and carefully planned by the course development team to meet the learning outcomes. Higher weightages were apportioned to the discipline knowledge to ensure the course was rigorous. The team felt that engineering programmes should produce graduates with adequate engineering knowledge and qualities that meet the expectation of the industries.

In addition to the weekly tutorial submission, a 2 hour test was conducted mid-semester to assess individual student's ED knowledge. A 90 minute test was conducted near the end of the semester to assess individual student's CAD skill.

Teamwork, personal and interpersonal communication skills were demonstrated when they worked individually and in groups. These qualities were assessed from the quality of their submitted work. Oral and presentation skills were assessed through the presentation activities.

Critical thinking skill was practised in activities such as machine component selection, establishing constraints in CAD assembly and the design of missing parts. It was assessed indirectly through the tutorials and CAD drawings.

Project management was assessed in their schedule presentation and ability to meet schedule.

LEARNING EXPERIENCE

There were lots of communication among different groups of students when they had to put up the purchase requisition of standard parts (e.g., fasteners, gears, etc) and when they exchanged raw data on the machine parts so that each group could model all the machine parts. Students challenged each other and/or groups on the incomplete raw data they received from them.

Ownership for the project by students was evident with their display of commitment and enthusiasm. They were taking charge of the various activities, urging the group members to complete their tasks on schedule. As tasks were distributed to every group members by the group leader, peer teaching and learning were evidence. The weaker students would learn from their group members in order to deliver the tasks assigned to them.

Feedback

Feedback on the students' ability to learn and apply knowledge and skills to realise the intended machine was obtained through a questionnaire and blogs. About 75% of the cohort indicated that they picked up skills useful for their career as a technologist while 68% felt that they had acquired the disciplinary knowledge/skills. Teamwork was consistently mentioned in the students' journals.

Both students and teaching staff felt that the workload was quite heavy as each group had to model and create drawings of the whole machine. With the feedback, the workload was reduced in the following semester. Each group concentrated on their sub unit. They did not have to create part models and drawings of the whole machine. The teaching schedule was also modified and fine tuned so that CAD lessons were taught first and ED was covered later in the programme. An assessment on individual contribution was incorporated to award students for their active participation and attitude towards the course.

Management Support

To realise the adoption of the CDIO framework into a well established programme that had existed for decades required strong support from management. It was very natural that staff refused the change. They saw sufficiency in the existing programmes which yielded many graduates' successes in the industries. The challenge faced by management was to change the mindset and belief of staff and to get them to come onboard the CDIO journey. Management's active participation to echo the message for change was important especially for this course with a magnitude of 6 credit units and a cohort size of more than 160 students.

The key success factor for CDIO implementation was managements' commitment and support to motivate staff to come onboard this innovative CDIO journey by breaking away from the norm and thinking out of the box.

CONCLUSION

Besides acquisition of disciplinary knowledge/skills, students also learnt personal and interpersonal skills, product and system management. The active learning activities used in the course promoted teamwork, communication, self discipline within group members and other groups, and management of learning. The completion and compilation of the project portfolio was a team task. Students managed their own learning activities through the schedule which in term provided them with a better understanding of project management. Different forms of communication were learnt by students, such as group communication to complete tasks, presentations of case-studies, and in proper drawing presentation.

With the trimming machine as the context, the course was comprehensive and industry relevant. Students were more ready for the advanced Final Year Project (FYP) done in the third year of the programme and, subsequently, work ready in the Industry. Students were advised to keep a copy of their submitted portfolio for future use with their resume for job interview which could put them one notch higher.

REFERENCES

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Biographical Information

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