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An Integrated CDIO Project-Based Approach for Introduction to Engineering Education

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***Abstract*—For a Duy Tan engineering student, the course entitled Introduction to Engineering Education plays a critical role in the student's future careers. The methodology behind this course involves acquiring all four stages of the product life cycle (CDIO Standard 1). The overarching goal of the CDIO initiative involves providing students with an engineering fundamentally stressed education. This education more specifically focuses on the ideas of Conceiving, Designing, Implementing, and Operating real-world systems, processes, and products. The mission statement of Duy Tan University is to create a foundation for learning and to guide students on more in-depth training and research. In accordance with the mission statement, an outline must be formed from the beginning of the engineering process that outlines a series of steps that the students must follow to achieve a solution to the given problem. The students must use critical thinking and implement those ideas in the real-world using concepts such as cost-analysis. One of the projects assigned to the class in Spring 2019 was to design and construct an industrial robot that travel autonomously. The robot project was selected as the technology necessary for a robot to handle various tasks can be applied to a wide range of skill set and industries. In the data collection process, students worked closely with industry leaders and involved them with all aspects of the robot designing process. Using the data collected from this process, the student teams individually proposed a market-friendly solution of a base level robot. The instructor lends their input for the final design of the robots, adding different components such as embedded controllers and sensors that provide the robot with the navigation assistance necessary to avoid collisions. The final design for the robot was then fabricated and assembled. The use of the CDIO program provided an excellent learning experience for both the faculty and the students. For the process to work smoothly, a series of CDIO standards was used in a well-integrated curriculum to ensure the students' knowledge in all aspects of the initiative. The skill taught include advanced engineering and entrepreneurial skills. A self-assessment of the course was conducted by the responsible faculty. A set of performance criteria was utilized to verify that specific learning outcomes were met**

Keywords—engineering education; intoduction to enginnering course; engineering projects;

I. INTRODUCTION

Based on Duy Tan University's statement "… focus on in-depth training and research of technologies and sciences in order to produce graduates with recognizable levels of patriotism, confidence, creativity, flexibility, humanities, community…" activities, organized by Duy Tan University, allows students to work in specific areas that they are interested in, as well as areas that have an social impact. With this approach of teaching technical disciplines, students can choose themselves an area of specialization related to their major thereby enhancing their learning. It is in clear understanding to us that the project idea is the focal point of inspiration and creativity. The instructor therefore set forth simple presentation of ideas and develop demand forecast for the product in the market areas. This is the most valuable source of information that will help the student team to set up their rough draft of entrepreneurship plan [1].

II. CDIO STANDARD 2, 3 CONCEIVE AND DESIGN STAGES

The first stage - Conceive stage is focused on identifying the problem. All students freely discuss in teams the preliminary idea of the design approach they wish to follow. Initially these ideas may be unfeasible but if the proposal meets the basic guidelines and has practical applications based on CDIO syllabus learning outcomes, we encourage them to test the design idea. In addition, CDIO program require competence in personal and interpersonal skills, especially oral and written communication skills. During conceive stage students gain proficiency in, development ability, guidance skills, systematic thinking, creative thinking, selective criticizing, problem solving, teamwork through following activities [2]:

In the initial step, the instructor asks the students for information, which was obtained through meetings with companies, as well as identified practical problems in the subject area. The student must describe their envisioned outcome, as well as create an outline using mind maps (Fig. 1) to visually organize information [3]. To complete and improve the mind maps, students require cognitive and affective development, along with critical and creative thinking. In this context, we pay attention to professional ethics as an important aspect of education. Pertaining to standard 2, this procedure validates learning outcomes.

Help and support students in visualizing the knowledge they acquired through discussion with industrial partners.

The students are advised that the original designs are most often not used, and adjustments to their initial plans are encouraged. These adjustments come from meetings with industrial partners. This allows students to be innovative with their designs and adjust their mind maps themselves. The goal of this exercise is to help students improve their communication skills, creative thinking, and analysis skills as well as expose them to constructive criticism.

This model is applied for the purpose of promoting discussion and allowing the student's personal views impact the project. The students can reorganize their teams as well due to these discussions. The end goal of these discussions is for the students to produce a product, whether that be a robot for an assembly line or a process for a factory.

The educator serves as the connection between all information brought forth by the students. They foster understanding as well as supervise the student teams for them to conceive of an idea, and to complete their engineering concepts. The students are also placed in charge of time management for meetings, seminars, workshops, and presentations with stakeholders. The instructor ensures that the students practice good time management, and make sure that the workload for the students is sufficient for the time allotted.

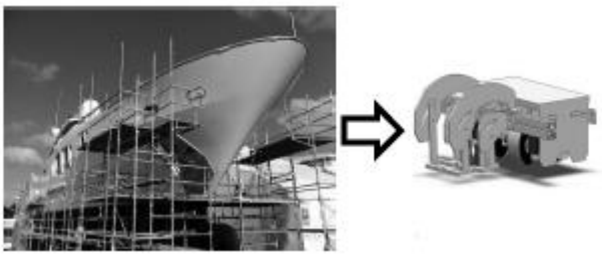

Fig 1. Mind map of a robot for weld quality

In Spring 2019 we divided the class into three teams of five students each, working directly under the supervision of the instructor and technical staff members of CEE (Center of Electrical Engineering, an Engineering division of Duy Tan University). The teams competed for the best-designed model and the most cost-effective robot. With only three teams participating in the project, we handled most of the discussion and feedback regarding the project through short interviews and focus group discussion sessions. The project required the development and delivery of a completely functional robot for a given application, utilizing whatever technology needed to get the job done. This indeed later called for a major revision of the learning outcomes of our Mechatronics engineering program to better prepare our students for real world applications. In addition, the students did not have a good knowledge of how to raise or manage money for an entrepreneurship project.

The idea for conception of robot was created by the student teams using the above-mentioned mind map. This concept originated from the practical demand of robots in ship building industry for inspection of weld quality. Another student's team contacted disable association and families to approach disabled people to find their mobility needs [4]. explored the technology required to develop technical plans for electric wheelchair for the disabled. Communication with disabled people help them learn skills such as interviewing, data collection, observation, evaluation and creating technical proposal.

The student teams also educated themselves about existing solutions and began the second stage – the Design stage, by sketch design of a mobile robot [5].

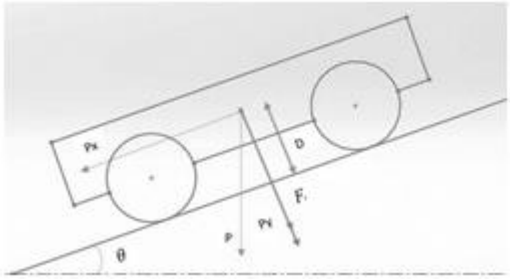

Fig 2. Dynamic calculation for stability of robot

They analyzed and proposed some design and engineering details of the robot (*Fig 3*). In this stage, along with effective teamwork, students should be capable of utilizing software tools such as Microsoft Visio, AutoCAD (Fig 4), and Autodesk Inventor, proficiently, to develop and simulate the mechanical aspect of the project [6][7]. Result of this stage is to find a well-rounded technical solution, which satisfy the given specification and operation of the robot. During this phase, the instructor provides guidance in the process and helps with mechanical and dynamical stability calculations. These types of activities help reinforce the learning surrounding engineering prototypes, processes, and system design.

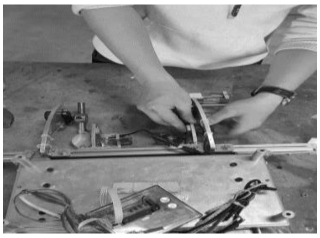

Fig 3. Students design mechanical components

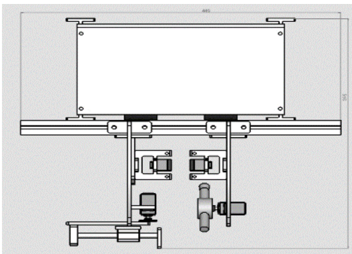

Fig 4. Robot design on Autodesk

The students are also encouraged by the instructor to use AutoCAD and Autodesk Inventor to model some details of their prototype, which will be created using a 3D printer [8]. This is a basic skill integrated in the curriculum to design and implement the product and is the basis of the entrepreneurial skill [9] [10]. The instructor instils culture of continuous improvement and cost cutting by refining design model and methods to cut down cost by using modern technology.

In the third stage - Implementation, under the guidance of the instructor, the students will work and test in the University's workshop (*Fig 5*). The students will use laser cutting machines, as well as CNC milling and turning machines, to fabricate a prototype of the robot. Since students have already taken courses in manufacturing, they are skillful in making the prototype. Through practice they improve their implementation process. The teams put their product to rigorous tests to ensure quality and more importantly the safety in operation.

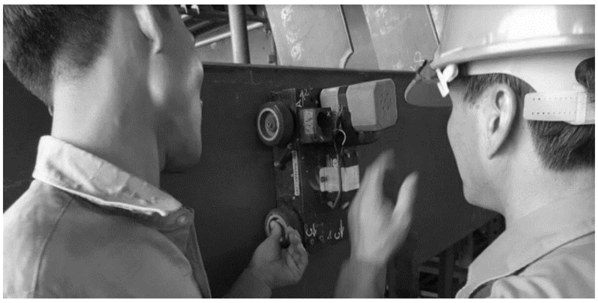

Fig 5. Students are testing mechanical components and electronic automation for robot

III. CDIO STANDARD 6, 7, 8 IMPLEMENT AND OPERATE STAGES

After following a series of training activities, the student teams are actively engaged in discussions, creating fabrication proposals, implementing models, emphasizing team collaboration, analyzing products, and provide feedback along with compliments. The fabrication process provides students the experience on improving practical & professional skills and developing problem solving skills and techniques (standard 8).

At this stage, the instructor guides the students in utilizing the CEE facilities for mechanical manufacturing, programming, and simulation. CEE personals, who are knowledgeable in the process, provide support to the students so they can materialize their ideas in engineering design and especially be responsible for social obligations to the user of the robot. We applied this unique teaching and learning activity (Standard 7) in CDIO Project during Spring 2019 due to availability of working technical space in CEE for students (Standard 6). Students show their proposal to the technical staff of CEE, before they can use the equipment, instruments, modern software, and practical production processes in the center to manufacture the robot. This methodology has the following advantages:

- To allow the students to utilize the classrooms, workshops, and laboratories of CEE, the CDIO class working space was modified. Learning in an open space aided student in grasping information more effectively, as well as allowed for a more attractive setting, compared to a traditional classroom.
- The students worked with the instructor and communicated directly with CEE staff, to expand their skill set. With the observation of experts, the reliability of the final product was increased by eliminating mistakes and shortcomings of students due to a lack of practical experience. The robot could be tested and operated stably, and results compared against design calculations.
- Taking advantage of the existing facilities and materials of CEE, helped student save on project expenses. Duy Tan University is exploring the use of their modern technical facilities, in research and training, by making it available to local businesses.
- The last stage – Operation, the students are required to test the robot for practicability and flexibility under actual operating conditions. Previously, students were not required to do this, as the end results of the CDIO Project were limited to grading on completeness of the assigned project, as well as the knowledge gained during the execution of the project. In the current semester, the CDIO Project aimed to provide students additional experience and entrepreneurial skills. Therefore, the project was evaluated by a series of criteria as relevance, fulfillment of objective, efficiency, effectiveness, impact, and sustainability. As instructors, all criteria are followed; however, more attention is paid to entrepreneurial skills and integrated approach in assessment. The operation stage requires the students to deliver a final product to the shipbuilding industry for testing, where they will instruct the staff on how to operate the robot in actual conditions.

IV. IMPACT OF THE COURSE

In Duy Tan University, this is totally a new approach of applying CDIO methodology to teach the course. To create well-rounded graduates with strong engineering and entrepreneurial skills, a series of CDIO standards were required, in a systematic and integrated curriculum. In this respect, the integrated approach (CDIO Standards) in teaching the technical discipline was modified, by adding the manufacturing processes. A self-assessment of the Introduction to Engineering Education course was conducted by the responsible faculty. A set of performance criteria (*Table 1*) was developed to indicate that specific learning outcomes were met. A list of assessment tools was developed that included weekly progress, project display and demonstration, oral presentations and final written report and other course deliverables that were used to show that the performance criteria were met. For example, ABET Criteria 3. Student Outcome C was assessed using the following performance indicators:

TABLE 1. PERFORMANCE INDICATORS [11]

Performance Indicator	***Faculty members cumulative score***
defines customer needs	88%
defines design constraints	86 %
offers alternative solutions	67 %
defines problems to be solved	87 %
defines project scope	73%
compares alternative solutions	64%
defends selection of final design	79%
build prototype to meet needs	100%
validates performance of prototype	91%

The assessment results shown in *Table 1*, demonstrate that upon completion of the course 82 % of the students were meeting the performance indicators given above as required by ABET learning outcomes.

V. CONCLUSION

The Project engineering robot for industrial application is a typical example of motivating, integrating and simultaneous implementation of CDIO standards to strengthen and enhance professional skills of students in Engineering programs. The approach requires students to conduct market study, analyze the practicality, take care of social obligations, construct and implement, combine cross discipline knowledge in an integrated education environment, taking advantage of new technology. The product should be practical and reasonably priced paying attention to safety considerations. These skills and knowledge are very important for students to acquire before they join the labor market. Throughout all of the stages of this unique project, the students, instructors, and research staff of CEE applied the CDIO Standard, in order to create a useful commercial product, while at the same time teach inter-disciplinary subjects and upgrade the curriculum. This project is evident how Duy Tan University implemented the CDIO methodology while preparing the syllabus, but also in all stages of the education process.

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BIOGRAPHIES

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