CDIO IMPLEMENTATION FOR MECHANICAL COURSES AT PHAROS UNIVERSITY IN ALEXANDRIA

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ABSTRACT

Effective and sustainable education of engineering fundamentals is the main objective for any accreditation body such as ABET, in particular the criteria of "Design, Conduct Experiment and Analyze the results." From this perspective, the Mechanical Engineering Department at Pharos University in Alexandria, Egypt, adopted the concept of CDIO (Conceive-Design-Implement-Operate), aiming to stress these criteria over the past three years starting in the academic year 2017/2018. Six courses in mechanical power engineering were selected, and their course specification modified to stress their educational fulfillment in the context of CDIO and enhance the real-world systems approach using prototypes designed and built by students. The presented work intends to summarize the adaptation and implementation of CDIO-based learning through the Engineering Fluid Mechanics course by replacing most of the laboratory instructional experiments with hands-on learning using the CDIO approach where the professional practice is in focus. The CDIO implementation in spring 2018 pursued the four stages (conceive-design-implement-operate), which are described and outlined in this manuscript. Furthermore, based on the students' feedback, satisfaction assessment, and semester grades, the CDIO method proved its capability to enhance student learning and gave a chance for close encounters with the course instructor as well as the mechanical design professor. This is reflected in the overall students' learning, as well as their achievements in comparison to previous semesters. Although the semester work grade still follows the normal curve shape, its standard deviation became smaller, which meant that most students benefited from the CDIO approach in teaching and learning.

KEYWORDS

CDIO implementation, engineering education, enhanced learning, CDIO projects, Standards 8

INTRODUCTION

There are no doubts that educators strive to achieve the highest standards of education practices. Through the past years of strategic cooperation between the Faculty of Engineering at Pharos University in Alexandria (PUA) and the KTH in Sweden, the concept of integrating CDIO within the undergraduate education of mechanical engineering program has received considerable attention.

June 2011 was the first graduation of students from the Faculty of Engineering – Pharos University in Alexandria. Since establishing the faculty in 2006, the university administration and faculty were keen on providing an outstanding learning environment with distinct and developed methods of teaching and learning. The educational and scientific partnership agreement with the Royal Institute of Technology in Sweden KTH marks the efforts of the faculty in the field of international cooperation in order to apply high academic standards concerning the syllabus and follow up. Based on this cooperation, programme at the faculty of engineering at Pharos University adopt the CDIO methodology as the centre for their curriculum. The expected learning outcomes of the courses are structured in four sections; disciplinary knowledge, professional skills, interpersonal skills, and general skills, which include; conceiving, designing, implementing, and operating systems in the enterprise, societal and environmental context.

CDIO Standards consists of twelve properties that characterize an education program that follows the CDIO framework. The CDIO Standards are useful tools in the development of an education program, and it can also be used for self-evaluation.

CDIO recommendations are adopted as best practices aiming to improve the curriculum and to enhance students' learning. The Faculty of Engineering at Pharos University in Alexandria is committed to regular curricula reviews and reform. The implementation of CDIO for the Mechanical Engineering program is a result of such an initiative.

The present manuscript presents the initiatives carried out at the Department and gives highlight to the corresponding outcomes. The different stages of the implementations are described, and related experiments and projects are discussed.

OVERVIEW OF THE IMPLEMENTATION INITIATIVE OF CDIO

Effective education of engineering fundamentals is the main objective for any accreditation body such as ABET, in particular, the criteria of "Design, Conduct experiment and Analyze the results." From this perspective, the Mechanical Engineering Department of Pharos University in Alexandria, Egypt, adopted the concept of CDIO (Conceive-Design-Implement-Operate) to stress these criteria three years ago in the academic year 2017/2018. Practical work and experimentation are of indispensable importance in undergraduate engineering education. Six courses in mechanical power engineering were selected, and their course specification modified to stress their educational fulfillment in the context of CDIO and enhance the real-world systems approach using prototypes designed and built by students.

The CDIO concept has found noticeable attention in engineering curricula worldwide (Poblete, P. et al. 2007). It has been introduced (Yang Yong et al., 2016), the idea of establishing a new application pattern of LAB-CDIO（LABORATORY-CDIO). The LAB-CDIO is the new pattern that runs the CDIO scheme and process in the laboratory-like environment. It combines the assembly of the experimental equipment and the simulation process with the idea, the design, the implementation, and the operation (CDIO). Furthermore, it has been indicated (Karl-Frederik Berggren, et al., 2003) that CDIO is an open architecture endeavor. It is specifically designed for and offered to all university engineering programs to adapt to their specific needs. It is an ongoing developmental effort. Several educators (Cheah Sin Moh et al., 2013) reported that their effort, during the last five years, to integrate the various CDIO skills appeared to be successful, as validated by the feedback received from students on their learning experience in CDIO-enabled modules; as well as from graduates who responded to their surveys.

In order to overcome the gap between real-world applications and curricular standards, it has been reported that CDIO is an effective approach to achieve such an aim (Crawley, E. et al., 2007). In a comprehensive paper (F. Edward, 2009) the idea of 'Re-understanding of Engineering Education -International CDIO training mode and method' has been raised and indicated that the CDIO engineering education pattern is the latest achievement of international engineering education reform in recent years where students take the active and practical way which has a link between classes and project. It is worth mentioning that it has been emphasized (Edward F. Crawley, et al., 2008) that the proper context for engineering education is in engineering practice, that is, lifecycle development and deployment of products, processes, and systems. They adopted the Conceive-Design-Implement-Operate approach to engineering education and indicated that there are other models that describe engineering practice, which can be used effectively for teaching and to learn engineering.

In a recent paper (Lahtinen, T. and Kuusela, J, 2016) it is reported on why, what, and how they ran this project, and they pointed out that the trigger for this project was the feedback from the students: "we want hands-on projects." Also, they indicate that with proper motivation, the students can form a strong link between theoretical and practical knowledge and skills.
In a recent paper (Cosgrove, T. and O'Reilly, J., 2019), it has been outlined how the reflective dimension has been embedded in the Civil Engineering undergraduate program at the University of Limerick. This paper summarizes the adaptation and implementation of CDIO-based learning of some courses over the past three years by replacing most of the laboratory instructional experiments with hands-on learning using the CDIO approach where the professional practice is focused.

The cited work by (Liang, Z. et al., 2012) pointed out that the use of the CDIO teaching practice in the Hydraulic Driving Technology proves that a positive and effective result can be obtained by the pedagogical method based on practice capability and teamwork collaboration. The reasonable adoption and arrangement of the teaching case of the control valves in the hydraulic molding machine promotes the cultivation of a student's comprehensive ability.

CASE STUDY AND LESSONS GAINED

In this section, a case study related to the implementation of CDIO is presented. Results and outcomes are discussed. The CDIO method is implemented each academic year in 6 senior courses extended through 6-semesters: namely:

A. Three Courses During Fall Semester:
   1. EM 211 Mechanics of Material
   2. EM 214 Mechanical Vibrations
   3. EM 220 Measurements and Sensors

B. Three Courses During Spring Semester:
   1. EM 212 Mechanics of Machinery
   2. EM 252 Engineering Fluid Mechanics
   3. EM 333 Renewable Energy

To illustrate CDIO implementation, EM 252 “Engineering Fluid Mechanics” 3 Credits (2,1,2) is selected in spring 2018. EM 252 has the following catalog data “Similarity and model testing; Flow through pipes; Pipes networks; Pumps.” In this course, piping and pumping are stressed by implementing CDIO in the course contents, as shown in Table (1). As indicated in Table (1) the CDIO implementation pursues the following stages:

In the third week, Stage # 1: Conceive: ideas and creative thinking related to piping & pumping are proposed and discussed with students. They form a group of 5 students with one as a leader to carry out a specific piping system and specific pumps arrangement (4 different systems x 3 pump arrangement x 5 students cover the 60 students enrolled in this course)

In the sixth week, Stage # 2: Design: a specific system associated with piping losses and pumping for each group to be designed. Along with the instructor, a design professor is appointed. A weekly meeting is held for the remaining weeks to help each group in their system design and material selection as well as the practicality of components of the prototype before purchasing any items

In the twelfth and thirteenth week, Stage # 3: Implement: purchasing, fabricating, and assembling the parts into a working piping system, including two pumps and different piping systems. Each system is connected to a pumping system on the hydraulic bench, which has been designed and fabricated by all students through their leaders. The lectures during these weeks concentrate on obtaining the operating point for each group and the associated theoretical analysis for piping losses and pumping different arrangements (single, 2-pumps in parallel and in series). Plate (1) shows the designed and built hydraulic bench including two pumps & four piping systems

In the fourteenth and fifteenth week; Stage # 4: Operate: measurements & analysis and reporting the results obtained by measuring the flow rate using lab rotameter. Also, a pressure gauge is used to measure friction and fitting losses. The number of experiments = 3 pumping arrangement X 5 piping systems = 15 experiments. The analysis involved uncertainty analysis and comparison with the Euler equation of Turbomachinery. A technical report is required from each group and discussed with the instructing professor, to be resubmitted two days later.

Table (1) implementation of CDIO in the course contents

Course Outline	Week
Dimensional Analysis & Flow Similarity and Model studies.	1 & 2
Energy Equation and Basic of Pipelines CDIO: Conceive	3
Pipe Flow Problems & Pipeline application Pipes in parallel and in series	4 & 5
Pipe Network; CDIO: Design	6
Introduction to Turbomachinery	7
Mid-Term Exam	8
Moment of Momentum & Euler Eq.	9
Pump Analysis & Velocity Triangles	10
Performance of Pumps & System Curve Pumps in Parallel and in Series	11
CDIO: Implement, Operate & Test and Results	12,13&14
CDIO: Results analysis and reporting & presentation	15

Based on the students' semester grades, this CDIO method proved its capability to enhance student learning and gave a chance for a close encounter with the course instructor as well as the mechanical design professor. This is reflected in the semester work grades in comparison to grades of previous spring terms. Although the semester work grade still follows the normal curve shape, its standard deviation became smaller, which means that most students benefited from the CDIO way of teaching.

Before CDIO implementation, the course had seven instructional experiments for a large number of students (20 to 25 students per lab), with limited effectiveness of achieving course objectives and a lack of planning and practical hands-on experience. Also, not all students were involved in executing each experiment from a to z. The concern of each student was just completing the data in given tables as per the instruction sheet hand-out. In fact, students without CDIO implementation were studying to pass the exam, after which the subjects were quickly forgotten.

The new course specification retains only two selected basic instructional experiments for piping losses and operating point with one single pump only. The remaining 5 experiments are replaced with the context of CDIO, which stimulates thought and gives time for the students to think and ask questions and get answers during their close encounter with the instructor and design professor. Students became part of the deep learning process involving design and built a prototype to work on the course objectives, which will be retained even after graduation. Also, students have the chance to use pump manufactured data and compare it with theoretical analysis for different pump arrangements.

CDIO was implemented through design, and an apparatus was built to determine water head losses due to fluid friction and minor losses through 4 different piping systems. The operating point for each group was obtained by the intersection of the characteristic curves for pumps purchased from the market. In their report, each group requested to write a user manual for their system, the problems encountered, the cost involved, and also the usefulness of the prototype for future experiments.

Figure 1. Plate (1) Designed and Built Hydraulic Bench including Pumps & Piping Systems
1-Water tank 2-Two identical pumps arrangements (can be operated as single, in series or in parallel) 3-Pressure gauge 4-Rotameter for flow measurements 5-Helical pipe 6-Tube banks 7-Gate valve and Globe valve

In Spring 2019 another set of CDIO prototypes related to the course objectives were designed, implemented, and tested, namely:

Firefighting Experimental Model

The objective of this CDIO project is to design and implement an automatic fire sprinkler system used to save buildings and people according to NFPA 13. The theory involved in the CDIO project is to calculate the pressure losses up until the remotest location in the building from which the pump head and flow rate are calculated.

Three Water Reservoirs Model

The aim of this CDIO project is to identify the change in the flow rate as a result of changing the elevation levels. Three pipelines connect three reservoirs at a common junction. The three reservoirs have different elevations, and water flows from the highest to the lowest reservoir. The main question is: will water flow to or from the middle reservoir? The classic problem concerns the calculation of the steady flow rates and hydraulic grade lines in the system. Three different tanks were used with one designed to be movable by using a motorized mechanism.

Piping Network Model

The objective of this CDIO project is to implement and operate the design and piping network, which consists of 2 pipe loops and 8 -junctions with one supply pipe and one discharge pipe. The theory is based on the Hardy Cross method by assuming the flow rate and iterate to calculate the flow rate and its direction for each pipe (At each junction ∑Flow rate = 0.0 & Pressure for each loop = 0.0)

Venturi Pump Model

The objective of this CDIO project is to implement the design of Venturi, which operates as a pump in a system of piping, tanks, and circulating pump.

CONCLUSION

In conclusion, it can be reported that adopting CDIO-based learning in some engineering courses motivates students and increases the effectiveness of learning objectives which is reflected not only on the deep understanding of piping and pumping systems but also on acquiring the ability to work in a team and enhancing their professional and practical skills. Moreover, student-faculty interaction is greatly improved through continuous supervision throughout the semester and answering questions that were never asked before implementing CDIO.

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