Application of the CDIO Standard for teaching the Architectural Composition Subject with a practice competition about green architecture at Ho Chi Minh City University of Technology, Vietnam

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Abstract

Innovative teaching methods is a matter of great concern to many universities in Vietnam, especially in the context that higher education in the world is changing and requiring higher standards of graduates. To meet the needs of businesses and keep up with the sustainable education standards in the world, universities in Vietnam have to make improvements in teaching methods. CDIO is an international standard system for training engineering students that has been applied in many developed countries around the world. In Vietnam, the Ho Chi Minh City University of Technology (HUTECH) has started to implement this method and this has brought positive results. This article introduces the experience of applying CDIO in university teaching around the world, as well as solutions for applying CDIO in teaching the Architectural Composition Subject for architecture students at the Faculty of Architecture and Art. The end result of this is that second-year students groups will complete a competition for architectural design called: "Feeling the natural beauty in the heart of the city - Finding the natural awakening design solutions" by TOTO Information Center organized, inspired by an architect Takaharu Tezuka from Japan. The purpose of this application is to improve teaching quality, improve the curriculum to help students approach practical architectural competitions, and ensure they can meet the requirements of sustainable design after graduation.

Key words: *CDIO, innovating teaching methods, Architectural Composition Subject, green architectural competition, HUTECH, Vietnam.*

1 Introduction

At present in the world, the theory of sustainable architecture, green architecture and practical projects under this design model has been included in the architecture curriculum at many universities. Requirements for architectural design in harmony with nature are an inevitable trend because of the need for sustainable development for the global future. In order to keep up with this trend, architects training at Vietnamese universities need to be taught about sustainable design trends from around the world. At the same time, universities in Vietnam are also innovating in teaching methods, changing the curriculum to improve teaching quality, helping students get closer to advanced education, as well as meeting the future requirements of society and business.

"Technical education and the practical needs of engineers in recent years have been increasingly far apart. From the awareness of have to close that wide gap, leading technical universities from the US, Europe, Canada, the United Kingdom, Africa, Asia and New Zealand have jointly created the CDIO Initiative: globally collaborative effort to launch ideas and develop a new vision about technical education." (Duong, 2015)

CDIO standards have been researched, applied and verified to achieve positive results for students after graduation. CDIO is now considered as a new initiative for education, a methods system, forms of accumulating knowledge and skills in improving the quality of higher education to meet the requirements of businesses and society. As part of taking the first steps in the application of CDIO model in teaching architecture students, the Faculty of Architecture and Art of HUTECH University is gradually applying CDIO to teach some subjects including theory and practice. The Architectural Composition Subject was chosen to apply the CDIO standard to teach the second-year architecture students to approach the sustainable architectural theory design and apply it to do an exam for realistic green architecture competition.

1.1 *Concept of CDIO*

CDIO, which stands for Conceive - Design - Implement - Operate, originated from the Massachusetts Institute of Technology (USA). Up to now, this model has been applied more and more by universities and colleges around the world. In essence, CDIO is a solution to improve training quality, meeting social requirements on the basis of determining outcome standards, from which to design training programs and plans. This process is formulated scientifically and logically, and can be applied to many different training areas. (NEWS, 2018)

1.2 Architectural Composition Subject

Architectural Composition is a subject with the objective of providing a general and basic knowledge of architectural definition, the nature of architectural creativity, concepts of form, architectural language, and basic components of the architecture such as the point, line, area, cube, space, time, the theory of architectural combination, rhyme, scale system, proportion, and problems about methodological and creative thinking. (Hai-Yen, 2019, *Architectural Composition Book)*

2 Research Methodology

This paper is a qualitative research, using a mixed method including the data synthesis method, statistical method, survey method and expert method. The data synthesis method is used to analyze and assess the situation of teaching at the current architecture training universities in Vietnam, evaluate the suitability of the current training program compared to the outcome standards requirements of businesses. The statistical method is applied to reference experience of CDIO application in the world with certain effects. The survey method is used to examine the quality of current students, to survey the feedback of businesses on the quality of graduates and the businesses requirements for students. The expert method is used to synthesize standards in the application of the CDIO model.

3 Experience of CDIO application in the world

3.1 American Experience (Massachusetts Institute of Technology)

The CDIO Initiative was pioneered by the Massachusetts Institute of Technology (MIT), to address the gap between industry needs and the quality of engineering graduates being produced (Taylor's University, *CDIO Initiative*). Immediately after the first five years of implementation (2000-2005), MIT has realized the remarkable achievements that CDIO brings to its training programs: the skills that are focused on the CDIO program are in accordance with the requirements of research institutes and businesses, students are satisfied with the "design-build experience" and a deeper understanding of technical principles, lecturers use a variety of teaching methods and assessment methods, the quantity of people who are participating in the CDIO program is increasing and quantity of people who fail the exam is significantly decreasing. (Massachusetts Institute of Technology *el al.*, 2000)

3.2 Situation of CDIO application in universities in the world today

At present, universities around the world are increasingly applying the CDIO model and its advantages and effectiveness have been confirmed and verified over time in many different universities. As of now, the CDIO program has expanded to more than 50 universities in 25 countries. The countries that have CDIO-applying universities are the United States (University of California Daniel Webster, Massachusetts Institute of Technology, Naval Academy), Canada (Royal University, Ontario, Calgary, Manitoba, ...), France (Telecom Bretagne), New Zealand (University of Auckland), the United Kingdom (Lancaster University, Liverpool, Leeds, Aston and Royal University of Belfast-Northern Ireland), Sweden (Chalmers University of Technology, Jnkping, Linkping , ...), Finland (University of Applied Sciences), South Africa (University of Pretoria), Portugal (Advanced Institute of Engenharia do Porto), Singapore (Polytechnic University). (Vo, 2011)

4 Scientific basis of the application CDIO in training engineering students

4.1 CDIO nature

CDIO is a system of methods to develop engineering students training programs, but this is essentially an outcome-based training process outcome-based to design income standards. This process is built to ensure scientific and rigorous practicality.

Table 1: Intended CDIO Outcomes (Karl-Frederik *el al*.,2003).

	Curriculum	**Teaching and Learning**	**Laboratories and Workshops**	**Assessment**
Programme	Models for curriculum structure and design.	Understanding and addressing barriers to student learning.	Models for the design and use of laboratories/ workshops.	Tools and processes for programme evaluation.
Student Experience	Curricular materials for CDIO education.	Active and experiential learning with enhanced	Workshop-based educational experiences.	Tools and processes for assessing student

		feedback.		achievement.

Following the CDIO approach, students will learn individual skills, communication skills, product creation skills, process and system building along with specialized knowledge in specialized practice training programs. It is integrated learning. Integrated learning has the advantage of allowing students to use the dual time to both learn knowledge and learn specialized application skills.

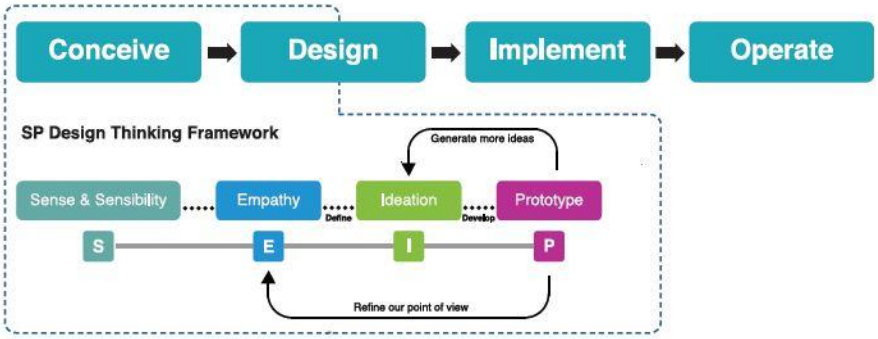

Figure 1: Steps to proceed with CDIO (APC, 2019).

CDIO model training helps to connect students' ability to work with the requirements of employers, helping learners develop comprehensively with "hard skills" and "soft skills" to quickly adapt to an ever-changing working environment and even be at the forefront of that change. Helping training programs are built and designed according to a standard process. The training processes are connected and closely linked with science, linking the development of training programs with the transmission and evaluation of the effectiveness of higher education, and contributing to improve the quality of higher education.

4.2 CDIO standards

1 - **The Context:** Adoption of the principle that product, process, and system lifecycle development and deployment Conceiving-Designing-Implementing-Operating — are the context for engineering education.

2 - **Learning Outcomes:** Specific, detailed learning outcomes for personal and interpersonal skills; and product, process, and system building skills, as well as disciplinary knowledge, consistent with program goals and validated by program stakeholders.

3 - **Integrated Curriculum:** A curriculum designed with mutually supporting disciplinary courses, with an explicit plan to integrate personal and interpersonal skills; and product, process, and system building skills.

4 - **Introduction to Engineering:** An introductory course that provides the framework for engineering practice in product, process, and system building, and introduces essential personal and interpersonal skills.

5 - **Design-Implement Experiences:** A curriculum that includes two or more design-implement experiences, including one at a basic level and one at an advanced level.

6 - **Engineering Workspaces:** Engineering workspaces and laboratories that support and encourage hands-on learning of product, process, and system building, disciplinary knowledge, and social learning.

7 - **Integrated Learning Experiences:** Integrated learning experiences that lead to the acquisition of disciplinary knowledge, as well as personal and interpersonal skills; and product, process, and system building skills.

8 - **Active Learning:** Teaching and learning based on active and experiential learning methods.

9 - **Enhancement of Faculty Competence:** Actions that enhance faculty competence in personal and interpersonal skills; and product, process, and system building skills.

10 - **Enhancement of Faculty Teaching Competence:** Actions that enhance faculty competence in providing integrated learning experiences, in using active experiential learning methods, and in assessing student learning.

11 - **Learning Assessment:** Assessment of student learning in personal and interpersonal skills; and product, process, and system building skills, as well as in disciplinary knowledge.

12 - **Program Evaluation:** A system that evaluates programs against these standards, and provides feedback to students, faculty, and other stakeholders for the purposes of continuous improvement. (Edward *el al*., 2007)

4.3 Teaching level and competency level

Teaching level: I (Introduce); T (Teach); U (Utilize).

Competency level: 1: Knowing or experiencing; 2: Can participate in and contribute; 3: Can understand and explain; 4: Have practical skills or implementation; 5: Can lead or be creative.

5 Ability to apply CDIO in training engineering students in Vietnam and HUTECH University

In Vietnam, the application of CDIO is initially being tested. Beginning in the 2009-2010 school years, Hanoi National University and HCMC National University started to apply CDIO to train some majors at its member schools. According to a report at the Asian CDIO Conference at the end of March 2015, after more than five years of implementation, HCMC National University has implemented the reform of 45 training programs under CDIO approach. The greatest achievement, as judged by CDIO implementation experts here, is that the lecturers have been greatly improved. The first students that graduated are full of hope as a result of the CDIO implementation. (Duong, 2015)

Since then, the application of CDIO has been expanded to many universities in Vietnam as a solution in improving training programs and improving the quality of higher education. Aiming towards an application-oriented higher education model, HUTECH University has applied the main methods in the CDIO model such as integrated teaching and learning methods, active learning in the curriculum and achieved positive results.

The CDIO approach requires that some basic conditions: facilities, lecturers, staff, training programs, and students meet the basic standards of CDIO. In order to apply the CDIO training program, universities have to review and reconstruct the training program and outcome standards. Lecturers need to be trained to suit the curriculum, as the amount of teaching work, and assessment increases for each lesson. Students

need a lot of practice so the quantity of exercises and projects increases. In addition, the budget for developing training programs with CDIO standards is very large. With private university such as HUTECH, the quantity of students in a class is very large, while the quantity of lecturers is small, which is also a challenge in the process of applying CDIO standards in teaching.

6 Application of CDIO to teach the Architectural Composition Subject at HUTECH University

6.1 Course Goals

Equip architecture students with certain knowledge about architectural creation, aesthetics and architectural design. As a precursor to help students in-depth study in the field of architecture of civil engineering, planning, industry and urban management.

6.2 Course Outcomes

Table 2: Course Outcomes standards of Architectural Composition Subject (Hai-Yen, 2019, *Architectural Composition Outline).*

Course Outcomes	Teaching Level
Knowledge: - CO1: Understand, apply and practice the specialized basic knowledge in designing and shaping architectural. Understand the method of architectural creation.	I2, TU2
Skill: - CO2: Understand and apply the basic knowledge of architectural creation skills. - CO3: Willing to accept new trends in a positive, non-conservative way.	TU2
Autonomy, self-responsibility: - CO4: Ability to work in groups. - CO5: Ability to analyze and apply the principles and rules of architectural design, in making academic conclusions. - CO6: Having capacity to manage and promote collective intelligence in the implementation of architectural design projects.	TU2

6.3 Teaching methods

Use a combination of methods: Case Stud based learning; Put theoretical knowledge into practice, promote the ability to think creatively, generalize; Study based on discussion and teamwork; Evaluate feedback between student groups and the lecturer.

Table 3: Methods of Teaching Architectural Composition Subject (Hai-Yen, 2019, *Architectural Composition Outline).*

Methods	Goals
Learning theory	Provide students with the basic knowledge of the subject through direct classroom lectures.
Presentation	Provide students with the basic knowledge system of the subject in a scientific and logical way through homework and presentations.
Discuss	Through Questions & Answers between teachers and students, between students to clarify the content knowledge in the subject.
Exercises	Help students understand and apply subject content into practical issues.
Study the lessons, read the references	Help students strengthen self-study and self-research capacity. Raise excitement for students in order to find the way to resolve the problem.

6.4 Level of meeting the standards of CDIO in Teaching Architectural Composition Subject

Table 4: Level of meeting C-D-I-O standards (Source: Author, 2020).

The Content	Meet CDIO standards	Meet Course Outcomes
Students learn the theory in parallel with the practice, development and deployment of architectural design products according to processes and systems: forming ideas, designing and implementing.	Standard 1	CO1, CO2, CO3
Specific outcome standards with communication skills when working in groups, presenting concepts, product creation skills, professional knowledge fit with the Architectural Composition Subject.	Standard 2	CO1, CO2, CO3, CO4, CO5, CO6
Integrated training program, integrating personal and communication skills, product creation skills to complete the exam with standard technical drawings and models.	Standard 3, 4	CO1, CO2, CO4, CO5, CO6
Students experience the design and implementation according to the theme of the competition from idea to product, and work in an architectural practice workshop.	Standard 5, 6	CO2, CO3, CO4
Students take proactive approach in studying. To do the competition, students need to actively learn more specialized knowledge and learn about competitions subject to create the right product. When students need further information and advice, they have the help from a lecturer.	Standard 7, 8	CO2,CO3
When students join the national architectural competition, the lecturer also needs to learn more about the requirements of the competition, as well as modern architectural trends to advise students. In addition, the lecturer is also an inspirational person to help students be more motivated to do the competition.	Standard 9, 10	CO1, CO2, CO3

Assess the learning results of the subject with a complete submission including drawings and models. Students present in class, then submissions are sent to the evaluation company. There are small architectural projects, so it is possible to evaluate the ability to create products as well as specialized knowledge.	Standard 11	CO1, CO2, CO4, CO5, CO6
Subject results are evaluated by lecturer, students and company for the purpose of improving the subject and teaching quality in the future.	Standard 12	CO1, CO2, CO3, CO4, CO5, CO6

6.5 Comparing the students quality that studying Architectural Composition Subject in CDIO program and usual teaching program

Architecture students trained through following the CDIO model are able to better meet job requirements after graduation due to training in professional practice skills as well as soft skills from the subjects. Particularly with Architectural Composition Subject, the curriculum according to CDIO will have a significant difference compared to the conventional curriculum. Specifically expressed as follows:

Table 5: Comparing the student quality between usual teaching program and CDIO program (Source: Author, 2020).

The usual teaching program	**CDIO program**
Teaching theory and assessment with the final exam.	Teaching parallel theory and practice. Assess intertwining in teaching and learning process with practical Architectural competition.
Evaluation to track learning.	Assessment to promote students' ability to find ideas.
The focus is on the right answers.	The focus is on asking questions to find problems and learning from mistakes.
Learning results are assessed indirectly through the exam.	Desired learning outcomes are assessed directly through the process of making projects, communicating, and presenting.
Promote individualism.	Promote teamwork, coordination, support.
Only students are considered learners.	Teachers and students learn together.
Students acquire knowledge passively.	Students learn proactively and confidently in life.
Students have difficulty to approach real- jobs at the industries due to theoretical study only.	Students can easily access the jobs after graduation and communicate well with colleagues because of practical training from the 2nd year.

6.6 Students practice on the competition "Feeling the natural beauty in the heart of the city - Finding the natural awakening design solutions"

Purpose – Requirement: The competition "Feeling the natural beauty in the heart of the city - Finding the natural awakening design solutions" was organized by the TOTO Information Center in Vietnam, and

inspired by an architect Takaharu Tezuka, a famous Japanese architect with a philosophy of architecture design inspired by nature this is human centered.

The competition requirement is to design urban spaces intertwined with the element of "living", feeling the natural voice and people in the modern world, where people are bound in artificial spaces. The harmony between nature and people, maintaining the connection between the past, present and future and what is familiar to create the architecture of life is the main purpose of the competition.

Learning based Case Study: Answering the question: "What is the living factor in urban space?"

Implementation process:

With an interesting topic and a design trend close to nature, which is an interesting architectural trend nowadays, the competition has brought excitement to the students. Being integrated into the content of the architectural composition subject helps students to be more excited with the subject when participating in the second year. The content of the competition is also consistent with the lesson "Architecture and nature" in this subject. A class with 30 students is divided into groups, with 2-3 students per group.

Figure 2: C-D-I-O process to do competition (Source: Author, 2020).

The order of groups to perform this competition in 5 steps is as follows:

Step 1: Problem detection: Research design tasks from competition requirements.

Step 2: Clarify the problem: Answer the question: "What is the living factor in architectural space?". Determining the type of buildings and the design area. Students can choose a small space to renovate or design a new building. Find references related to the selected building type, the design trend of Takaharu Tezuka Architect and the current of the selected site.

Step 3: Innovative solutions: Analyze the land and give preliminary ideas with 2-3 options. Students discuss in groups, compare the proposed solutions with the initial goals of the project, then find out the advantages and disadvantages of each option, which is the basis for making a selection option.

Step 4: Evaluate the solutions: The groups presented the first time about the given options. Based on the analysis of the group with the review of lecturer and the other student groups, provide the choice option.

Step 5: Implement and design the project: Students revise their projects through each session with the lecturer to complete the project. Students show their design ideas in the form of technical drawings including plans, elevations, cross sections and technical solutions on A1-sized papers, with a model. Student groups will present the final option with evaluation from lecturer and other student groups.

In the implementation process always compare with the original goals of the competition in step 1,2. Implement the Backward Design process. The project results obtained at each stage are compared with the original goals to ensure that the designs meet the requirements of the topic and the groups are on the right track. Always take Case Study as a keyword for the whole process of finding ideas and executing projects.

Evaluation criteria:

- Cross-rating between student groups (30% of the total score): When one group of students gives a presentation, the remaining groups will evaluate and give a cross score. Take the average of the scores of the groups to evaluate this criterion.

- Teacher evaluation on CDIO model (70% of the total score):

Table 6: Evaluation criteria on C-D-I-O standards (Source: Author, 2020).

No	Evaluation criteria	Assessment scale				Meet Course Outcomes
		Fail	Pass	Good	Excellent	
1	Solving Case Study: the "Living" factor in urban space.					CO2, CO3
2	Clearly design ideas, in line with the topic goals.					CO2, CO3
3	Architectural functions, Architectural forms are appropriate.					CO1, CO2
4	Materials used, Technical solution.					CO1, CO2, CO3
5	Sustainability, Green factor.					CO2, CO3
6	Community.					CO2, CO3
7	Feasibility of the projects, Future development direction.					CO4, CO5, CO6
8	The technical drawings are shown in accordance with regulations.					CO1, CO2, CO3
9	Power Point making and presentation skills.					CO4, CO5, CO6
10	Teamwork skill.					CO4, CO5, CO6

After the presentation, students complete the test according to the lecturer's opinions and send them to TOTO company. At completion, students have completed a design competition from begin to the end, and can make products. Participating in an architectural design competition with 2nd year students is only for practice and experience. Following on from this, students will accumulate more experience for the learning process, work and take part in other competitions later. The meaning of a practical project-based learning process is in the process of students working on the projects and self-learning, developing personal skills, teamwork skills, as well as attitudes when approach new problems, find the way to solve them together. Through teamwork process, students improve themselves and make progress over time. At the end of the project, students come up with a better way to solve the problems than at the start.

Figure 3: Students discuss, work in class (Source: Author, 2019).

Figure 4: Group of students implement the project and correct as instructed by the lecturer (Source: Author, 2019).

Figure 5: Student presentation exam report (Source: Author, 2019).

7 Conclusion

Innovating teaching methods to meet businesses requirements is becoming an urgent need for universities in Vietnam. In the context of globalization, as well as the development of the science and technology revolution 4.0, industry requires engineering, and architecture graduates to have professional practice skills as well as soft skills in communication to meet work requirements. CDIO was born as a breakthrough in engineering training that has been successfully applied in many countries around the world. In Vietnam in general and HUTECH University in particular, they have understood the importance of improving the training program and the positive benefits when applying the CDIO model in higher education, especially in the technical sector.

The Faculty of Architecture and Art is an environment of practical architectural training, with the goal that graduates can meet the needs of businesses right after graduation. With a training program that emphasizes practice and creativity, student autonomy, lecturers are just a guide as well as inspiring career for students like previous colleagues. The introduction of sustainable architecture design, and green architecture competitions such as the competition: "Feeling the natural beauty in the heart of the city - Finding natural awakening design solutions" for students to approach from their first year is a positive direction to help students with skills to find ideas, practice, communicate and create products early, and to catch up with the current trend of sustainable architecture design. This method needs to be researched and integrated into specialized subjects to help develop soft skills and practical knowledge for students after graduation, contributing to closing the gap between the universities and businesses, which is the goal that CDIO set out.

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