

## Active Teaching Techniques for Engineering Students to Ensure The Learning Outcomes of Training Programs by CDIO Approach

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**Abstract**—Recent research results show that students' ability to absorb and apply lessons increases when they are actively learning. In the innovative teaching method, learners - objects of teaching activities as well as subjects of learning activities - are attracted to active learning activities organized and instructed by teachers. By this way, learners are self-reliant to discover what they do not know, not passively absorb the knowledge arranged by the teacher. Placed in situations of real life, learners' experience, directly observe, discuss, experiment, and solve problems posed by their thinking, both working in groups, thereby gaining new knowledge, new skills, promoting creative potential. Depending on the objectives of the specific subject, which level of knowledge or skill needs to be achieved according to the CDIO approach, the lecturer will organize appropriate activities to help students actively learn to achieve the goals. The paper explores and evaluates innovative teaching methods to help students actively learn and experience to achieve the subject's goals and training program following the CDIO approach, as well as meet the requirements of society.

**Keywords**— CDIO approach; active teaching methods; engineering students; active learning; experiential learning.

### I. INTRODUCTION

Vietnam is in a transition to a knowledge economy, the role of universities contributing to economic growth has become more critical than ever, especially university training in maritime engineering [1]. One of the critical challenges faced by universities is how to train students to meet the growing needs of society to master new technologies and materials [2]. One of the approaches to improving quality and standardizing the engineering and technology training program is the CDIO (Conceive - Design - Implement - Operate) program [3]. In particular, the application and implementation of CDIO approach in engineering and technology programs at universities require continuous changes and interactions in 3 elements: Intended learning outcomes, teaching and learning activities and assessment (Fig. 1)[4]. Thus, we need to care about improving teaching methods because of three reasons:

First, learning outcomes change, teaching and learning activities must also change accordingly. After building the learning outcomes for the training program as well as for each specific subject, the next question for the instructor is: "How can we help our students achieve those goals?" [5]. This means that we need to pay attention to the methods of teaching and learning for students throughout the training program as well as for each specific subject in a highly

effective way to be able to meet the expected learning outcomes [6].

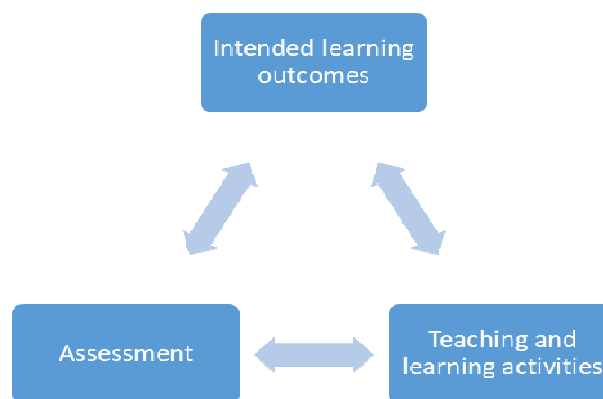


Fig.1. A relationship between learning outcomes, teaching and learning, and assessment [4]

Second, one of the characteristics of engineering-technical training programs by approach CDIO is an integrated curriculum (Fig.2) [7]. This means that the training program must have specialized knowledge courses that support each other, have definite plans for integrating personal skills and communication interactions, as well as product creation skills, processes, and systems [8]. Thus, to be able to organize integrated training, teachers and students

themselves should be equipped with integrated learning and teaching methods to be able to adapt and achieve the target of this new program.

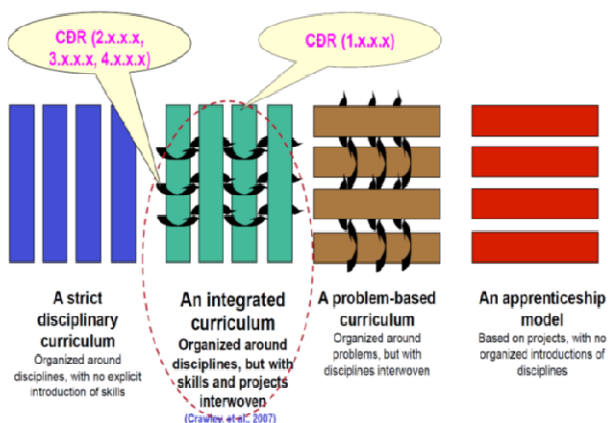


Fig. 2. The objectives of the integrated training program [7]

Third, for skill-oriented learning outcomes, teachers also need to have specific teaching plans and methods. For example, asking students to work in groups does not mean that they will learn effective teamwork skills. Issues such as how to form a group, how to plan and divide the work in the group, and how to resolve conflicts in the group, need to be taught clearly [9]. Effective learning occurs only when teaching activities provide specific opportunities for students to practice, reflecting on their experiences, and applying the concept of theory. This is a considerable challenge for the majority of Vietnamese lecturers when there is currently no adequate and consistent training on new teaching methods.

Advanced teaching methods are considered methods to arouse, promote the activeness, creativity, and positiveness of teachers and learners. It takes learners as a center by promoting the role of orientation, an organization of teachers, the role of execution and construction of learners; combine with the power of modern technical means to conquer the truth in all three aspects: knowledge, skills, attitudes. The teaching method is called positive if the following 5 elements are converged: (a) clearly showing the role of information resources and available resources, (b) clearly showing the motivation of the person learning at the beginning of the course, (c) clearly showing the nature and level of knowledge to be mobilized, (d) clearly showing the role of learners, teachers, the role of interactions in the course and (e) demonstrate the expected results of the learner. In this view, learning is not about watching football; students do not learn much by sitting in the classroom listening to the teacher, remembering the lesson, the exercises have been built in advance, opened the answer, the answer. Learning is about students must talk about what they are learning, write it down, relate to past experiences, apply it to everyday life, and turn what they learn into a part of themselves [10].

There are many active teaching methods. In this paper, we only briefly introduce a few active teaching methods that are being used commonly in advanced universities around the world, aiming to contribute less effort to improving the method — teaching students of engineering majors at Vietnam Maritime University.

## II. MATERIALS AND METHODS

The active teaching method is a short term, used in many countries to refer to the methods of education and teaching towards promoting the activeness, initiative, and creativity of learners [11]. "Active" in active teaching methods is used in the sense of being active, positive, antagonistic with passive and passive. Teaching methods are proactively aimed at activating and activating learners' cognitive activities, meaning focusing on promoting learners' autonomy rather than focusing on promoting the activeness of the learners. Teachers, however, to teach proactively, teachers must make more efforts than teaching passively.

The design of the course syllabus should also demonstrate this. We should not conceive that the course syllabus is a list of knowledge content that needs to be learned but should be understood as a plan of activities to help learners achieve goals [12]. Therefore, teaching and learning methods should be demonstrated in the syllabus. Trainers must create learning opportunities, through diverse activities, to stimulate students to explore, apply, analyze, and evaluate ideas rather than conveying one-way information. Students will have the opportunity to ask questions, raise issues to revolve around concepts or ideas, and then solve problems. Learners will always be aware of their learning process, what they are learning, and how to learn. This is also an advanced way for people to learn how to build learning motivation and form lifelong learning habits [13].

Studies show that students almost achieve the desired results and they feel satisfied with the education they receive when they are actively learning, actively involved with a variety of activities. Active Learning Study helps students gain a deep approach to learning. The deep approach means that students intentionally learn about concepts, rather than merely re-expressing information in exams.

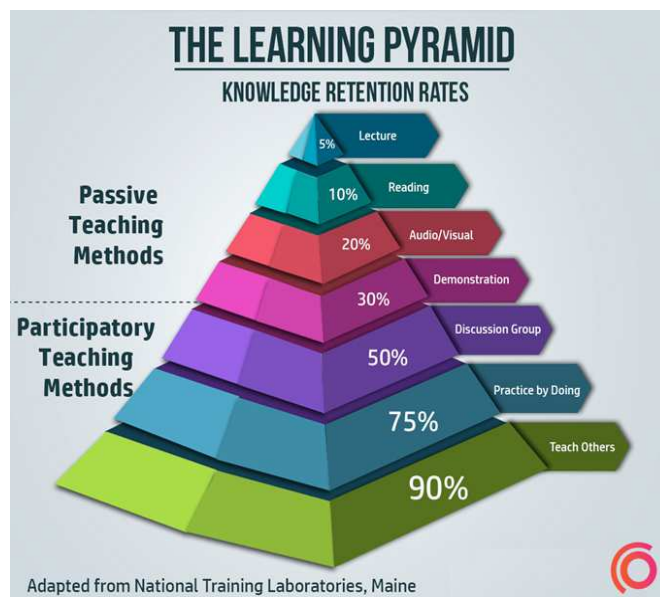


Fig. 3. Learning Pyramid represents the percentage of students' ability to acquire knowledge corresponding to learning activities [14]

Some studies of Biggs show that there is a close relationship between learner activities and learning effectiveness. The rate of knowledge acquisition of learners

increases highly when being able to apply multi-senses to learning activities, used in practice and especially if taught again (imparted) to others. Active teaching is the organization of diverse and rich learning activities that increase the ability to acquire knowledge (Fig.3) [14].

### III. RESULTS AND DISCUSSIONS

#### A. Valuation of Characteristics of Active Teaching Methods

1) *The learner is the center:* In active teaching methods, learners - the object of "teaching" activities, are also subjects of "learning" activities - are attracted to learning activities organized and directed by teachers, through which self-determination to discover what we do not know, not passively absorbing the knowledge arranged by the teacher. Placed in situations of real life, learners directly observe, discuss, do experiments, solve problems posed by their thinking, thereby grasping new and medium skills knowledge [10]. Understand the method of "making" that knowledge, skills, not follows the existing patterns, reveal, and promote creative potential. Teaching in this way teaches not only simple communication but also action guidance.

2) *Focus on training self-study methods:* The active teaching method considers the training of learning methods for students not only as a measure to improve teaching effectiveness but also a teaching goal. In a rapidly changing modern society - with a boom in information, science, and technology - teachers cannot collect enough information themselves and cannot cram in their students' minds are more and more knowledge. For example, when teaching students about the effects of lubrication degradation in the engine, students should not be required to learn all the issues related to combustion, engine emissions and deposits formation [15]. The teacher's role is no longer "information communicator." On the contrary, care must be taken to teach students the method of self-study from the first subjects of the program. Saying so does not mean that the teacher's role is no longer important, but now the teacher will be the guide for learners to find knowledge. In learning methods, the core is the self-study method [3]. If training for learners who have self-learning methods, skills, habits, will create a desire for them to learn, stimulate internal forces inherent in each human being, the learning results will be multiplied.

3) *Coordination between individual learning with cooperative learning:* In a class where the knowledge and thinking level of students cannot be evenly equal when applying proactive methods [8], it is necessary to accept the differentiation of the intensity and progress of learning tasks, especially is when the lesson is designed into an independent work sequence. Applying the more active method at a higher level, the greater this division. However, in learning, not all knowledge, skills, and attitudes are formed by individual independent activities. The classroom is a communication environment for lecturers - students, students - students, creating cooperative relationships among individuals on the way to gain knowledge. Through discussion, debate in the collective, each's opinions are expressed, affirmed or rejected, through which the learners raise themselves to a new level. For example, in a certain class, the lecturer raises the issue of using biofuels effectively in diesel engines [16],

asking student groups to discuss and propose ideas. This is consistent with the real environment of the future when students graduate and work, forcing people to lifelong learning, combining personal learning and collaborative learning [17].

4) *The role of lecturers in active teaching: the instructor, the organization operates:* As mentioned above, active teaching, teachers are no longer merely the role of knowledge communicators but become instructors for students on the path to finding knowledge. More specifically, the teacher also plays a role of designing, organizing, guiding independent or small group activities for self-help students to dominate the learning content, proactively achieving the knowledge objectives, skills, and attitudes required by the program. In class, active students are the main; the instructor is just a guide [18]. However, before going to class, lecturers have to invest much time to design the lesson to achieve the learning outcome under CDIO; select teaching methods and assessment methods appropriate to the objectives and content of the lecture. In the teaching process, outside of class time, teachers also have to monitor students' self-study activities, help when needed, discuss discussions and make suggestions to learners on the right track. For example, for students to actively learn in the lesson about the impact of biofuel fuel being heated to motivation [19], teachers need to prepare references for students to learn. Thus, teachers in active teaching and learning need to invest a lot of time and effort compared to passive teaching and learning to be able to carry out a lesson in the role of evangelist and catalyst, encouraging, advising, referees in exciting research activities, a lively debate of students.

5) *Combine teacher evaluation with student self-assessment:* Previously, lecturers kept monopolizing students' assessment, but in the proactive method, lecturers had to guide students to develop self-assessment skills to adjust their learning. About this, teachers need to create favorable conditions for students to participate in assessing each other [13]. Proper self-assessment and timely adjustment of activities are essential for the success in life that the school must equip for students. One point to pay attention to in the evaluation is formative assessment; avoid focusing on the assessment at the end of the semester and a variety of assessment activities so that learners have the opportunity to demonstrate progress. Your set during the learning process.

#### B. Teaching Methods Help Active Learning

1) *Brainstorming method:* The method of brainstorming is defined as a way to apply each person's experience and initiative in the minimum amount of time required to maximize the best data [12]. Brainstorming is a method that helps students in a short time to develop many ideas and assumptions about a particular issue, including many creative ideas. Implementing this method, lecturers need to provide a system of information as a premise for the discussion. This method can meet the learning outcomes according to CDIO syllabi such as Creative thinking, Solution, and proposal.

2) *Think-Pair-Share method*: This method is done by having students read the same material or think about a topic, then the students sitting next to each other can talk about each other's ideas and experiences for a particular time (a few minutes), then share with the whole class. This method has the advantage of being very easy to implement all class structures; anyone can participate in sharing their ideas, creating confidence for learners who dare to speak their thoughts (this is a weakness for most Vietnamese students), helping students focus on the topic they are learning, knowing what they are learning and how they understand the problem, even raising new issues. For example, when teaching lessons about methods of utilizing engine exhaust heat [20], teachers should let students use this method to motivate students to make personal comments. This method can help achieve the learning outcome according to CDIO syllabus such as Communication structure; Critical thinking [21].

3) *Problem-Based Learning method*: The goal of problem-based learning (defined as in-depth research on a learning topic) is to learn more about a topic rather than just finding the right answers to the sentences. Ask the teacher for advice. In the problem-based learning method, students have gained new knowledge, grasped the method of acquiring that knowledge developed active, creative thinking, and prepared a capacity to adapt to life. Social, timely detection and reasonable resolution of problems arise [22]. This method can help achieve the learning outcome according to CDIO syllabus such as Identity and formulate problems; proposing solutions; Exchange, judge, balance in a solution.

4) *Group-Based Learning method*: Classes are divided into small groups of 5 to 7 people. Depending on the purpose and requirements of the learning problem, the groups are randomly or intentionally divided, maintained, or changed in each part of the course, assigned to the same task or other tasks. When working in groups, members must work according to the rules set by the teacher or by the group themselves. The members must work proactively, not relying on a few more knowledgeable and active people [23]. Team members help each other learn about the problem raised in the atmosphere of competing with other groups. When a group makes a presentation, the remaining groups have to ask critical questions or ask questions to clarify the problem. Group working method helps team members share their concerns, experiences, and build new awareness together. By saying what you are thinking, each person can identify his or her level of understanding of the topic and see what he or she needs to learn [24]. The lesson becomes a process of mutual learning, not a passive reception from teachers. This method can help achieve the learning outcome under CDIO syllabus such as Teamwork skills, communication skills.

### C. Teaching methods help experiential learning

Experiential learning is defined as the learning process of students who undergo practical, highly practical, and highly applicable simulation jobs, such as design projects - deployment, case studies. From which students draw into experiences for themselves, further clarifying theories

learned [25]. According to Cheng [26], learning processes can be divided into four basic groups, in accordance with four different learning styles: (1) Reflective observation: learning through observation activities performed by others or contemplating themselves, pondering and drawing experiences; (2) Abstract conceptualization: learning through building concepts, synthesizing, interpreting and analyzing what is observed; (3) Active experimentation: learning through specific activities, behaviors, actions; (4) Concrete experience: learning through experiments, proposing solutions to solving problems and making decisions. In practice from the learning process, each learner will use the process in different ways, at the level of uneven depending on the characteristics of psychological, level, the power of perception and social experience. Usually, in the traditional way of teaching, teachers often start lectures from concepts or abstract generalization before for students to practice and do the actual operation. However, for an active teaching approach, the experience is considered the first activity in the learning process. The learning model through CDIO experience is illustrated in Fig.4.

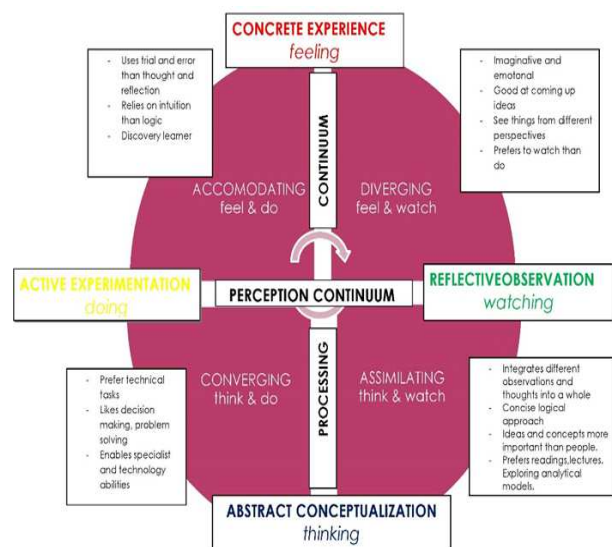


Fig. 4. Model of experiential learning [27]

1) *Project-Based Learning method*: The project-based learning method is to organize teaching and to learn through practical projects or projects. The project here is understood as complex tasks from questions or problems that stimulate learners to learn and explore. That solution may include design-deployment experiences. From here, learners will participate in designing, making decisions or surveying activities related to the project with this method of learning, learners would have to work in groups and explore the problems associated with life, then present them to the class and share what they have done in their projects. During the presentation, audio-visual media, a play, a handwritten report, a website, or a product can be used. For example, student groups are assigned to complete the project on assessing the impacts of the oil spill on Vietnam's marine environment [28]. The project-based learning focuses on interdisciplinary and interdisciplinary learning activities and is often associated with problems arising from current life. In

addition, project-based learning also creates opportunities to help learners pursue their interests, and make decisions about their answers or find solutions to problems. This method can help achieve the learning outcome according to CDIO syllabus as Making assumptions; Design - deployment skills; Writing communication skills; Presentation skills [29].

2) *Case studies method*: Although case studies have been used extensively in law, commerce, and medicine education, they are equally relevant to the technology and technology sectors. The key component of this new training method is based on real situations of both students and faculty. The primary purpose of situations is to describe, exchange experiences about how to solve problems and conflicts while performing assigned tasks. By different situations that need to be addressed in a fixed time with limited resources, learners are put in a position to make a decision or call for support from members of the same group to find directions [30]. Reasonable resolution. The diversity of situations is brought up not only to encourage learners to take the initiative and creativeness but also to bring comfort and mental refreshment when attending class. This factor makes learners able to absorb the content of lecture lessons more efficiently and more deeply than traditional teaching methods. This method can help achieve the learning outcome under the CDIO syllabus such as proposing solutions; Qualitative estimation and analysis.

3) *Service learning method*:

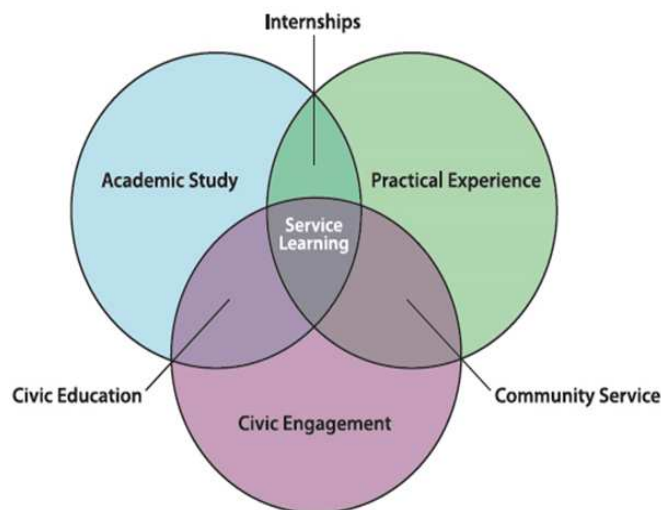


Fig.5. Community service learning in the relationship between learning and service activities [33]

Service Learning or Community-based learning dates back to the 1960s in the US [31]. Service learning (SL) is a teaching and learning method through which learners can apply the knowledge learned in the classroom to real conditions, and the results of the learning process to meet the needs of the community copper and used by the community. SL has been applied at many universities around the world, so far in the United States, more than 1,000 universities and

colleges apply this method to more than 6 million students. SL is considered a sustainable development strategy of US universities and is gradually affecting other universities in Asia. Method SL is a combination of work, cooperation by the relationship of 4 participants: school administrators, faculty, community, and student. The advantage of SL is to help the learners enrich their knowledge from the theory to the reality and vice versa (bring books to life and life to books), the process of learning through experience so that the learners have conditions strengthen academic knowledge, train and develop soft skills such as critical thinking, critical thinking, teamwork, communication, presentation and life skills (Fig. 5). For example, when exploiting diesel engines installed on buses in Haiphong, there is a mount of deposits on the injector, then the instructor had a question for students to conduct research on technical solutions to improve the quality of engine exploitation [32].

Community service learning is carried out in the following steps: (1) Community issues to be solved; (2) Teachers integrate community issues to be addressed subjects as practice topics of students [31]. It is important to note that these topics must be relevant to the content of the subject, the level, and skill of the student; (3) Students are organized into groups to implement topics under the guidance of teachers. When implementing the topic, students must apply the knowledge of the subject to solve problems with the community; (4) Results of the topic used by the community. This method can help achieve the output standard according to CDIO outline such as Role and responsibility for society; Recognize the context of social organizations; Ham learns and learns lifelong, thinking; Working group; Skills of writing communication and presentations [33].

D. *Some Problems Notice in Implementing Active Teaching Methods*

1) *A subject can be applied flexibly and diverse learning forms*: Each teaching method emphasizes a certain aspect of the learning process. We believe that no matter how effective the methods are, it still has some aspects that learners and teachers have not fully exploited. Therefore, no teaching method is considered ideal. Each method has its advantages, so teachers should build their method suitable to the objectives, the nature of the issues to be exchanged, by the class composition and resources available and final teaching-learning tools that fit your interests. An example of advanced aerodynamics subject at MIT has a combination of four methods [34]: Conceptual questions with the help of electronic answering systems, Readings and problems pre-class sessions, Project-based learning, Oral exams at the end of the course [35].

It is useful for teachers to apply flexible and diversified forms of teaching; we present a summary of the active teaching methods outlined above corresponding to the benefits to learners in Table I.

TABLE I  
SUMMARY OF ACTIVE TEACHING METHODS

| No.                          | Method                 | Brief description  | Benefits for learners             |
|------------------------------|------------------------|--|-----------------------------------|
| <b>Active Learning</b>       |                        |  |                                   |
| 1.                           | Brainstorming          | - Teachers raise issues to be solved and regulated the time and how to work;   | - Creative thinking;              |
| 2.                           | Think – pair –share    | - Students work individually, quickly list ideas.                              | - Solutions and suggestions       |
| 3.                           | Group-based learning   | - Teachers raise issues to discuss, regulate the time and ways to share;       | - Communication structure;        |
| 4.                           | Problem-based learning | - Students work in pairs, listen and present ideas, protect and disapprove.    | - Thinking and critical thinking. |
| <b>Experiential learning</b> |                        |  |                                   |
| 5.                           | Project-based learning | - The teacher prepares the content of course projects;                         | - Assume a hypothesis;            |
| 6.                           | Case study             | - Students are assigned to implement projects on an individual or group basis. | - Design - deployment skills;     |
| 7.                           | Service learning       | - Teachers build "case" related to teaching content;                           | - Writing communication skills;   |
| 8.                           | Project-based learning | - Students are assigned to answer "case" on an individual or group basis.      | - Presentation skills.            |

In the course of implementing CDIO teaching, the problem for teachers is how to choose appropriate teaching methods corresponding to CDIO output standards. To solve this problem, teachers need to compare the specific requirements of each standard output item (level 4) according to the CDIO syllabus and the benefits brought

about in each teaching method [36]. The fact that teachers can apply a teaching method to achieve more than one CDIO output standard item and a standard output item can also be taught by various methods. We present some examples of active teaching methods corresponding to each learning outcome item under the CDIO syllabus (Table II).

TABLE II  
INTRODUCING SOME EXAMPLES TO ILLUSTRATE TEACHING METHODS AND LEARNING CORRESPONDING TO THE LEARNING OUTCOMES UNDER CDIO SYLLABUS

| From the results of active and experiential learning, learners can achieve the ability               | Related to CDIO syllabus                          | Teaching and learning methods may apply |
|--|---|---|
| Explain at a level understandable by a non-technical person, how it works ....                       | 1.3 Advanced technical background knowledge       | Think - Pair - Share                    |
| Compare experimental data with available models  | 2.2.3 Research experiments                        | Problem based learning                  |
| Create solutions for problems with creativity and effective decision-making skills                   | 2.4.3 Creative thinking                           | Brainstorm, Case study                  |
| Analyzing the advantages and disadvantages of the group  | 3.1.1 Establish an effective working group        | Group based learning                    |
| Use appropriate non-verbal communication, such as gestures, eyes, postures when making presentations | 3.2.6 Presentation and communication              | Service Learning                        |
| Accepting the responsibilities of engineers to society   | 4.1.1 The role and responsibility of the engineer | Service Learning                        |
| Evaluate the operation system for the product of the group and propose improvements                  | 4.6.4 Improving systems and processes             | Case studies, Project based learning    |
| Identify the needs and opportunities of the market in the field ...                                  | 4.3.1 Set goals and requirements of the system    | Project based learning                  |
| Select the requirements for each component or part drawn from the system goals and levels            | 4.4.1 Design process                              | Project based learning                  |

2) *Applying teaching methods takes into account the conditions for organizing classes:* Active teaching methods are effective for small classes, about 30 - 40 students. When

implementing these methods in larger classes, help from tutors or electronic technical devices is needed. For example, when you need to quickly check the ability to understand and grasp the concepts of students in the classroom with

about 100 students, the lecturer cannot ask the whole class questions. For example, in the lesson on alternative fuels, teachers should not ask general questions such as "How many alternative fuels and fuel additives are being used today?" [37]. American universities are often equipped with Personal Answer Systems (Personal Response System - PRS) or Clicker for large classes. Also, for engineering majors, when applying teaching methods to help students learn through experiences, such as simulation or case studies, the class should be equipped with some machines and equipment qualify for students to manipulate or learn design-related skills [38], [39]. For organizational activities outside the classroom such as project-based learning or community service learning, finding suitable business or internship partnerships has an important meaning to contribute to the results of student learning [40].

#### IV. CONCLUSIONS

According to the CDIO approach, students will learn personal skills, communication, skills to create products, processes, and systems along with specialized knowledge in the context of professional technical practice; it is integrated learning, (CDIO 7 standard). Integrated learning has the advantage of allowing students to use both times to learn knowledge and learn skills. However, to be able to use the dual use of study time, it is important to acquire new teaching and learning methods, how to make the most of time but not aggravate the program. The new theory is already dense in content. Teaching and learning based on active learning methods and experiential learning (CDIO standard 8) is a solution to the above problem. The role of teachers is to create learning opportunities, through diverse activities, stimulating students to explore, apply, analyze, and evaluate ideas rather than conveying one-way information. Many innovative teaching methods help students learn proactively and experience; each method has its advantages and disadvantages. Depending on the specific goals and conditions, teachers will flexibly coordinate methods in their teaching process. It can be said that the improved teaching methods help the training program achieve the output standards according to the CDIO approach, and at the same time achieve two standards 7 and 8 of CDIO. It means that after building the subject's learning outcomes, what is taught to teachers is no longer important but how to teach. Therefore, the faculty should be trained and equipped with the necessary skills and teaching methods before starting the student training process.

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