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CDIO-based teaching at universities: A case study for students majoring in electrical and electronic engineering technology, Vietnam

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Abstract

In the 1980s of the twentieth century, universities in developed countries began to realize the growing gap between the capabilities of new graduate engineers and the actual requirements of engineering branches. The strong progress of technology requires engineers to have the intellectual abilities and necessary job-specific skills to master that progress. This paper focuses on Conceive, Design, Implement and Operate (CDIO) approach-based teaching for students majoring in electrical and electronic engineering technology at engineering universities in Vietnam to demonstrate the feasibility of the teaching model. The experimental method of synthesizing qualitative and quantitative results for 90 students in control and experimental classes was used. The experimental and control classes both had 45 students. SPSS software version 22 was used to gather data and evaluate the learning results of the two experimental and control groups. According to the findings of the T-test analysis of the independent variables for the two groups, the experimental class performed better in academics and had students in the experimental group who were more satisfied with their post-test scores. This result contributes to confirm that the use of the CDIO-based teaching model in Vietnam is effective for students majoring in electrical and electronic engineering technology.

Keywords: Approach the teaching model, CDIO, Electrical and electronic engineering, Impact, Learning outcome standard, Professional skill.

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Contents

Contribution of this paper to the literature
This study addresses the CDIO approach-based teaching practice for students majoring in electrical and electronic engineering technology. The outcome demonstrates that introducing CDIO-based instruction is a step that improves students.

1. Introduction

Conceive, Design, Implement and Operate (CDIO) was established in 2010 as a direct response to the information industry providing universities with the attributes and competencies they needed from graduates. In recent years, the industry in Vietnam has begun to notice that engineering graduates have technical proficiency but lack many skills and abilities needed to perform in real-life situations (Alejandra, David, Maria, Mariela, & Luis, 2018). It has been discovered that traditional educational institutions often fail to achieve the goals that the education sector and many teachers have set. According to several studies on the CDIO model, the abilities that graduates of engineering programmes possess and the skills that the engineering business requires differ significantly (Kermanshachi & Safapour, 2017; Sampada & Rajesh, 2019). Those findings have contributed to creating a balance between practical skills and theory (Wang et al., 2014).

In addition to specialized knowledge in "hands-on training" programmes, many studies (Dizaho, Salleh, & Abdullah, 2017; Fontinha, Easton, & Van Laar, 2019; Sampada & Rajesh, 2019) believed that traditional teaching methods frequently neglected personal skills, product creation skills and system process building. These studies led to the proposal of CDIO with 12 relevant standards. Therefore, CDIO provides not only learning outcome standards but also a clear guide in a closed cycle with 12 standards including standard 8 to help students with "Integrated learning and active experience". According to the CDIO model, integrated learning experiences offer the development of professional knowledge, interpersonal and communication skills as well as abilities for developing products and systems. This learning method directly engages students in activities that develop creative thinking and problem solving (Backlund & Garvare, 2019). Therefore, CDIO is currently considered a new initiative for education, a system of methods and forms of accumulating knowledge and skills to improve the quality of higher education to meet the requirements of businesses and society especially in the environment of training engineering students (Gulikers, Kester, Kirschner, & Bastiaens, 2008; Smigiel, Macleod, & Stephenson, 2015; Wrenn & Wrenn, 2009).

Teaching using the CDIO approach requires taking into consideration the needs of the students allowing them to participate and experience and assessing the students' knowledge and abilities in order to assign learning projects (Cao & Guan, 2013; Mills & Treagust, 2003). Engineering students tend to learn from reality rather than generalization. During the COVID-19 pandemic, many students did not go to university but instead stayed at home and worked on projects set by their teachers. However, students were equipped with practical experience from building cars making radios or designing electrical circuits before implementing the projects (Nanjing Institute of Technology, 2021; Wright, 1997). University students frequently lack skills and have limited personal experience with practical concerns. CDIO based-teaching is an effective solution to help students with four areas: enhancing positive learning and practice, forming ideas and solutions to problems and innovation, increasing emphasis on conceptual learning and enhancing feedback mechanisms in learning.

An environment for learning can be created where students can work on a particular project at a company, institution or workplace or they can participate in routine activities there in addition to the special focus and learning structure. It may be most appropriate to think about designing a work experience on a continuum that reflects the different levels of student involvement in a combination of project execution and work engagement (Chandrasekaran, Stojcevski, Littlefair, & Joordens, 2012; Dahms & Stentoft, 2008). Integrative active learning is a solution for students to learn and experience from integrating experiences in the educational environment (Billett, 2009).

2. Literature Review

Universities in developed countries began identifying the growing difference between the skills of recently graduating engineers and the practical needs of engineering fields in the 1980s of the 20th century. Engineers must have the specialized professional skills and intellectual capacity necessary to understand rapidly advancing technology. Developing training programmes in a more suitable manner that emphasises the engineering foundation in the context of Conceiving, Designing, Implementing, Operating (CDIO) actual systems and products is necessary to increase students' abilities in skills, knowledge and characteristics (Gareth & Klara, 2022). Engineering graduates must meet certain requirements for CDIO-based training programmes including personal competence, interpersonal communication ability, group work ability and engineering organizing competence. CDIO takes the life cycle of the product and operates the product as a carrier to achieve the training objectives. It allows students to combine theory with practice in their research to not only learn fundamental knowledge and skills but also cultivate and renew the spirit of group work by undertaking a complete engineering project (Li, He, Zhang, Tong, & Zhang, 2011).

Common skills are defined as "skills that are attainable, worthwhile and necessary for all university students regardless of their fields of study. They are the foundation for education and provide the basis for lifelong learning" (Gulikers et al., 2008). The high demand for a wide range of skills among graduates also places great emphasis on educational programs and individual teachers in providing students with the ability to learn a wide range of skills and gather appropriate skills during their training. In response to this and to train future engineers, the CDIO model (Crawley, Malmqvist, Ostlund, Brodeur, & Edstrom, 2007) provides a broad base for common skills that both current and future engineers can expect with proper design and implementation.

The requirements of employers for graduates of engineering branches are proficiency in skills, the ability to manage projects and the ability to communicate in a foreign language (i.e. English) (Chandrasekaran et al., 2012). Lecturers concentrate on teaching throughout the teaching process and creating learning projects for students. These projects have a significant influence on students' abilities and may also inspire students to participate in their own learning process (Dahms & Stentoft, 2008). Furthermore, integrating professional skills into advanced electricity practice courses can increase students' motivation and provide them with expertise in a more real-world context (Gulikers et al., 2008; Van Tran, Thanh Le, Chi Phan, Phuoc Hoang, & Minh Phan, 2022). This makes the relevance of the project outcomes important. Previous research has shown that having real-life projects deeply integrated into education and using interdisciplinary skills to solve electricity practice problems both increase students' motivation and help them focus better on expertise and value-based problem solving (Wang, Zhan, & Lei, 2018).

After 2015, several studies on CDIO proposed and improved the curriculum (Thomas & Jimmy, 2018; Thomas Mejtoft, 2015), applying CDIO into training for students at engineering universities such as integrating CDIO skills into project-based learning in higher education (Hoang, Chu, & Van Tran, 2017; Marika, Sanna, & Janne, 2017), experience in developing CDIO skills for students using construction design projects (Therenlkham, Nyamsuren, Uuganbayar, & Khishigjargal, 2018), research on using project-based learning in "reform of teaching electronic technology based on CDIO approach" (Juan, 2018; Thomas Mejtoft, 2015) did the research on "project-based teaching towards the CDIO approach for engineering students through digital".

In teaching with engineering students, project-based learning is a common and appropriate implementation for integrating the skills required for a professional engineer both in disciplinary knowledge and in general skills (De Graaf & Kolmos, 2003; Mills & Treagust, 2003). Focusing on teaching and learning on projects can also increase students' motivation in relation to their own learning process. Furthermore, integrating common skills into courses can increase student motivation and provide students with specialized knowledge in a more realistic context (Mejtoft, 2016). Integrating projects into teaching is necessary to help students integrate knowledge and skills and apply them to solve practical problems related to the major they are studying. Mejtoft (2015) studied the "Lessons from Student Satisfaction Survey after CDIO Project Courses" with the result that students gained the expected skills in research.

CDIO allows students not only to work through projects inside the classroom but also to gain experiential learning outside the classroom (Al-Huneidi & Schreurs, 2011; Hendry, Frommer, & Walker, 1999; Meredith & Burkle, 2008). Students are more active when they experience designing and manufacturing products on their own or in groups according to the teacher's requirements. The application of active learning principles (Candido, Murman, & McManus, 2007) to some extent include its application to real-world engineering challenges (Berggren et al., 2003). "Learning through experience" exposes students to real-life situations and requires them to imitate situations that engineers face in their daily work (Bonwell & Eison, 1991; Hall, Waitz, Brodeur, Soderholm, & Nasr, 2002). It has also become an important task for engineering teachers to create constructively linked learning activities. However, it is difficult to assess which specific learning activities are used by extracurricular activities and there remains a question of how accurately they can be measured with respect to student learning.

This case study illustrates and analyzes the CDIO approach in an advanced electricity practice course through a learning project accelerating student progress towards the ideas of CDIO. It uses the experimental research method with the experimental class consisting of 45 students and the control class consisting of 45 students in the module "Advanced electricity practice course" under the teaching model with active teaching methods through the teaching-learning process towards CDIO.

3. Research Methods

3.1. Research Design

The goal of implementing the CDIO method is to train them in such a way that they develop comprehensively in terms of knowledge, skills, attitudes and core competencies related to their profession. This idea derives from the philosophy of CDIO approach-based teaching. Therefore, CDIO approach-based teaching is a closed cycle. Each subject or module is designed with teaching and assessment methods aiming at standards such as students having an integrated learning experience (standard 7), students having a positive working space (standard 6), students learning actively based on experiential learning (standard 8), how to assess student learning in terms of personal and interpersonal skills, product, process and system building skills and professional knowledge (standard 11) and students' learning outcomes to meet the learning outcomes standards of the module or subject and finally the learning outcomes standards of the training program. The designed learning outcomes of the course are given in Table 1.

Table 1. Learning outcomes for the module "Electronic circuits".

CLOs (Course learning outcome)	LO (Learning outcome) standards	PLO (Program learning outcome)	Level of cognition
1	Applying mathematical and circuit knowledge to calculate polarization and amplification problems of BJT (Bipolar junction transistor), FET (Field effect transistor), OP-AMP (Operational amplifier).	1.1	Application
2	Applying modern tools such as computers, electronic design and simulation software to solve the polarization and amplification problems of BJT, FET, and OP-AMP, designing and simulating electronic circuits.	1.3	Application

3.2. Research Subjects

The purpose of this pedagogical experiment is to assess how teaching the CDIO method in electrical and electronic engineering technology courses affects student learning outcomes that satisfy learning outcome requirements. In this experiment, pre-and post-test measurements will be conducted to observe the change in student learning outcomes. Then, the analysis compares the results before and after the experiment between the control class and the experimental class and can point out the effects of teaching according to the CDIO approach on the learning performance and learning outcomes of students after the course.

Statistical methods with the use of SPSS software version 22 to analyze and process data are used. Specifically, SPSS software is used to analyze the Cronbach alpha reliability of the questionnaires, the Friedman test is used for the survey data and the t-test is used to analyze the pedagogical experiment data with 95% reliability. In addition, the study uses mathematical methods of testing variance to demonstrate the feasibility and reliability of experimental results.

The experiment applies active teaching methods in the teaching process towards CDIO in the module: "Advanced electricity practice " in the training program for students majoring in electrical and electronic engineering through the design of detailed course outlines according to the CDIO approach, design of lesson plans according to experiential teaching towards the CDIO approach. The experimental subject or module is "Electronic Circuits".

Phase 1 consists of the first 8 weeks of the term and then the midterm exam.

Phase 2 consists of the later 8 weeks (from weeks 9 to 16) and then the end of term exam.

3.3. Teaching Methods

A combination of experiential and project-based teaching methods was used.

The balance between core modules and electives, the methods of teaching and learning, evaluation and above all the integration of theory and practice through laboratory work and professional engineering practice are all crucial components. Therefore, for academic and practical skills curricula, the big challenge is how to design a curriculum that is innovative and ensures the integration of graduation attributes such as personal competencies, teamwork, developing life skills and emotional skills. Therefore, the teaching and learning method based on active experiential learning is one of the appropriate teaching methods for training engineering students and CDIO-based training.

Active learning methods engage students directly in thinking and problem-solving activities. There is less emphasis on the passive transmission of information and more emphasis on engaging students in applying, analyzing and evaluating ideas. Active learning in lecture-based courses can include methods such as peer and small group discussions, demonstrations, debates, conceptual questions and feedback from students about what they are learning. Active learning is considered experiential when students take on the roles of simulating professional engineering practice, for example, project design-implementation, simulations and case studies.

Students learn more when they are asked to think critically about topics especially new ones and when they are asked to answer honestly. They also become more aware of how and what they are learning. This process helps improve students' motivation to achieve learning outcomes according to the program and form lifelong learning habits. Teachers can support students in applying their knowledge in unfamiliar contexts and assist them in drawing relationships between important concepts through the use of active learning techniques.

3.4. Teaching Facilities

Teaching facilities are an indispensable condition for CDIO approach-based teaching because students need practical experience. It is necessary to have mechanical equipment, practice rooms, factories, technological equipment, electronic components and circuit boards.

Some examples of electronic components are shown in Figure 1.

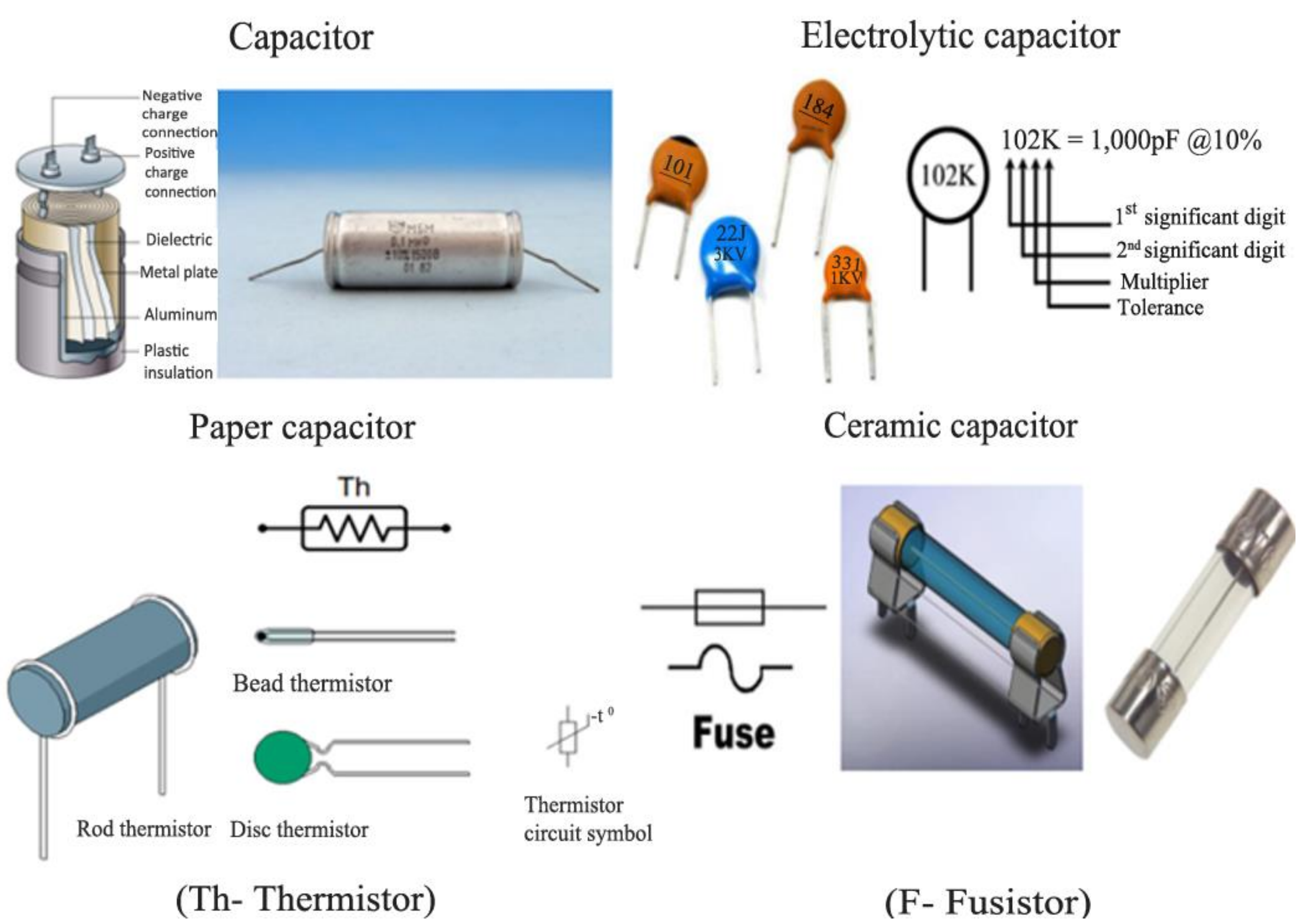

Figure 1. Some electronic components.

3.5. The Process of CDIO Approach-Based Teaching

The paper uses the design process depicted in Figure 2 to experiment with CDIO approach-based teaching.

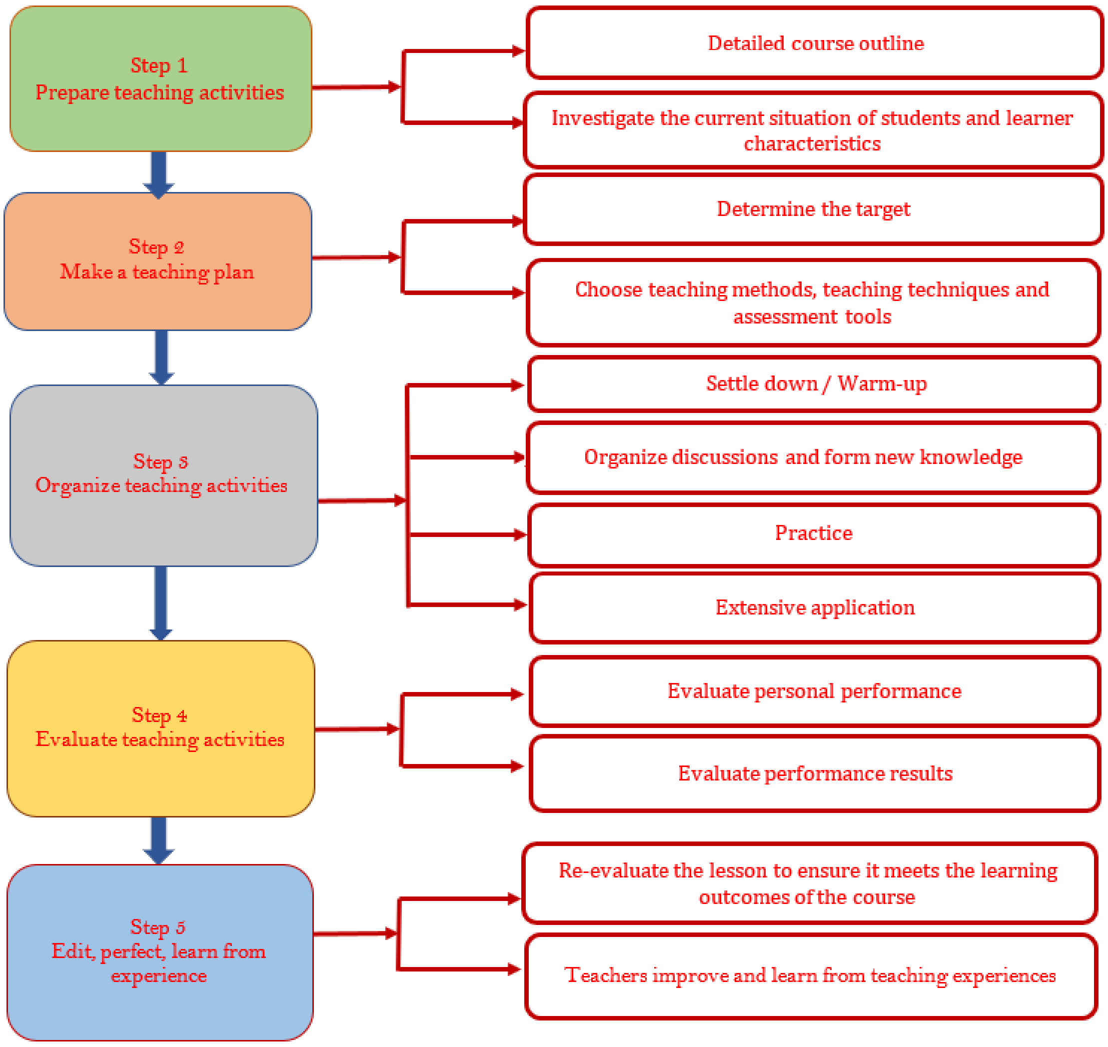

Figure 2. Process of CDIO approach-based teaching.

Table 2 presents a sample selection of control and experimental classes.

Table 2. Sample selection of control and experimental classes.

Number of students		45	45
Sex (%)	Male	90%	95.5%
	Female	10%	4.5%

4. Results and Discussion

4.1. Midterm and Final Results of the Control and Experimental Classes

The study continues to test the correlation level between the two sample pairs (control and experimental) based on the results of the pre-test (before the experiment). The results of 2 sample pairs (experimental and control) are given in Table 3.

Table 3. Relationship between two samples on mean and standard deviation.

Class		Mean	N	Std. deviation	Std. error mean
Pair	E	8.429	45	0.854	0.127
	C	7.628	45	0.944	0.140

Table 4. Results of sig. for two samples (the experimental and control classes).

Class		Paired differences					t	Df	Sig. (2-tailed)
		Mean	Std. deviation	Std. error mean	95% confidence interval of the difference				
					Lower	Upper			
Pair	E - C	0.768	0.276	0.041	0.685	0.851	18.664	44	0.000

The sig of both sample pairs in Table 4 has a value of 0.797 > 0.05 (95% reliability level) indicating that the means of the two sample pairs are identical. The experimental and control groups are at the same cognitive stage.

4.2. Analysis and Evaluation of Quantitative Results

- The evaluation of students' learning outcomes for the mid-term experiment using the teaching model towards the CDIO approach is as follows:

SPSS software is used for the statistics of the frequency of experimental and control classes which gives the results of table Fi (number of students scoring Xi), frequency table fi (%) and frequency table of backward convergence fa↓ (number of students scoring Xi or less) listed in Table 5.

Table 5. Results of midterm test scores for both experimental and control classes.

Score	Point	Value	Experimental class		Control class	
			Number	Frequency (%)	Number	Frequency (%)
F	<= 49	2.45	0	0	0	0
D	[5.0-5.4]	5.2	0	0	0	0
D+	[5.5-5.8]	5.65	0	0	0	0
C-	[5.9-6.1]	6.0	0	0	2	4.44
C	[6.2-6.4]	6.3	1	2.22	4	8.89
C+	[6.5-6.9]	6.65	1	2.22	6	13.33
B-	[7.0-7.4]	7.2	4	8.89	6	13.33
B	[7.5-7.9]	7.7	7	15.56	11	24.44
B+	[8.0-8.4]	8.2	8	17.18	7	15.56
A-	[8.5-8.9]	8.7	11	24.44	5	11.11
A	[9.0-9.4]	9.2	8	17.78	3	6.67
A+	[9.5-10]	9.75	5	11.11	1	2.22
Total			45	100%	45	100%

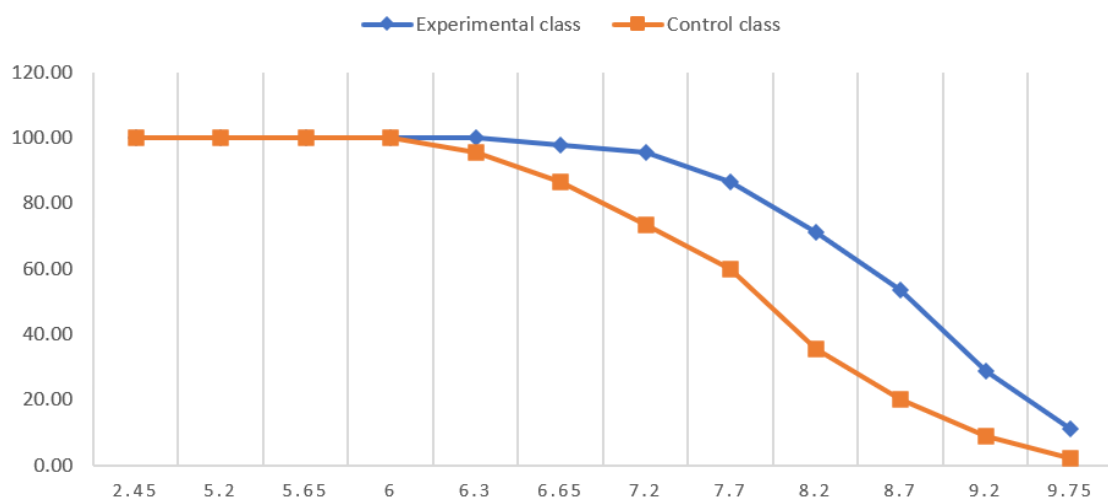

Figure 3. Convergence frequency graph between the experimental and control classes.

Figure 3 shows the convergence frequency graph between the experimental and control classes.

The statistics in Table 5 show that the percentage of B+ grades or higher (from 8.2 or higher) in the experimental class (70.51%) is higher than that of the control class (35.56%). Figure 2 displays the experimental class's convergence frequency line above and to the right of the control class. It can be seen that the average midterm score of the experimental class is higher than that of the control class.

The T-test was used to compare two separate mean values of the experimental and control classes and extract the characteristic parameters of the samples from SPSS in Table 6 to confirm that the result is statistically significant. The statistical characteristic parameters were calculated with the tool giving the following results:

First, it is necessary to determine whether there is a difference in statistical reliability between the mean values of the two samples. The F-test was performed because different calculations were made for the T-test depending on whether there was a significant difference between the variances. The F-test results are as follows:

Table 6. Statistical characteristic parameters.

Class	Mean	Standard deviation	Df	F	F critical one-tail
Experimental class	8.429	0.854	44	0.821	0.606
Control class	7.628	0.944	44		

Table 6 shows that F critical one-tail (0.606) < F (0.820) which confirms the difference in mean. Next, the variance of the test scores of the experimental and control classes is analyzed. First of all, it is necessary to consider whether the difference in the mean ($\overline{X}$) of the test scores of the samples is significant or not. The standard (t Stat) in z-Test was used to test the hypothesis H_0: "There is no difference between the learning outcomes of experimental class and control class"; H_1: "There is the difference between the learning outcomes of experimental class and control class". The results are shown in Table 7.

Table 7. Test of variance, T-test and z-test for midterm exams.

Class	Mean $\overline{X}$	Standard deviation	Df	t- stat	z-test	z critical two-tail
E	8.396	0.854	88	22.147	2.026	1.960
C	7.628	0.944				

The data in Table 7 shows that, $\overline{X}_E > \overline{X}_C$, absolute value |t Stat| = 22.147 is greater than the standard z-value (1.96). This allows us to confirm that the difference in mean scores between the experimental and control classes is statistically significant.

Quantitative analysis is conducted to assess the learning results of students when participating in the "Electronics practice module " of experimental and control classes at the end of the term. Specific results are given in Table 8.

Table 8. Results of the experimental and control classes at the end of the term.

Score	Point	Value	Experimental class		Control class	
			Number	Frequency (%)	Number	Frequency (%)
F	<= 49	2.45	0	0	0	0
D	[5.0-5.4]	5.2	0	0	0	0
D^+	[5.5-5.8]	5.65	0	0	0	0
C^-	[5.9-6.1]	6.0	0	0	1	2.22
C	[6.2-6.4]	6.3	0	0	3	6.67
C^+	[6.5-6.9]	6.65	1	2.22	6	13.33
B^-	[7.0-7.4]	7.2	3	6.67	7	15.56
B	[7.5-7.9]	7.7	5	11.11	6	13.33
B^+	[8.0-8.4]	8.2	13	28.89	10	22.22
A^-	[8.5-8.9]	8.7	10	22.22	6	13.33
A	[9.0-9.4]	9.2	8	20.00	4	8.89
A^+	[9.5-10]	9.75	5	8.89	2	4.44
Total			45	100%	45	100%

The statistics in Table 8 show that the percentage of A- grades (from 8.7 and above) in the experimental class (49%) is higher than that of the control class (26%). In Figure 4, the convergence frequency line of the experimental class is located above and to the right of the convergence frequency line of the control class. It can be seen that the mean score of the experimental class is higher than that of the control class.

Table 9 indicates the relationship between two samples based on the mean and standard deviation of the final exam.

Table 9. Relationship between two samples based on the mean and standard deviation final exam.

Class		Mean	N	Std. deviation	Std. error means
Pair	Eck	8.504	45	0.754	0.112
	Cck	7.820	45	0.981	0.146

Table 10. Paired samples test.

Class		Paired differences					T	Df	Sig. (2-tailed)
		Mean	Std. deviation	Std. error mean	95% confidence interval of the difference				
					Lower	Upper			
Pair	Eck – Cck	0.684	0.323	0.048	0.587	0.782	14.209	44	0.000

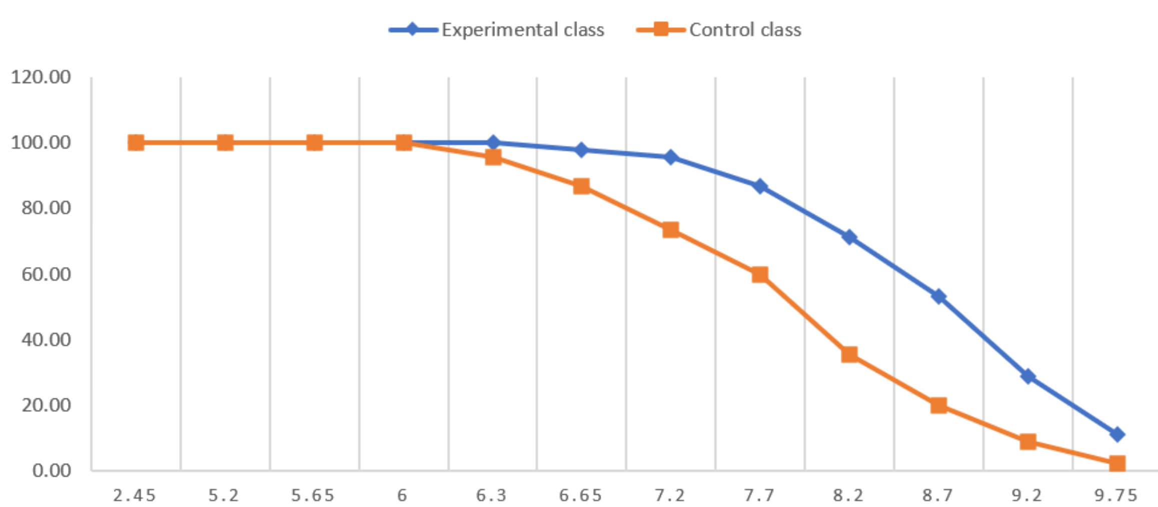

Figure 4. Convergence frequency graph of experimental-control classes at the end of the term.

Next, the variance of the experimental and control groups were tested with the hypothesis H_0: *"The difference in the variance is insignificant"*. The characteristic parameters of the samples were extracted from the SPSS software in Table 10 to confirm the statistical significance of the result.

Table 11. Test of variance, T-test and z-test at the end of the term.

Class	Mean $\overline{X}$	Standard deviation	Df	t- stat	z-test	z critical two-tail
E	8.504	0.754	88	16.553	3.786	1.960
C	7.820	0.982				

Table 11 shows that $\overline{X}_E > \overline{X}_C$, absolute value |t Stat| = 16.553 is greater than the standard z value (1,960), rejecting H_0. This confirms that the difference in the mean scores of the experimental class and the control class in the end-of-term exam is statistically significant. In the midterm and final exams for the experimental and control classes mathematical statistics were used to explain the experimental results in order to ensure mathematical reliability.

The t-student test was used to review and check the effectiveness of the experiment. $t = \sqrt{\frac{\overline{X_E}}{S_E}} = 3.95$. Looking up the t-student table with N=45 and α =0.05, we got t_α=1.67. Thus, $t = 3.95 > t_\alpha = 1.67$. This proves that the pedagogical experiment has been obviously effective.

Next, we tested the variance of the experimental and control classes with the hypothesis H_0: *"The difference in the variances between the experimental and control classes is not significant"*. We had the results of the test quantity as follows: $\boldsymbol{F} = \frac{S_E^2}{S_C^2} = 0.3$

F_α in the F table with α =0.05 and $f_{Experimental(E)} = 45$, $f_{Control(C)} = 45$ was 1,69; $F < F_\alpha$: Accepting H_0, the difference in the variances between the experimental class and the control class is not significant.

To compare the test results, we tested the hypothesis H_0: *"The difference in the mean scores between two samples is not significant with the same variance"*. For α =0.05, in t –student table with $N_E + N_C - 2 = 45 + 45 - 2 = 88$, we got t_α = 1,66. The test value is calculated by the following formula (Van Hung, Yellishetty, Thanh, & Patil, 2017):

$$\boldsymbol{t} = \frac{\overline{X_E} - \overline{X_C}}{s.\sqrt{\frac{1}{N_E} + \frac{1}{N_C}}} \text{ with } \boldsymbol{s} = \sqrt{\frac{(N_E - 1)S_E^2 + (N_C - 1)S_C^2}{N_E + N_C - 2}}$$

$t = 4.07 > t_\alpha = 1.66$. This confirms that hypothesis H0 is rejected proving that the difference in the mean scores between two samples is significant. The test results show that the learning quality of the experimental class is higher than that of the control class.

The above analysis has shown that the knowledge as well as the learning quality of the experimental class are higher than those of the control class. This proves that the teaching model has brought effective learning to students. Different testing methods have shown that the difference in adjusted mean test scores over the course of the experimental class is significant. Therefore, H_0 means *"There is no significant difference in the adjusted mean scores between the experimental and control classes"*. This shows that the students who were taught according to the CDIO approach with active teaching methods in the study benefited from the experiment. The results of this study are proved by the findings of Sampada and Rajesh (2019) who found that the teaching model for CDIO is to help students experience, be creative and improve their learning outcomes. Table 12 indicates the effect size.

Table 12. Table of effect size.

Name	The experimental class at the end of the term	The control class at the end of the term
The mean value	8.504	7.820
Standard deviation	0.754	0.982
ES	0.697	

Where $ES = \frac{Mean_{Post} - Mean_{Pre}}{Standard\ Deviation_{Pre}} = \frac{\overline{X_E} - \overline{X_C}}{S_C}$ is the difference in the mean of the experimental and control group divided by the standard deviation of the control group. ES was assessed according to Cohen (1998).

Table 13. Cohen's table.

ES	Effect
>1.0	Very high
0.8-1.0	High
0.5-0.79	Medium
0.2-0.49	Low
<0.2	Very low

The effect size (ES) level in the experiment was 0.697 indicating the experiment was effective. The research results show that the application of the CDIO approach to the teaching model has a clear effect on the experimental class. It can be confirmed that the teaching methods, teaching process and teaching techniques according to the CDIO approach for students majoring in electrical and electronic engineering we proposed are feasible.

The quantitative analysis of the mid-term and final term results of the experiment with ES = 0.697 (from 0.5 to 0.79) confirmed that the experiment had a medium effect.

With a reliability level of 95%, the difference in results between the experimental and control classes clearly shows "teaching electrical-electronic engineering" towards the CDIO approach brings good results in the course "advanced electrical practice" with active and experiential activities to help students be creative.

4.3. Student Feedback on the Level of Satisfaction after the Course

Mathematical statistics was used to explain the experimental results in the midterm and final exams for the experimental and control courses to demonstrate mathematical dependability. Descriptive statistics with a 5-point Likert scale was used to survey the level of student satisfaction after the experiment. Next, data was collected and SPSS software was used to process it for evaluation of the reliability of the items. We conducted a survey on the satisfaction of 47 students participating in the experiment. (Max-Min)/n was used to calculate the gaps between the levels (5-1)/5 = 0.8. Therefore, the level can be distributed as follows:

Table 14. The satisfaction scale.

Level	Mean $\bar{x}$	Satisfaction
1	$1.00 \le \bar{x} \le 1.80$	Totally unsatisfied
2	$1.81 \le \bar{x} \le 2.60$	Unsatisfied
3	$2.61 \le \bar{x} \le 3.40$	Partly satisfied
4	$3.41 \le \bar{x} \le 4.20$	Satisfied
5	$4.21 \le \bar{x} \le 5.00$	Totally satisfied

Table 15. Student satisfaction after the course.

No	Student satisfaction after the course	Level					Mean	Rank
		①	②	③	④	⑤		
1	This course has improved my practical skills.	3	4	12	15	11	3.89	4
2	This course has improved my group work skills.	1	4	19	14	7	3.49	9
3	The project descriptions given by the lecturer make it easy for me to understand what needs to be done in the project.	0	7	20	14	4	3.33	11
4	This course has improved my problem-solving skills.	1	5	17	16	6	3.47	10
5	Teaching in the classroom has helped me understand the topic more clearly.	0	6	22	15	2	3.29	12
6	I like other courses taught like this one.	1	3	11	25	5	3.67	6
7	The course has helped me to be confident when interacting with lecturers and students in class.	0	3	8	19	15	4.02	1
8	Lecturers have designed, organized and used time in a scientific, reasonable and logical way.	0	8	10	20	8	3.61	7
9	Lecturers are interested in encouraging students to participate in group activities and discuss and solve learning tasks.	0	7	10	23	5	3.58	8
10	Lecturers have used diverse and rich teaching and learning materials, creating favorable conditions for students to exploit and solve learning tasks.	0	4	6	23	12	3.96	2
11	The lessons have helped me gain the practical skills needed for the future.	0	3	8	24	10	3.91	3
12	The lecturers' teaching has helped me appreciate the value of this course.	0	5	7	25	8	3.8	5

Through Table 15, the students had the highest level of satisfaction with the item *"The course has helped me to be confident when interacting with lecturers and students in class"* with a mean value of 4.02. Many students also agreed with *"Lecturers have used diverse and rich teaching and learning materials, creating favorable conditions for students to exploit and solve learning tasks" (mean = 3.89)* but were not satisfied with *"Teaching in the classroom has helped me understand the topic more clearly", that is, the class organization still has some points that need to be improved* (Mean = .29). Meanwhile, students were satisfied with the lessons that the teacher gave and said, *"The lessons have helped me gain practical skills needed for the future" (*mean = *3.91).* Nearly 69% of students said, *"Lecturers have designed organized lessons and used time in a scientific, reasonable and logical way"*, 44% of students partly agreed with "*This course has improved my group work skills*" and nearly 40% of students totally agreed with *"This course has improved my practical skills".* However, the majority of students also highly appreciated the course and they said that the course had also helped them improve their practical skills with a high level of satisfaction (40%). Some students said *"Lecturers' teaching has helped me to appreciate the value of this course".* The rate of students partly agreeing to totally agreeing is 90%. This is a very high rate which proves that lecturers' teaching with the teaching methods proposed in the research has helped students improve their learning. Students agreed with the rate of more than 50% saying *"The project descriptions given by the lecturer are easy for me to understand what needs to be done in the project".* It can be said that lecturers' organizing group activities, guiding group projects and organizing their teaching process to help students achieve the learning outcomes of the subject curriculum need to be improved. On the other hand, it is necessary to survey each student on their own assessment of their degree of attainment of the learning outcomes following the course in order to evaluate each experimental class individually.

5. Discussion

In the experiment involving the experimental and control classes, the variance testing technique (Variance Analysis) was analyzed with SPSS and Excel to find the difference in average scores between the experimental and control groups. The effects of the CDIO-based teaching model on students in the experimental group after being exposed to the CDIO-based teaching strategy were researched. Quantitative results have proven that when implementing the CDIO approach-based teaching strategy with experimental and control groups for electrical and electronics engineering technology students, there was a difference in the learning outcomes of these two groups (experimental and control groups) that was more effective compared to the control group. That also confirms that the CDIO-based teaching model with teaching methods and teaching processes according to the CDIO approach is effective, helping students actively create and experience (Zha, 2008) through the module "Electronic Circuits". However, it needs to be done many times to improve and enhance the feasibility of the teaching model (Henderson, Selwyn, & Aston, 2017) including project-based learning (Gülbahar & Tinmaz, 2006), teaching based on simulation and modeling (Henderson et al., 2017; Yan & Wang, 2009) helping students become people with group competencies and skills (Hoang & Do, 2019), problem solving and creativity (Trinh & Nghia, 2014).

For the method of collecting students' feedback after the experiment, students were asked 12 different questions about the course and the level of satisfaction of students after the course is also shown in Table 14. Qualitative results showed that students not only actively participated in classroom activities but also actively participated in the learning process with the support of teachers. In addition, students actively participated in group discussions. Surveying students' feedback on the course confirmed that the CDIO-based teaching model with effective teaching methods and processes had an effect on the students. Students personalized learning, actively participated in group discussions when working on projects, interacted with other groups of students, collaborated in group work, improved thinking and increased problem-solving ability. One of the higher-level qualities that students strive for is improving practical competence. Moreover, students evaluated whether teachers' teaching organization was effective. However, some students were still dissatisfied with the course. These are also issues that teachers need to pay attention to and learn from to improve and adjust for future courses.

6. Conclusion

Currently, universities across the country have identified the goal of becoming a creative, pioneering and proactive in international integration. Therefore, building and developing the CDIO approach-based training programs with solutions to improve training quality will be a significant contribution to achieving the goal and quality improvement, especially improving the qualifications of Vietnamese engineers ready to work to meet the needs of domestic and international businesses.

The CDIO approach is essentially a solution to improve training quality, meeting social requirements on the basis of identifying learning outcome standards, thereby developing programs and solutions to ensure the effective implementation of training programs according to LO standards (Dinh & Tran, 2022). CDIO has an impact on education through its standards and programmes even if it is not regarded as a tool for quality assurance. Both students and lectures benefit from this approach as it provides them with the ability to master different competencies. It supports extensive multidisciplinary collaboration between students and lecturers and is therefore used in all programmes in addition to engineering (Abdul Halim & Buniyamin, 2016).

The CDIO offers many benefits to universities that have adopted it in engineering programs and other faculties. In this regard, all students have the opportunity to learn and experience a system that focuses on both theory and practical application. Students not only have to learn the necessary skills and knowledge in the training program but also have the opportunity to apply whatever they learn in reality. This helps them fully understand what they are learning from their teacher. As a result, institutions using the CDIO approach can produce competent graduates who can tackle different problems in their career fields.

The CDIO approach is essentially a solution to improve training quality and meet social requirements on the basis of determining learning outcome standards, thereby building programs and solutions to ensure the effective implementation of training programs.

The CDIO method is basically a way to design programmes and solutions to enable the successful execution of training programmes while fulfilling societal requirements and improving training quality based on learning outcome standards. At the same time, the relationship between items shows that students are satisfied with their learning as they learn by doing practical projects and by working in groups in a collaborative environment. These results confirm that the CDIO approach has an impact on learner capacity and collaborative space.

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