



Research Article

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The Implementation of the CDIO Approach in Teacher Training Programs: The Vietnamese Case

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Abstract

The CDIO (Conceive-Design-Implement-Operate) approach was originally developed for engineering education programs. However, this approach has also been adopted to support non-engineering programs. This paper aims to discuss the implementation of the CDIO approach in teacher training programs in a university in Vietnam. Five tests focusing on assessing students' competence of lesson plan preparation, lesson planning, teaching organization, student learning assessment, and teaching portfolio management were developed and administered to the experimental group of 40 last-year students and the control group of 40 last-year students. When the data were collected and analyzed with the assistance of the SPSS statistics, the p -value was .000 ($p = .000$, $p < .05$), which means that the experimental group and control group had statistically meaningful difference. The results of this study show that students enrolling in programs that implemented the CDIO approach performed better than those who enrolled in programs without the support of the CDIO approach.

Keywords: CDIO approach, teacher training program, competence, integration, higher education, Vietnam

1. Introduction

The Conceive-Design-Implement-Operate (CDIO) approach is a systematic framework for developing engineering education curricula. Its focus is to help students have an in-depth apprehension of technical essentials and professional skills every engineer has to be well-versed with (Edström, et al., 2020). According to Crawley et al. (2014), the CDIO approach develops double-impact learning that

supports comprehensive learning of practical skills and technical fundamentals. It takes advantage of new learning surroundings, innovative teaching strategies, and pedagogical strategies to offer robust learning experiences. As a result, a cognitive outline is developed to facilitate the learning of abstractions related to technical fundamentals that ensure there is understanding and knowledge retention. Learning is imparted on interpersonal and personal skills, system, process, and product building skills.

The CDIO Standards ensure there is a reliable framework for guaranteed successful engineering learning. They provide guidelines to facilitate bench-marking, creation of goals, continuous improvement, and educational program reforms. The CDIO strategy is founded on the enhancement of learning results, project- and problem-based studies. They are all integrated into a wider framework used in the whole operation and design of the engineering curriculum. The CDIO framework development tools effectively create programs that are non-engineering nature (Hladik et al., 2017; Malmqvist et al., 2016; Rinder et al., 2016). The study offers an example of how the CDIO approach is applied in engineering and implementing this CDIO model specifically in high school training programs for teachers being offered in a Vietnamese university. This proves that CDIO is used in engineering education programs and can be applied in various non-engineering programs, such as library science, business, food processing, science, and art.

2. The CDIO Approach

The CDIO strategy began towards the end of the 90s in MIT (Massachusetts Institute of Technology) to react to typical engineering learning, where many higher education institutions provide engineering science switching to engineering practice. The Swedish industrialists and educators got interested in what MIT had done. Thus, the CDIO initiative was founded by MIT, Linköping University, Chalmers, and KTH Royal Institute of Technology, alongside four years of guaranteed funding from Knut and Alice Wallenberg Foundation. Furthermore, apart from the four founding institutions, others also expressed interest in participating. Since then, the CDIO has tremendously grown in that it has more than 100 learning institutions as collaborators (Edström & Kolmos, 2014).

The CDIO aimed to ensure:

- understanding the strategic impact and significance of technological development and research on society.
- guiding the development and operation of new systems, processes, and products.
- offering a deeper understanding of technical fundamentals (Crawley et al., 2014).

With the growth of the CDIO approach, there was a need to accommodate different institutions and programs. As a result, the twelve CDIO standards were established to give an overview of engineering program development. The focus was on defining a holistic and comprehensive strategy, highlighting the initiators of change and proper alignment of policies. There are seven great significance standards to defining a minimal strategy of creating CDIO program (Crawley et al., 2014). The CDIO programs offer a wide variety of project and problem-based learning actions. The Design-Build is crucial since students are allowed to develop designs and implement processes, systems, or products. It is with no doubt that engineering projects tend to be different in the many engineering fields. However, the intention remains to study using near-authentic activities to support working models which are in line with professional engineering practice (Edström & Kolmos, 2014). CDIO is popular among engineering programs, and it has successfully provided positive results on graduates' personal, interpersonal, and design skills, and independent perceptions on the quality of education (Malmqvist et al., 2015).

According to Crawley et al. (2014), the CDIO strategy may be applicable in programs that are non-engineering through:

- Applying the CDIO quality assurance and curriculum development processes.
- Using curricular and pedagogical elements of the CDIO strategy.

- Defining engineering practice as a basis of educational design.
- Cooperating with clients to determine their graduates' requirements.

The generalized standards of CDIO in other disciplines can be adapted in any other program (Doan et al., 2014). An experience that is practical is vital in the translation of the CDIO strategy standards to the non-engineering fields such as library science, business, food processing, science, and art. The CDIO framework has also been adapted to facilitate elementary and high school teacher training curricula (Hladik et al., 2017; Nguyen et al., 2020).

3. Implementation of the CDIO Approach to Teacher Training Programs

The investigated university started to implement the CDIO approach in its teacher training programs in 2016 for the purpose of meeting the requirements of the Fourth Industrial Revolution in Vietnamese higher education institutions (Nguyen et al., 2020). First of all, the University interpreted the twelve CDIO standards to teacher training sector (Table 1).

Table 1: Twelve CDIO standards and their implementation for teacher training

CDIO standards (CDIO, n.d.)	Implementation for teacher training
Standard 1: The Context <i>Adoption of the principle that product, process, and system lifecycle development and deployment -- Conceiving, Designing, Implementing and Operating -- are the context for engineering education.</i>	Training teachers with high quality, creative capacity, adapting to the context of increasing the application of technology and information technology in teaching for high schools, meeting the requirements of general education innovation and international integration. Forming 6 groups of knowledge on the basis of 4 knowledge blocks of CDIO for teacher training.
Standard 2: Learning Outcomes <i>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.</i>	Building a 7-step process of developing learning outcomes at levels 3 and 4. Equipping students with knowledge and skills in the field, personal qualities in professional activities, communication and cooperation skills and important competencies of teachers in a modern education, meeting the requirements of differentiated, integrated teaching; designing and organizing creative experiential activities for students; assessing students according to the competency approach including 6 groups of knowledge and skills.
Standard 3: Integrated Curriculum <i>A curriculum designed with mutually supporting disciplinary courses, with an explicit plan to integrate personal and interpersonal skills, and product, process, system, and service building skills.</i>	Building a 6-step process of developing an integrated curriculum for teacher training.
Standard 4: Introduction to Engineering <i>An introductory course that provides the framework for engineering practice in product, process, system, and service building, and introduces essential personal and interpersonal skills and the rationale of sustainability in the context of engineering.</i>	Developing introductory courses for teacher training programs.
Standard 5: Design-Implement Experiences <i>A curriculum that includes two or more design-implement experiences, including one at a basic level and one at an advanced level.</i>	Developing two courses that require teacher students to design and implement experiential activities for students.
Standard 6: Engineering Learning Workspaces <i>A physical learning environment that includes engineering workspaces and laboratories that support and encourage hands-on learning of product, process, system, and service building, disciplinary knowledge, and social learning, combined with a digital learning environment that includes on-line tools and spaces that support and enhance the quality of teaching and student learning.</i>	Providing more facilities, equipment and learning materials that support for students' hands-on learning and creativeness.
Standard 7: Integrated Learning Experiences <i>Integrated learning experiences that lead to the acquisition of disciplinary knowledge, as well as personal and interpersonal skills, and product, process, system, and service building skills.</i>	Designing and implementing integrated learning experiences for students; encouraging students to do research in education; organizing students to practice in the labs and schools.

CDIO standards (CDIO, n.d.)	Implementation for teacher training
Standard 8: Active Learning <i>Teaching and learning based on active experiential learning methods.</i>	Designing and implementing teaching based on active experiential learning methods such as project based and problem solving.
Standard 9: Enhancement of Faculty Competence <i>Actions that enhance faculty competence in personal and interpersonal skills, and product, process, system, and service building skills.</i>	Organizing training and capacity building for teachers with CDIO skills.
Standard 10: Enhancement of Faculty Teaching Competence <i>Actions that enhance faculty competence in providing integrated learning experiences, in using active experiential learning methods, and in assessing student learning.</i>	Training teachers with teaching methods consistent with CDIO; teaching in the direction of developing students' competence; using active experiential learning methods for teacher students.
Standard 11: Learning Assessment <i>Assessment of student learning in personal and interpersonal skills, and product, process, system, and service building skills, as well as in disciplinary knowledge.</i>	Assessing students according to competence approach; designing scales based on Bloom taxonomy to assess student leaning in communication skills, process, product and specialized knowledge.
Standard 12: Program Evaluation <i>A system that evaluates programs against these twelve standards and any optional standards adopted, and provides feedback to students, faculty, and other stakeholders for the purposes of continuous improvement.</i>	Self-assess the program and registering the program for external assessment by AUN-QA (ASEAN University Network – Quality Assurance).

The learning outcomes were then developed with seven steps as mentioned in Standard 2. The seven steps include:

- Step 1: Establishing a committee for developing learning outcomes at levels 3 and 4.
- Step 2: Developing a feasible plan.
- Step 3: Drafting learning outcomes at level 3.
- Step 4: Surveying key stakeholders about the drafted learning outcomes.
- Step 5: Revising learning outcomes based on feedback from key stakeholders.
- Step 6: Organizing workshops to get comments from experts.
- Step 7: Finalizing learning outcomes and getting them approved by the University Council of Science and Training.

After the learning outcomes based on the CDIO approach had been completed, the University started to develop the curriculum with 6 steps as discussed in Standard 3. These six steps include:

- Step 1: Benchmarking the current curricula with new learning outcomes. These new learning outcomes are the basis for the development of new curricula.
- Step 2: Designing the curriculum framework. Restructuring the new curricula with new learning outcomes and ideas. In this case, it is the development of integrate curricula.
- Step 3: Developing teaching sequences of learning outcome topics on skills and attitudes.
- Step 4: Allocating teaching sequence topics into courses. This process is to make skills and attitudes be integrated in the courses.
- Step 5: Designing course outlines. After all the teachers have agreed on the allocation of the teaching sequence of the learning outcome topics into the courses, each teacher can develop the course outline according to the learning outcomes assigned to her/his course.
- Step 6: Getting feedback and comments on the curriculum framework and course outlines. Finalizing the curriculum and having it approved by the University Council of Science and Training (Nguyen et al., 2020).

The University started to implement the new curricula developed according to the CDIO approach in its teacher training programs in the academic year 2016-2017. The University has been aware that the application of the CDIO approach in developing the learning outcomes and curricula helped train core competencies for students and make them easily adapt to the changes of sciences

and technologies as well as the innovation of general education.

4. Research Design

It was hypothesized that there would be significant differences in the competence of students enrolling in programs that implemented the CDIO approach and those enrolling in programs that had not been developed according to the CDIO approach. The five criteria for evaluating the students' competencies were suggested as "lesson plan preparation", "lesson planning", "teaching organization", "student learning assessment" and "teaching portfolio management". Consequently, five tests based on these criteria were developed. Each test has a certain number of indicators and each indicator would be marked with three levels: level 1 (1 score), level 2 (3 scores) and level 3 (5 scores). Table 2 presents the test for teaching portfolio management competence as an example. The number of indicators in the tests are below:

- Test for lesson plan preparation competence: 9 indicators
- Test for lesson planning competence: 24 indicators
- Test for teaching organization competence: 29 indicators
- Test for student learning assessment competence: 10 indicators
- Test for teaching portfolio management competence: 5 indicators

Table 2: Test for teaching portfolio management competence

Indicators	Level 3 (5 scores)	Level 2 (3 scores)	Level 1 (1 score)	Average score
1. Structure of the portfolio				
2. Openness of the portfolio				
3. Scientificity and rationality in the structure of the portfolio				
4. The extent to which information in the portfolio is used in teaching planning				
5. The extent to which information in the portfolio is used in testing and assessing students				
Average score				

These five tests were administered for 40 last-year students who enrolled in teacher training programs that implement the CDIO approach (called experimental group) and 40 last-year students who enrolled in teacher training programs that have not implemented the CDIO approach (called control group). As all the students in both the experimental group and the control group had similar admission scores, it can be seen that they had similar competence when they began to enroll in the University. Students' scores for each test were calculated with average one, ranging from 1.00 (minimum) to 5.00 (maximum). When all the data were collected, they were analyzed by the software SPSS statistics to find out if the implementation of the CDIO approach made good performance in the students' competence or not.

5. Research Findings

5.1 Result of lesson plan preparation competence test

When the data were collected, a paired samples t-test was conducted to compare the outcomes of the experimental group and control group. As shown in Table 3, the p-value equaled .000 and ($p = .000$ $p < .05$). It can be seen that there was a difference in statistics between the experimental group and control group. Additionally, the mean score of the experimental group was 2.99, which is higher than that of the control group (2.84).

Table 3: The p-value and mean score difference of lesson plan preparation competence test

	N	Mean	Std. Deviation	Std. Error Mean	Sig.
Experimental group	40	2.99	.32	.05	.000
Control group	40	2.84	.34	.05	

5.2 *Result of lesson planning competence test*

The results for lesson planning competence as highlighted in Table 4 show that the mean difference between the experimental group and the control group was 0.33. The p-value was .000 ($p = .000$ $p < .05$). This means that the experimental group and control group experienced a difference in terms of statistics.

Table 4: The p-value and mean score difference of lesson planning competence test

	N	Mean	Std. Deviation	Std. Error Mean	Sig.
Experimental group	40	4.09	.32	.05	.000
Control group	40	3.76	.22	.04	

5.3 *Result of teaching organization competence test*

The results for teaching organization competence as illustrated in Table 5 reveal that the mean score of the experimental group was higher than that of the control group (4.23 and 3.84 respectively). Moreover, the p-value was .000 ($p = .000$ $p < .05$). The result shows a statistical difference the experimental group and control group.

Table 5: The p-value and mean score difference of teaching organization competence test

	N	Mean	Std. Deviation	Std. Error Mean	Sig.
Experimental group	40	4.23	.38	.06	.000
Control group	40	3.84	.44	.07	

5.4 *Result of student learning assessment competence test*

As presented in Table 6, the p-value equaled .000 and ($p = .000$ $p < .05$). This means there was a difference in statistics between the experimental group and control group. Furthermore, the mean score of the experimental group was 2.70, which was slightly higher than 2.52, the mean score of the control group.

Table 6: The p-value and mean score difference of student learning assessment competence test

	N	Mean	Std. Deviation	Std. Error Mean	Sig.
Experimental group	40	2.70	.26	.04	.000
Control group	40	2.52	.31	.05	

5.5 *Result of teaching portfolio management competence test*

The results for teaching portfolio management competence are shown in Table 7. It can be seen that the mean score of the experimental group was 3.56 while the mean score of the control group was 3.44. So the mean difference between the two groups was 0.12. In addition, the p-value was .000 ($p = .000$ $p < .05$). This implies that the experimental group and control group had statistically

meaningful difference.

Table 7: The p-value and mean score difference of teaching portfolio management competence test

	N	Mean	Std. Deviation	Std. Error Mean	Sig.
Experimental group	40	3.56	.34	.05	.000
Control group	40	3.44	.32	.05	

6. Discussion

With the CDIO approach being offered in the non-engineering programs, there have been some positive outcomes. This is an indication that even other faculties are taking up the CDIO approach to use it in teaching and various training programs. The objective of using the CDIO approach in such programs is to enhance the teaching of generic and design skills, enhance connections with work life, and improve the quality of education regarding continuous improvement alongside meeting the set international accreditation standards (Malmqvist et al., 2016). It is not all about the number of graduates an institution can pump into the job market. The graduates have to be very competent and very ready for the various tasks they will be expected to undertake in their careers. This is why it is very important they touch base with reality. It is at that point where the CDIO approach comes in handy. The CDIO approach ensures there are standards and goals to be met while teaching or training students. In that connection, the quality of education even goes up since their appreciation for value through the commitment to meeting the set accreditation standards. Furthermore, another reason for the use of CDIO in non-engineering programs is that it supports educational development in many universities that have adopted it. For example, in Vietnamese universities, the CDIO approach assists students in meeting the educational facilities and general education teacher requirements. It promotes international integration with regards to Industrial Revolution 4.0 (Nguyen et al., 2020). There is always a need to remain progressive. It is no secret that education systems are ever changing. Therefore, there is a need for students and teachers to always be ready for this change. The CDIO approach ensures students can think and innovate. They are allowed to come up with their own ideas, thus boosting their creativity. This is the essence of having them take part in projects in order to come up with an idea and achieve it.

In addition, the CDIO approach encourages students to undertake some projects to enhance their practical knowledge. But before that, students are expected to read and acquire knowledge about the upcoming projects. They can use whatever they have learned and their own research to develop projects that can be used to solve various problems in their field of study. This approach ensures students can be able to think critically and also become great problem solvers. Group discussions are encouraged in instances where students face problems, and there is a need to resolve them. The beauty of group discussions is that it allows students to share different views and ideas on the problem at hand. As a result, informed decisions are arrived at. The problem being handled can be done very easily. Should they can solve those issues, they are encouraged to consult their teachers (Yusuf & Tilfarlioğlu, 2020). Through consulting from the teachers, students get more information and knowledge they can apply to arrive at a sober solution. It helps prevent mistakes. The current research shows that students of the teacher training programs had good lesson plan preparation competence as they were trained to get to know their students, the subjects, facilities and learning materials as well as the local socio-economic-natural features. This was well noted by Xiao and Zhang (2020) that in CDIO classes, the teacher is expected to assist a student in understanding a text and being a problem solver. Furthermore, every student is expected to acquire some skills and information after class. In this regard, the students will learn effectively since they have the morale to learn, and the CDIO approach focuses on enhancing their attributes and skills (Armstrong & Niewoehner, 2008; Azasu & Gibler, 2016).

Next, the students studying in the teacher training programs applied the CDIO approach

showed their good competence in lesson planning. They are able to organize their work very well to ensure they can teach students effectively. Through Active Learning (CDIO'S 8th standard), students learn to identify problems and provide solutions under the guidance of their teachers. The students are encouraged to use different ways to resolve their issues (Yusuf & Tilfarlioğlu, 2020). This finding is consistent with that of Muñoz, et al. (2020), who explored lessons learnt from a CDIO-based curricular reform of the computer science program at a Chilean university. Furthermore, this also echoes Armstrong and Niewoehner's (2008) observation that students are expected to enhance their design, conception, product operation, process/system, and implementation skills.

Additionally, the students who adapted to the CDIO approach displayed competence during teaching practice. They were able to organize their lessons very well together with activities such as using language, class organization, and warm-up. Besides, they could effectively pass across the knowledge they acquired in training and their own research very effectively. But with the adoption of CDIO, comes some disruptions to the normal structure and routines in classrooms. These disruptions affect not only students but also educators. Educators ought to operate and interact in the broader system of the classroom. However, larger systems can facilitate or prevent teaching goals and intentions due to the resulting tensions depending on the culture and structure of the institution (Jambari et al., 2018). According to Malmqvist et al. (2016), opposition to change by the faculty is one of the main hindrances to educational development. The incorporation of generic skills such as ethics, communication, and teamwork may not be received well by teachers who are prone to teaching normally. But CDIO is one approach that favors integrated learning. The teachers can be subjected to training to acquire the generic skills that favor their subject. Through such an approach, teachers can learn new teaching strategies, be innovative and great researchers (Yusuf & Tilfarlioğlu, 2020). They can also learn to appreciate the advantages that come from using the CDIO approach.

Furthermore, the CDIO benefited students with great learning assessment competence. Such students showcased good skills and knowledge in assessment planning, organization, and providing feedback on assessment outcomes. Assessment and evaluation are crucial in the CDIO approach for engineering learning (Svensson & Gunnarsson, 2012). This can be seen in the CDIO Program evaluation and CDIO skills Assessment. They allow students to think, perceive, intellectualize, examine, communicate, make decisions, evaluate and gather experience. Students do not make well-informed decisions with such attributes after engaging in very intense research and consultation. The focus should not just be memorizing the knowledge. The students are discouraged against having a specific answer but instead be able to appreciate thinking critically and accepting divergent views. This has been made possible by subjecting students to open questions. Those questions allow students to formulate their ideas and opinions, make hard decisions, and enhance intellectual skills once they graduate (Yusuf & Tilfarlioğlu, 2020). With the introduction of new learning techniques, extra time is needed for preparing materials and assessment approaches. Basic rubrics are used in conducting student assessments, but according to Muñoz et al. (2020), an online repository of basics is very effective. In the context of Vietnam, Nguyen et al. (2020) stated that flexibility allows students to pick those subjects that suit their career, interests, competence, and orientation. CDIO provides that linkage between training facilities and the skills an employer requires from the graduate. Therefore, students have to develop both soft and hard skills, to quickly conform to the ever-changing working environment.

Last but not least, the CDIO approach is known for helping learners succeed in teaching portfolio administration. According to (Yusuf & Tilfarlioğlu, 2020), the Pportfolio refers to the combination of both students' works and assignments initiated in experimental studies. Every student has their portfolio with four-stage CDIO evaluations and documents, quick sharing of documents, group lecturing, reflections, social interview reports, and every student's work. The techniques are prepared in regards to the standards of CDIO and the researcher utilized them in teaching the control group. The CDIO approach attempts to not only give students knowledge but also enhance their innovation prowess. Since innovation requires readiness for change, students ought always to be ready, which is possible through the CDIO approach. The students learn how to

appreciate a practical life, whereby they acknowledge what they have been taught, after which they put it into practice. In that regard, they can graduate and quickly adapt to working in the enterprise (Geraskin et al., 2020). After graduation, they do not have a hard time getting the hang of what is required of them in their field of study. The practical skills acquired through project works allows them to exercise their creative capabilities hence touching base with the real-life issues in the engineering practice. The CDIO approach is a comprehensive and systematic basis for designing, applying, and analyzing the value of every engineering program that is intended to offer students authentic education. Information technologies and active learning can be fostered in classrooms, alongside giving early adopters the peer framework that supports them when perceiving, planning, implementing, and evaluating pedagogical innovations. The peer-based approach promotes successful experiences in various courses in any program, besides the engineering program (Muñoz et al., 2020).

7. Conclusions

The CDIO approach has become a fundamental teaching framework in non-engineering and engineering programs. Also, this approach has befitted other educational developments and initiatives. Some institutions have already adopted the CDIO approach on all their faculty programs across various courses. This is because CDIO approaches education from various perspectives and guarantees continuous improvement and evaluation. Even though it is not regarded as a tool for quality assurance, CDIO affects education through its syllabus and standards. Both students and teachers have benefited from this approach since it offers them a mastery of various competencies. It is for that reason it is used on all programs not limited to engineering, besides supporting in-depth multidisciplinary collaborations between students and the faculty (Malmqvist et al., 2016). The CDIO has come along with many benefits to the institutions that have already adopted it for use in engineering programs and other faculties. In that regard, all students have a chance to be taught with a system that focuses on both theory and practical application of the information being taught. Students do not just have to learn by heart whatever they are being taught. There is also an opportunity to put whatever they are learning into practice. This helps them to understand whatever they are being taught fully. As a result, institutions using the CDIO approach are able to produce very competent graduates who can solve different problems in their areas of qualification. It is also worth noting that it is a very progressive approach that allows students or graduates to put up with the ever-changing job market. To conclude, the teacher training programs at the University have successfully used and implemented CDIO by interpreting and adapting CDIO into their own field.

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