

Development of CDIO-Based Programs from the Teacher Training Perspective

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Abstract. To meet the requirements of the Fourth Industrial Revolution (4IR) Vietnam's K-12 education has shifted from a content-based to a competency-based approach. Teacher education institutions are, therefore, required to make comprehensive curriculum reforms to align with the K-12 education innovation. This paper is concerned with the adoption of the CDIO (conceive-design-implement-operate) initiative for teacher training programs at Vinh University in Central Vietnam. It gives an account of the large-scale changes that involve significant shifts in the culture of management, teaching, learning and assessment, the revamp of the structure and contents of the curricula, along with enhancement of faculty teaching competence, personal and interpersonal skills, product, process, and system building skills, as well as disciplinary fundamentals. It also describes how the university has adapted the 12 CDIO standards for teacher training programs, and how teacher training spaces, outcome-based assessment and program evaluation have been adjusted in accordance with the CDIO principles. The qualitative research method was employed for an evaluation of the CDIO-based program implementation. The data were collected from interviews with faculty members and students, observations, documents related to the CDIO program implementation, reports of departments and AUN-QA accreditation agency that assessed the programs. It was found that the CDIO approach is highly applicable for teacher training programs; it fits the outcome-based teaching and assessment and the development of professional skills and competencies with which future teachers need to be equipped.

Keywords: CDIO standards; program learning outcomes; competency-based; project-based learning; outcome-based assessment

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1. Introduction

The CDIO initiative (conceive-design-implement-operate) is an innovative educational framework originating from the Massachusetts Institute of Technology (MIT). This educational model came into being in response to several factors. First, the feedback from industries, graduates, and practicing engineers indicated that those certain important professional skills were not developed in the existing curricula. Second, the model meets the standards and criteria set by accreditation bodies such as Accreditation Board for Engineering and Technology (ABET). Additionally, the engineering enrolment was dropping, as students found that engineering was too dull and theoretical in the first year of study (Crawley et al., 2014). To date, more than 190 major universities in developed countries, such as the United States, Great Britain, France, Sweden, Finland, Portugal, Japan, China, Singapore, and Thailand, have applied CDIO programs (CDIO, 2022).

The CDIO training model can respond to the new requirements of businesses and stakeholders in enhancing students' ability to acquire fundamental knowledge, while promoting the learning of soft skills, professional skills, and interpersonal communication, building processes and systems, and manufacturing products (Foley & Kyas, 2021). The CDIO training process starts from determining training goals, building learning outcomes and designing outcome-based programs. This process is designed to ensure strict scientific requirements and feasibility with the participation of stakeholders, including employers, alumni, students, lecturers, and scientists.

CDIO-based learning outcomes are based on stakeholders' surveys and a careful analysis of labor market requirements, including four blocks of knowledge and skills: (1) disciplinary knowledge and reasoning; (2) personal and professional skills and attributes, (3) interpersonal skills including teamwork and communication; and (4) CDIO systems in the enterprise, societal and environmental context. These knowledge and skills are integrated in the training program and specifically assigned for each course based on the program matrix. Thus, each course contributes to the achievement of the program learning outcomes at different levels. Each instructor must adhere to the curriculum standards for content and the respective teaching level I-T-U (*introduce, teach, utilize*) to avoid duplication or omission of teaching identified piece of knowledge and skills (Nhut & Trinh, 2010).

CDIO comes from aeronautical engineering and the application of CDIO model has been still the most popular in the field of engineering to date (Kamp, 2021). Recent studies indicate that this training model has shown its relevance and superiority to the training of engineers in the 4IR (Malmqvist et al., 2016; Crawley et al., 2020). Furthermore, students trained in the CDIO model can work straight after graduation and there is almost no need of retraining them. They are quicker at understanding the market and grasping customer needs. In addition, students' interpersonal skills, such as communication, teamwork, and presentation skills, also show improvement.

Research shows that the CDIO initiative can be applied to many different areas of training, in addition to engineering, because it ensures a framework of knowledge

and skills (Crawley et al., 2020; Malmqvist et al., 2016; Martin et al., 2017; Tangkijviwat et al., 2018; Kuptasthien, 2020). Therefore, in recent years, the CDIO training model has also been applied in teaching humanities and social sciences by many universities around the world. Some specific cases of the CDIO program are at Instituto Politécnico do Porto in Portugal that developed the CDIO program for a Master's degree in Development Practice, which was based on 12 engineering CDIO standards (Martin et al., 2017). Singapore Polytechnic applied the CDIO training program for the fields of Food Science and Technology, Music Technology and Sound Engineering, and the University of Applied Sciences in Finland applied CDIO training for the discipline of Business Administration and Library Information. In Vietnam, the National University of Ho Chi Minh City applied CDIO for disciplines in humanities and social sciences, such as International Business, Journalism (Malmqvist et al., 2016), University of Economics. The Hanoi National University applied CDIO for International Economics major (Dung & Nha, 2012).

Crawley et al. (2014) also noted that CDIO could be applied to non-technical disciplines based on the 12 CDIO standards, which can be summarized as follows:

- Developing a description of the profession's context of practice as a starting point for educational design (corresponding to CDIO standard 1).
- Working with stakeholders to identify their requirements on the graduates (CDIO standard 2).
- Adapting the pedagogical and curricular elements of CDIO (CDIO standards 3-11 mainly) to the discipline's needs.
- Applying the CDIO curriculum development and quality assurance processes (CDIO standard 12).

Even though the CDIO model has been applied to several disciplines, including humanities and social sciences, it has not been adopted for teacher training programs anywhere else in the world. This paper, therefore, presents an account of the first ever CDIO-based framework for teacher education at Vinh University, Vietnam.

2. A CDIO-Based Teacher Training Model

Vinh University is the first institution to adopt the CDIO initiative for teacher training programs. Located in Central Vietnam, the institution was initially established as a teacher training college in 1959, and then became a comprehensive university in 2001. It offers 55 undergraduate programs, 38 Master's programs, and 17 doctoral programs, among which teacher education programs comprise of 14 undergraduate, 12 Master's, and four doctoral. The university follows a concurrent model of teacher training (Dinçer & Bikmaz, 2020), which means that pedagogical courses are delivered during the four years of study at an education college.

It should be noted that Vietnam has undergone a comprehensive education reform which shifted from the traditional knowledge-based to competency-based education. While higher education institutions are relatively autonomous in deciding their model of training, K-12 schools adopted a unified system known as the National General Education Program 2018 (Ministry of Education and Training, 2018). Given the changing context, the university is undergoing a comprehensive educational reform with an ambition to utilize and implement innovation in higher education to produce graduates with international standards and to meet the pressing needs of the emerging market-based economy in Vietnam.

The CDIO-based approach, which was first introduced to Vietnam in 2008, has been adopted by the university since 2017. The CDIO framework for undergraduate teacher education programs has been adapted to align with the teaching profession and Vietnam's national qualifications frameworks (Ministry of Education and Training, 2021; Vietnam's government, 2016).

Table 1 features the adaptation of the CDIO initiative for the 14 teacher training programs of English, Mathematics, Physics, Chemistry, Literature, History, Geography, Civic Education, Primary Education, Nursery Education, Physical Education, Biology, Education Management, and Information Technology Education.

Table 1: Adaptation of the 12 CDIO standards for teacher training

Standard	The 12 CDIO standards for engineering (version 2.0) (CDIO, 2011)	Adaptation of the 12 CDIO standards for teacher training at Vinh University
1 <i>Pedagogical 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.	The pedagogical CDIO program is designed in accordance with the national general education curricula in the context of Vietnam education in the period of international integration and the 4IR.
2 <i>Program learning outcomes</i>	Specific, detailed learning outcomes for personal and interpersonal skills, and product, process, and system building skills, and disciplinary knowledge, consistent with program goals and validated by program stakeholders.	The learning outcomes of teacher education include knowledge, skills, qualities, attitudes, which are consistent with the Vietnamese teacher competency framework for each specific subject and with the consultation of stakeholders.
3 <i>Integrated curriculum</i>	A curriculum designed with mutually supporting disciplinary courses, with an explicit plan to integrate personal and interpersonal skills, and product, process, and system building skills.	Designed to integrate related and complementary courses to form knowledge, personal and interpersonal skills. Teachers need to know and be familiar with the National General Education Curriculum 2018.
4 <i>Introduction</i>	Introduction to engineering: An introductory course that provides the framework for engineering practice in product, process, and system building, and introduces essential personal and interpersonal skills.	Introduction to teaching profession: An introductory course providing the framework for teaching practice at school, and introducing essential personal and interpersonal skills for teachers, as well as preliminary school experience.
5 <i>Design implementation experiences</i>	A curriculum that includes two or more design-implement experiences, including one at a basic level and one at an advanced level.	The curriculum includes at least two design-implement experiences, including one at a basic level and one at an advanced level, namely the Introduction to Pedagogy project and Graduation Project. Other projects may only include partial elements in CDIO but they are systematically designed to ensure full formation of competencies and skills upon completion of the program.
6 <i>Learning spaces</i>	Engineering learning workspaces: Engineering workspaces and laboratories that support and encourage hands-on learning of product, process, and system building, disciplinary knowledge, and social learning.	Spaces for pedagogical training and practice: In addition to the traditional classroom, the university builds learning spaces for students' self-study, teamwork, and designing educational activity. Furthermore, the university sets up a network of affiliated schools so that students can regularly observe classes and directly participate in educational activities.
7 <i>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, and system building skills.	Organizing teaching that combines specialized knowledge with the development of personal qualities and interpersonal skills, a systematic vision in educational practice; Increase the participation of teachers at high school level and stakeholders in the training process.
8 <i>Active learning</i>	Teaching and learning based on active experiential learning methods.	Applying active experiential teaching methods that involve teamwork, project-based learning, presentations, discussion, micro-teaching, etc.
9 <i>Enhancement of faculty competence</i>	Actions that enhance faculty competence in personal and interpersonal skills, and product, process, and system building skills.	Actions that enhance faculty competence in personal and interpersonal skills, ICT skills, and understanding of the National General Education Curriculum 2018.
10 <i>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.	Actions that enhance faculty competence in providing integrated learning experiences, in using active experiential learning methods, and in assessing student learning outcomes.
11 <i>Learning assessment:</i>	Assessment of student learning in personal and interpersonal skills, and product, process, and system building skills, as well as in disciplinary knowledge.	Outcome-based assessment of student learning in personal and interpersonal skills, in disciplinary knowledge, as well as product, process, and system building skills required for teachers.
12 <i>Programme evaluation</i>	A system that evaluates programs against these 12 standards, and provides feedback to students, faculty, and other stakeholders for the purposes of continuous improvement.	A system that evaluates programs against these 12 standards in line with the national education regulations, and provides feedback to students, faculty, and other stakeholders for the purposes of continuous improvement.

The CDIO-based teacher training program consists of 126 credits and 36 courses, which are structured to integrate the knowledge and skills identified in the learning outcomes of each program with the following structure:

General knowledge— 18 credits, including:

Political science and civic education modules (five courses with 11 credits): These courses are delivered in the first six semesters; and foreign language courses (English 1 and English 2 with 7 credits).

General pedagogical disciplines – 14 credits, including:

Introduction to Teaching Profession (3 credits); Psychology (3 credits); Educational studies (4 credits); and ICT in education (4 credits).

Group disciplines (natural sciences education, social sciences education, etc.) – about 24 credits, including:

Depending on the structure and characteristics of each discipline group (natural pedagogy, social pedagogy), different number of credits for each discipline may be required.

Disciplinary foundation and pedagogy – 70 credits, including:

There are some striking pedagogical differences between the traditional teacher training programs and the new CDIO-based teacher education model. For CDIO programs, students actively participate in project-based learning that involves teamwork and interdisciplinary collaboration (Jaca et al., 2021; Chia, 2021). The integration of learning topics will help students gradually familiarize themselves with the new national general education curriculum.

Project-based learning also requires students to be the ones who directly do the work, proactively in the process of discovering knowledge under the guidance of the lecturer. When doing projects, students have many opportunities to work at school. Right from the first year, they have their first school experience as partial requirement for the Introduction to Teaching Profession course. In doing so, a passion for the teaching profession can be instilled in students and the career orientation can be initiated at an early stage.

Furthermore, assessment schemes have also been significantly improved. The CDIO programs focus on outcome-based assessment (Gurukkal, 2020; Roslof, 2021), with various forms of evaluation including, but not limited to, portfolios, quizzes, presentations, micro-teaching, field trips, teamwork, midterm tests, and a final exam. The shift to the CDIO-based teacher training model is good preparation for graduates so that they are able to teach and work under the new National General Education Program 2018.

3. Methodology

The study employed the qualitative research method, which involves collecting, analyzing and interpreting non-numerical data (Atkins & Wallace, 2012; Creswell & Creswell, 2017). It gives an account of how the CDIO initiative has been adapted for teacher education programs at Vinh University and presents an evaluation of the CDIO-based program implementation after a cycle. The data were obtained from interviews with faculty members and students, observations, documents related to the CDIO program implementation, reports of departments and AUN-QA accreditation agency that assessed the programs. These different sources

provided varied perspectives on the evaluation of the CDIO-based teacher education programs and, hence, ensuring the validity and reliability of the assessment.

In qualitative research, the data in statistics can be categorically arranged according to attributes and properties of the phenomena under investigation. Therefore, the study focused on the six major CDIO-adapted standards (CDIO, 2011), namely, enhancing competence of faculty members, building CDIO-based teacher training programs, teacher training spaces, active learning methods, assessment of learning, and program evaluation. These six standards reflect the fundamental changes for innovation of teacher training programs at Vinh University.

4. Results and Discussion

One of the CDIO principles is to continuously improve the program. After a four-year cycle of implementing the program, the university conducted a comprehensive review of the CDIO program implementation. The teacher training departments conducted surveys of stakeholders and organized meetings to review the program implementation. Strengths and areas for improvement were pointed out for the next cycle of revision. Reflections of faculty and students, along with the AUN-QA's external assessment show that the implementation of the CDIO programs is a suitable choice for the university's educational reform.

4.1 Enhancing the Competence of Faculty Members

When the university started to build and develop the CDIO-based teacher training programs, only a few universities in the country applied this model. There was no model of CDIO teacher training to consult. Therefore, one of the priorities was to enhance the faculty's competence in curriculum development, teaching and assessment. A 16-member CDIO expert committee was established with representatives from different departments.

The committee gives advice to the departments and guidance for implementing the programs. The university also receives regular consultancy and advice from an American professor who is an expert in CDIO programs. Based on expert consultation and research, the university has developed CDIO competency framework for teaching faculty, as shown in Table 2.

Table 2: CDIO competency framework for teaching faculty (Yen et al., 2021)

Domain of competency	Components	Evidence
<i>Work ethics</i>	Political stance	Annual staff evaluation sheet Feedback from managers and colleagues
	Teacher conducts	Professional training certificate Feedback from managers, colleagues and students
<i>Field</i>	Knowledge	Master degree in the field
	Skills	Relevant degrees or certificates of training
<i>Field</i>	Planning the course	Course plans

	Designing and development materials	Coursebooks, lesson plans, books
	Using teaching methods and techniques	Diplomas in teaching methodology Certificates of participation in pedagogical training workshops
	Assessing student learning	Certificates of participation in training workshops on assessment
	Building the learning environment	Feedback from learners Evaluation from administrators
<i>Foreign language and information - technologies</i>	Using a foreign language and information-technologies in teaching, research and communication	Certificates in information-technology as required by the Ministry and the University Products showing competence in a foreign language and information - technologies (e.g., articles written in English, e-learning lesson plans, etc.)
<i>Research</i>	Designing and carrying out research and technological transfer	Research products
	Instructing learners to carry out research	Research products by the learners
<i>CDIO curriculum</i>	Designing CDIO curricula	CDIO-based course syllabi that have been designed and implemented
	Implementing and developing CDIO curricula	Improved CDIO-based course syllabi
<i>Communication with the industries</i>	Setting up the network of enterprises and/or associations Communicating with partners	An established network of enterprises and/ or associations Results from partnership with enterprises and/or associations

To enhance the competency of the faculty members to implement the CDIO program, the university regularly organized seminars and training workshops to share experiences. Experts from Vietnam and overseas were invited to train the faculty and staff for the construction and implementation of the CDIO program. The training workshops focused on the writing program and course learning outcomes, curriculum development, teaching methods, and especially on project-based learning, CDIO-based assessment, and program accreditation. In addition, faculty members and heads of departments were sent to other universities in Vietnam and in the United States to learn about the experiences and best practices of CDIO-based program implementation.

After four years of regularly implementing training and sharing experiences, the capacity of lecturers has been significantly improved. However, many lecturers are still not proficient in active teaching methods, especially project-based teaching. This is the point that the university needs to focus on improving their competency in time to come.

4.2 Building CDIO-Based Teacher Training Programs

The CDIO-based teacher training programs at the university began with building learning outcomes. First, the program learning outcomes of the CDIO-based teacher training programs were scientifically developed and highly practical because they were based on the survey results of stakeholders, including experts, teachers, alumni, administrators of high schools, departments and offices of education, pedagogical faculty and students. Based on the learning outcomes that have been consulted with stakeholders, the university built an integrated teacher training program including modules and knowledge blocks to ensure that students will achieve the learning outcomes after completing the program. Along with equipping specialized knowledge, students can form their personal qualities and interpersonal skills such as communication, teamwork, presentation, and critical thinking, which are critically important for teachers in the 4IR era. It can be said that the CDIO teacher training program has fully covered the "hard" skills as well as the "soft" skills that were insufficient in the previous programs.

The Introduction to Teaching Profession is a typical course of the CDIO program, which was absent in the traditional model. It outlines the framework of teachers' competencies and responsibilities, as well as familiarizing students with the school context from the perspective of teacher students. With project-based learning, students often work in groups, present, debate and go on field trips to collect information to for projects on educational activities.

The feedback from students for the introductory course has been very positive. Students are more interested when they can directly "switch roles" from students to teachers when they interact with high school students, build their own educational plans and feel like they are "being a teacher". Students are more confident and self-assured when presenting in front of many people. These are one of the many important skills a teacher needs and that are beneficial when formed early in the training process. The Introduction to Teaching Profession Course not only instills career passion for students from the first year, but also helps them define what knowledge and skills to be equipped with in the remaining years to become a teacher.

The instructor's feedback about Introduction to Teaching Profession has been *"very effective and highly practical. It is consistent with the philosophy of "Theory and Practice go hand in hand"* (Report of Primary Education Department).

The mentoring role of the teacher is promoted and students are closer to the lecturers: *"The bond between teachers and students is enhanced because teachers frequently contact with students during group work and project implementation"* (Report of Mathematics Department).

In the first phase of CDIO program implementation, the remaining issue is that project-based learning did not include interdisciplinary projects in the CDIO programs.

4.3 Teacher Training Spaces

CDIO training programs require a learning space that supports and encourages the practice of building systems, processes and products, accumulation of disciplinary knowledge, and interactive learning. The CDIO learning space for engineering requires restructuring of the system for practice, experiments, self-study and group work to support students in implementing the CDIO process. For pedagogical disciplines, in addition to traditional learning spaces, such as classrooms, lecture halls, libraries, and laboratories, the university has built an additional self-study area that is open from 7 am to 10 pm, and assigns each faculty member to connect with school teachers to set up a network for students to practice, do internship and to exchange professional expertise. All these activities are designed to link the training process with practice via partnerships with 62 satellite schools. The collaboration between the university and the satellite schools is mutually beneficial. The cooperation agreement includes the following main details:

Table 3: Cooperation agreement between university and satellite schools

University	Satellite schools
<ul style="list-style-type: none"> – Arrange faculty members to support and advise satellite schools on the contents and methods of teaching, testing, assessment, practice and experiments in accordance with the National General Education Program 2018. 	<ul style="list-style-type: none"> – Coordinate and support the university in teacher training such as internship, practice, implementation of educational research.
<ul style="list-style-type: none"> – Support satellite schools in digitalization, including building an online learning management system (LMS); technical guidance on building e-learning lessons; building a model of combined teaching and flipped learning classrooms; share digital learning materials in the teaching and learning process of teachers and students. 	<ul style="list-style-type: none"> – Support the university in collecting opinions from stakeholders in order to implement the strategic plan for development of the university and curriculum development.
<ul style="list-style-type: none"> – Transfer to the satellite school the model of active teaching, programs and necessary materials for teaching and learning English at the school, with the outlook to international standards. 	<ul style="list-style-type: none"> – Support the university in developing continuous professional development programs for school teachers.
<ul style="list-style-type: none"> – Support and advise the satellite school on experiential activities, career guidance, life skills education, academic counseling and soft skills for students. 	<ul style="list-style-type: none"> – Support the university to develop faculty's professional skills.
<ul style="list-style-type: none"> – Support and advise teachers of satellite schools to implement initiatives in 	

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- teaching, and participate in contests for exemplary teachers.
 - Support satellite schools to build English speaking community models.
 - Coordinate with the university to implement piloting teaching models in accordance with the National General Education Program 2018.

Thus, the CDIO-based learning space for teacher training is not only confined to the main campus of the university but also expanded to a network of affiliated schools. Surveys on the use of study space show that students use the self-study areas and library to their fullest capacity for group work, project implementation and self-study. Before implementing the CDIO program, self-study and group work were not as effective.

Students only focused on studying in the last month before the end of each semester because their academic results depended largely on the final exams. The CDIO programs require ongoing learning and continuous assessment from the first week to the end of the course.

Findings from the interviews with students show that students were very satisfied with the new teaching method that focused on developing skills concurrently with equipping disciplinary knowledge. Students can enhance their skills of self-study and teamwork. At the same time, they can have the opportunity to interact with school pupils regularly.

Previously, the training program offered only two weeks of observation in the fifth semester and eight weeks of practicum at school in the final semester. Now students are more independent in the process of exploring knowledge and they can have more opportunities to do internship and practice in real-world situation. The fact that students are trained in an active learning environment will be a solid foundation for effective implementation of the National General Education Program 2018.

The feedback from lecturers on the use of learning space is that "*Students are excited to study and actively explore, create, practice teamwork and presentation skills*" (Report of Chemistry Department). Changing the assessment methods which involves multiple components also has a positive impact on the use of the self-study space: "*Students are more active in self-study, group work, searching for documents and learning content; Students' ability to present written reports is improved*" (Report of Foreign Languages Department).

CDIO's integrated program and active teaching method proved to be critically effective in the training process and suitable for career orientation "*The content of the course is designed in such a way that students can understand and remember what they learn deeply and it is in line with the overall general education program 2018*" (Report of Physics Department).

4.4 Active Learning Methods

To implement the CDIO training program, the university adopted a blended learning model (Graham, 2013; Dziuban et al., 2018), which combines virtual classes on the LMS (learning management system) with face-to-face meeting. The

teaching methods used by the lecturers are diverse, in which group activities are prioritized for development of communication and cooperation capacity. Furthermore, ICT application is maximized for students' independent learning.

Active teaching methods to form and develop disciplinary and professional competencies for learners are highly encouraged. Project-based learning which involves teamwork and student-centric activities is dominant during the training process. Through group activities, students develop skills for future careers (organization and teamwork, project development, micro-teaching, and presentations). For lecturers, through the process of implementation teaching activities, as well as learning from experience, especially after revising curricula, the awareness and responsibility of faculty members has increased remarkably. They have invested more time into improving the quality of teaching to meet the requirements of CDIO-based training.

Initially, some students could not follow the pace of learning as they had to work harder both in face-to-face classes and e-classes. Some instructors complained that *"Although in general, the academic performance of students looks positive, some students find it difficult to respond to the CDIO-based teaching because of their poor self-study ability"* (Report of Literature Department).

For large classes, the organization of group discussions and individualization of learning faced certain difficulties. The traditional arrangement of desks attached with benches is inconvenient for discussion and group work because it is difficult to move and rearrange them due to restricted spaces. At the early stages of CDIO implementation, some lecturers also faced certain pressures: *"The faculty members have to invest a lot of time to carry out the stages of CDIO. Some lecturers are not very proficient in the application of information technology in CDIO-based teaching. Some lecturers do not know much about CDIO training methods, so they are still confused in organizing teaching and managing students' self-study and learning records. This exerts a lot of pressure on teachers"* (Report of Political Education Department).

These are the difficulties that need to be solved in the upcoming time to improve the effectiveness of the CDIO training program.

4.5 Assessment of Learning

In accordance with the CDIO principles, the university's learning assessment is based on learning outcomes, including both continuous and summative assessment. The former comprises, but it is not limited to portfolios, quizzes, presentations, teamwork, and a midterm test; the latter is a final exam or other alternative forms of assessment, depending on the course learning outcome requirements. This is a significant improvement as compared with previous assessment schemes, which mainly relied on midterm tests and a final exam. The outcome-based assessment makes learning process becomes more productive and focused. The constructive alignment of learning strategies and evaluation to course learning outcomes help students to be informed of their progress at each stage of learning.

Moreover, the application of many forms of assessment based on learning outcomes creates a favorable condition for students to enjoy many opportunities to strive for high results for each subject and to meet the requirements of

competence-based examination, instead of knowledge-based tests. Ongoing assessment eliminates the stress and pressure of the exam as it once existed, and requires students to work through the process.

However, the implementation of the CDIO programs reveal that some problems need to be improved. Some lecturers still resorted to tests, which could not meet the requirements of the outcome-based assessment. They did not effectively use the rubrics for assessment of project-based learning. The report of Mathematics Department indicated that “A number of lecturers were used to paper and pen tests. Therefore, the shift to alternative assessment was a challenge for them at the initial stage.... The rubrics did not adequately cover the academic content, skills and other competences as indicated in the learning outcomes”. There was little involvement of school teachers in the assessment of professional skills.

4.6 Program Evaluation

The reform of Vietnam's higher education in the past five years has involved many aspects, in which educational accreditation has been of increasing importance. The revised Higher Education Law and training regulations require higher education institutions and training programs to be accredited. The program has been highly appreciated by external assessors due to the implementation of the teacher training program that adheres to the 12 CDIO standards. This is a new model of teacher training in Vietnam whose implementation is consistent with national and international accreditation standards. Of the 14 teacher training programs, the Mathematics Teacher Education Program was the first to be internationally accredited by AUN-QA (ASEAN University Network–Quality Assurance) in April 2021. The international assessors gave a high opinion of the program regarding its strengths, as detailed as follows.

The information in the Bachelor Program in Mathematics Education (BPME) Programme Specification is comprehensive and up to date with structured and logically sequenced curriculum, allowing students to focus on graduation internship to demonstrate the application of all they have learned from their courses.

The constructive alignment of teaching and learning activities with the BPME ELOs is evident in course specifications. The AUN-QA program assessment report of assessor’s interviews with school headmasters indicated that:

Employers identify teaching methodology as one of the main elements for BPME becomes a quality programme that produces good graduates. Various teaching and learning activities are employed to foster life-long learning competencies. Students are informed about details of their assessments which include methods, timelines, weight distribution through the programme and course specification documents. (AUN-QA program assessment report, 2021, p. 18)

In addition to the AUN-QA assessment of the Mathematics Teacher Program, eight other teacher training programs have also been nationally accredited, including English, Literature, Geography, History, Primary Education, Nursery Education, Physical Education, and Chemistry. Thanks to CDIO-based curriculum development, all these programs were highly appreciated by the external assessors.

The assessed curricula are said to be structured and constructed in accordance with the program learning outcomes, integrating relevant knowledge, skills, attributes, and qualities that are required for future teachers. Methods of teaching and assessment are in line with competency-based education. For instance, the English Teacher Education Program is integrated with skills, knowledge, competencies, and attributes that are highly relevant to the teaching profession. The CDIO approach to curriculum development and program implementation gives students many opportunities to intensive practical experience during the training process.

The external assessors have a consensus that the CDIO approach to curriculum development at Vinh University is a new model of teacher training program that is highly relevant for the 4IR and it is particularly effective during the Covid-19 pandemic thanks to the integrated and blended mode of teaching and learning.

5. Conclusions

The CDIO-based teacher training programs at Vinh University grew out of the need for a fundamental education reform in the context of 4IR. It is shown that the CDIO-based education innovation requires implementing large-scale changes that involve significant shifts in the culture of teaching, learning and evaluation across the entire university. These changes involve revamping the structure and contents of its curricula, as well as changing the principles and practices of university management and governance.

Furthermore, a high priority and enabling factors for the curriculum reform process are enhancing faculty teaching competence, their personal and interpersonal skills, product, process, and system building skills, as well as disciplinary fundamentals. The study of the CDIO-based teacher training program implementation at Vinh University has proved that the CDIO framework is highly applicable for pedagogical programs. It is not only suitable for the outcome-based teaching and assessment, but also relevant for developing professional skills and competence with which future teachers need to be equipped.

It should be noted that the CDIO standards have been updated with version 3.0 (CDIO, 2022). In addition to a physical learning environment, a digital learning environment that includes on-line tools and spaces that support and enhance the quality of teaching and student learning is required for teacher training programs. This study is hoped to make contributions to the innovation of teacher training programs based on the CDIO standards.

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