International Journal of Engineering Research and Technology.
ISSN 0974-3154 Volume 11, Number 7 (2018), pp. 1129-1148

http://www.irphouse.com

Building CDIO Approach Training Programmes against Challenges of Industrial Revolution 4.0 for Engineering and Technology Development

Thi Lan Anh Vu

Ho Chi Minh city University of Transport, Ho Chi Minh, Vietnam.

Abstract

Industrial Revolution 4.0 has brought a great deal of opportunities and challenges to the Vietnamese economy in general and to the Vietnamese education in particular, especially in higher education. Students in Industry 4.0 are required to adapt to a comprehensive change from perception to action, from which they are able to adapt themselves to a new working environment with frequent changes and continuous development. The recent Age demands the personnel with critical thinking, creativity, innovation, information analysis and synthesis, independent working ability and decision making capacity based on an analysis of data and proof. These are the skills that most Vietnamese students lack. To fill in this gap, education 4.0 will be one of the efficient solutions that the higher education needs performing. This article focuses on clarifying the relationship between Industry 4.0 and education 4.0, presents the Vietnamese education practice and proposes some solutions related to the building and innovation of academic curriculum with CDIO methodology through analyzing CDIO standards.

Keywords: Industrial Revolution 4.0, Education 4.0, CDIO, innovation, higher education.

I. INTRODUCTION

The present world has been experiencing the most significant changes. The forth Industrial Revolution 4.0 or Industry 4.0 has been creating strong evolutions, influencing on every aspect of people's life in the 21th century [1]. This revolution will have significant influence on global economy and society in which education plays an important part. It poses urgent issues for education. If we considered education, especially higher education, as a preparation for learners to confidently step to the world of work, universities are required to equip them with necessary skills, not just for their present but also for their future as well. To meet the human resource requirements for the new industry and make use of Information Technology, many universities worldwide have been innovating comprehensively and so Education 4.0 is considered as a suitable model [2]. The reception of changes to meet the requirement and keep up with the Industry 4.0 has posed critical and urgent issues to higher education. Education 4.0 is a model applying advances of information technology to update the efficiency of training and education, making the teaching and learning activities take place anytime and anywhere. More specially, it helps change the thinking and approach to higher education model. In the Education 4.0, universities are not only the places where the research and training are preformed but they are also centers for creative innovation, practical problem-solving and society value addition [3].

Universities have been questioning how to innovate teaching methods, develop training curriculum, apply IT advances to upgrade the efficiency of teaching and learning and increase the popularity of teaching and learning. The Vietnam Ministry of Education and Training (MOET) encourage universities to carry out the fundamental and comprehensive reform requirements of the education sector in the spirit of the 12th National Party Congress's Resolution, approaching to a modern and internationally integrated education with the trend of innovation in teaching methods, testing and assessment, development of teaching staff and educational managers, individual branding to attract learners and most importantly, to a satisfaction of the increasing demands of the society [4]. In the time when the education and training tailored to meet the requirements of the society and enterprises have become an essential factor to the socio-economic development, the approach to CDIO is an inevitable part towards advancement, in accordance with the trend and tendency of the world development, combining academic curriculum development with Higher education transfer and assessment, contributing to an improvement of the teaching and learning quality of universities in global innovation and integration that takes place worldwide [5][6].

To face great challenges of Industry 4.0 and Education 4.0, the roles of standards in the 12 CDIO Standards needs adjusting and updating to be the basis for the guidance to reforms and assessments of education programs. The creation of new standards with the global application capacity in the Education 4.0 trend is crucial the present time. In recent years, Malmqvist, Edstrom & Hugo (2017) [7] have proposed a set of 7 optional standards aiming to upgrade and expand CDIO Standards [8]. Presently, the new CDIO Standards have been thoroughly studied and discussed to come to an agreement with an update of CDIO Standards. This article centers on a contribution of ideas and initiatives to CIDO Standards innovation in the new Age, based on the method approach of assessing 12 existing CDIO Standards in the vision of new manufacturing world of Industry 4.0 [9].

II. INDUSTRY 4.0 AND EDUCATION 4.0

II.I. INDUSTRY 4.0

The concept of "Industry 4.0" used the first time in 2011 at the Hannover Fair- a world leading Fair of Technology and Industry- is annually held in Germany. In 2012, the term "Industry 4.0" is mentioned in a document proposed to the Federal Government of Germany to collect recommendations to deploy strategic initiatives of "Industry 4.0" to ensure the future development of German manufacturing industry carried out by Industry 4.0 working team with the funding of Federal Ministry of Education and Science [10].

The concept "Industry 4.0" was the first time mentioned and was also the theme of the 46th Economic Forum organized on January, 20th 2016 in Davos-Klosters, Switzerland. However, the impacts of the Industry 4.0 were felt at the end of the 20th century and at the beginning of the 21st century especially in developed countries. Being different from the previous revolutions, Industry 4.0 is not associated with the birth of a particular technology, but the combining result of various technologies such as advanced technology for waste energy [11][12], the use of alternative and renewable fuels for the reduction of environmental pollution [13][14][15][16][17], the impacts of as-used technologies on the environment [18][19], the issues of environment [20][21][22][23][24][25][26], in which the Nano, biology and information- media technologies or advanced materials are the centre [27][28][29][30][31][32][33]. The evidences for this combination of these technologies and the revolutionary advances they bring are presented in a quite ambitious project called NEURALINK [34].

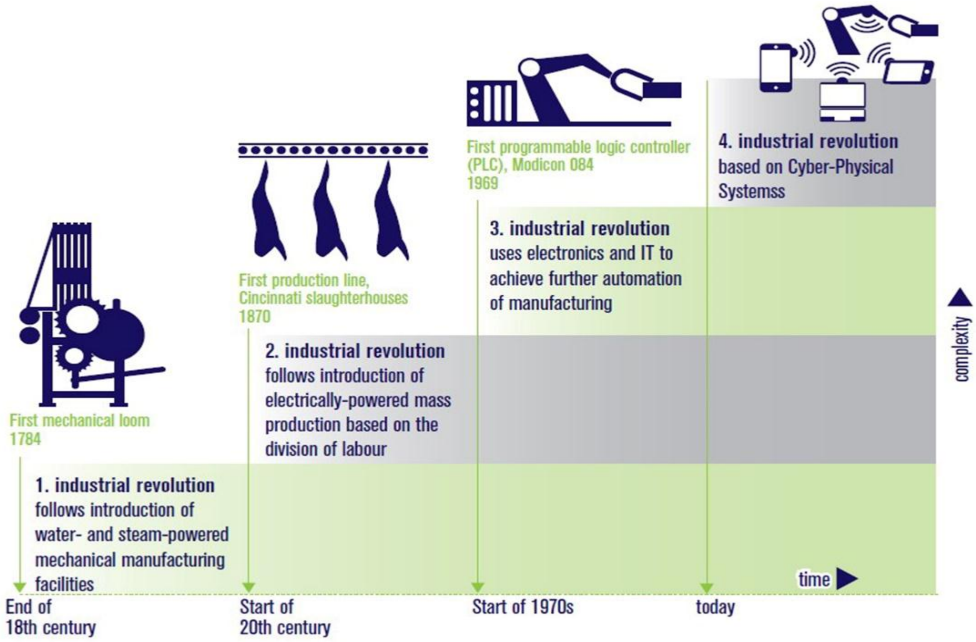

Figure 1. Four Industrial Revolutions [35]

The project funded by an American billionaire connects human brains with computers to create super artificial intelligence as compared to human intelligence. The American futurist, entrepreneur, and author Raymond Kurzweil predicted that by the 2030s robots with Nano-sizes implanted into the human brains will make human have God-like capacities. If Raymond Kurzweil's prediction is right, and Elon Musk's NEURALINK ambitious project is successful, the vision of robot-governed Humans will possibly become true in case the tech advances are not used in an appropriate way. The nature of Industry 4.0 is the formation of digital world, basically being lively reflection of, and in existence with the physical world. The combination of physical world and digital world has created revolutionary impacts on every aspect of economic, political cultural and social life of human beings. Digitalization both helps improve the operation efficiency of enterprises and fundamentally transform their business operation models. In the Age of Industry 4.0, globalization becomes deeper; change takes place at greater range, more insensitive strength and unpredictable speed.

II.II. CHALLENGES OF INDUSTRY 4.0 TO HIGHER EDUCATION

Education is one of the sectors experiencing the most rapid impacts of the Industry 4.0 because the education itself will create new versions of the following revolutions. Revolution 4.0 promises to provide new changes to education and training activities, transform traditional training objectives and models by transferring and training completely new knowledge. Information technology development, digital tools, connected network systems and super data will be good tools and facilities to change ways of teaching organization and methodology. Traditional classrooms with drawbacks including costly organization and limited serving spaces that are inconvenient to particular learners will be replaced by online and virtual classrooms [2]. The quality of online education can be easily regulated by assisting tools, such as sensors and network space connectors. Learning spaces will be more varied, instead of traditional laboratories or simulations, learners will experience learning with virtual spaces, with interactions in true-like conditions through software's and network systems. Big data will be unlimited data resources for analysis, trend identification or business prediction with high precise. Digital learning resources in the condition of connecting real and virtual spaces will be of full plenty. Library spaces will not be a particular place, but they will be able to be operated anywhere with very simple actions. Academic curriculum will also be more variedly and particularly designed and will better satisfy learners' demands [36].

Figure 2. Virtual reality

Apart from the advantages brought about by Industry 4.0, there is a great deal of problems posed to education sector that require universities to solve in the coming time. In the first place, the foundation of Industry 4.0 is the relationship between reality and vitality through IT software's, digital tech and network connections; therefore the knowledge and skills of IT and digital tech play a very important role to IT suppliers and consumers. The responsibilities of universities in the coming time are to provide adequate number of IT experts, equip graduates with relevant digital tech knowledge and skills to meet the society requirements in the Industry 4.0 [3].

Figure 3. Evolution of human beings over time

Secondly, the jobs and unemployment are the common issues as a result of the Industry 4.0, especially at the beginning time when labor forces fail to adapt to new industrial working conditions and a strong shift in the job structure among sectors. In fact, there have been job changes in the labour market, robots have taken over human beings to carry out manual work. Robots with unlimited learning resources can perform teaching of certain subjects such as geography, history and so on, and they can completely take over the teaching staff at present. Jobs in law consultancy, accounting, tax consulting will possibly be replaced by smart robots. Therefore, the problem posed to universities is the training orientation to satisfy occupation requirements of Industry 4.0 and retraining for new careers [37][34].

Thirdly, the present training programs are not flexible and their contents are not suitable with the need and trend of the labour market of Industry 4.0. Education and training is one of the 9 considerably changeable fields. Vocational systems will be strongly and entirely affected, occupational training lists and curriculum will be continuously adjusted and updated as there is a fine-line between fields. Universities undertake training activities in accordance with the two directions: on the one hand, they should meet the social orientation; on the other hand, they provide labour forces to satisfy the requirements of the labour market. However, the pressure to universities is higher when the training curriculum is not only able to meet the high expertise in particular majors, but also the interdisciplinary knowledge, for instance information technology, digital tech, networking and professional knowledge. The academic curriculum should cover inevitable skills, such as systematic thinking, synthesis, relating capacity between reality and virtuality, creativity, teamwork, interdisciplinary cooperation. In the context of fast changing tech knowledge, an acquisition of self-study and continuing study skills is of greater importance than the knowledge of the academic curriculum itself [38]. Thus, Industry 4.0 has created huge pressure on the university training activities, ranging from academic curriculum building and content update to providing learners with necessary skills to meet the industry demands.

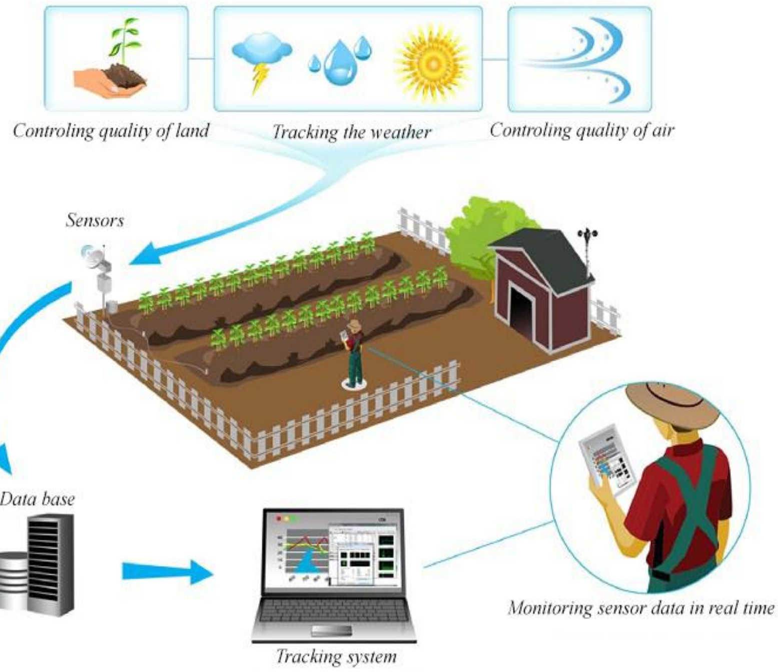

Figure 4. Ways of working in Industrial 4.0 [38]

Fourthly, another issue for higher education institutions is the way to organize the content of the curriculum to the learners. Revolution 4.0 requires innovative training methodology and methods with the powerful application of information technology [39], digital technology and networking. Online training, virtual training, simulation, digitizing lectures ... will be the trend of vocational training in the future. This puts great pressure on the training institutions to prepare resources for teaching, especially teaching staff, to build learning space.

II.III. EDUCATION 4.0

Education 4.0 - education is born to meet the needs of the 4.0 industry market. Education is popular in places where human beings, objects and machines are connected to create personal learning. The characteristics of education systems can be outlined in the following Figure 5 [3]:

	Meaning is ….
"Download" Education 1.0	Dictated
"Open Access" Education 2.0	Socially constructed, usually with aid of Internet access
Knowledge Producing Education 3.0	Socially constructed and contextually reinvented knowledge
Innovation Producing Education 4.0	Built through selective individual and team-driven focused innovations practices
	Technology is …..
"Download" Education 1.0	Confiscated at the classroom door (digital refugees)
"Open Access" Education 2.0	Cautiously adopted open access (digital immigrants)
Knowledge Producing Education 3.0	Everywhere (digital natives in a digital universe) for ubiquitous knowledge construction and transmission
Innovation Producing Education 4.0	Always changing with the direct input of learners acting as a major source of tech evolution in the service of innovation production
	Teaching is done….
"Download" Education 1.0	Teacher to student
"Open Access" Education 2.0	Teacher to student and student to student (progressivism); Internet resources are a normal part of learning activities
Knowledge Producing Education 3.0	Teacher to student, student to student, student to teacher, people-technology-people (co-construction of knowledge)
Innovation Producing Education 4.0	Amplified by positive innovation feedback loops; ubiquitously and creatively 24/7 in all phases of living, learning, and working;
	Schools are located in…..
"Download" Education 1.0	In a building (brick)
"Open Access" Education 2.0	In a building or online (brick and click), but increasingly on the Web through hybrid and full internet courses
Knowledge Producing Education 3.0	Everywhere in the "creative society" (thoroughly infused into society: cafes, bowling alleys, bars,
Innovation Producing Education 4.0	In the globally networked human body, a continuously evolving instrument innovatively supplementing

Figure 5. The characteristics of education systems

Education 1.0 Learners that want to learn must go to school

In the class, teachers read and learners copy (one-directional knowledge transmission). Learning resources are mainly from copied lectures and textbooks. This way of teaching is called lecturing.

Education 2.0 Teaching and learning is marked by the use of network

Internet expands online training space so that teaching and learning can be done anytime and anywhere. Teachers make good use of technology and teaching materials available online. With the Internet, the use of online information to supplement learning materials from teachers and textbooks has become popular. Learning is expanded through interactions with other students, not just only with teachers.

Education 3.0 Education serves intellectual economy.

Education 3.0 is marked by the formation of Massive Open Online Courses (MOOCs) such as Coursera, Udacy, edX, Udemy, Khan Academy, etc. so eductaion is globally socialized, not limited to particular participants. The philosophy of teaching and learning methods also varies a great deal from traditional classrooms to blended and reversal education [2]. The blended approach combines face-to-face with online teaching and learning to maximize time and space. Reversal classes completely change the traditional training process. Learners acquire basic knowledge outside class from the institutions' on-line documentation, MOOC open systems, Wikipedia, Youtube, etc. In the classroom, they learn to apply knowledge to solve problems, communicate with teachers and with their partners. The role of the teacher changes as well. Teachers play a role of facilitators and supporters for the learning process to take place, they not only 'teach' knowledge to students.

Education 4.0 Education serves creative economy

Education 4.0 will be marked by a major shift in training objectives, from the transfer of knowledge to the masses through the exploitation of resources (empowerment, capacity, and motivation) and empowering innovation to individual. Whilst the individualized training is increasingly upgraded, the mission of training transcends national boundaries to serve humanity.

Industry 4.0 and people in society 4.0 have brought many challenges to education to meet the needs of the development of every mation. Education in advanced countries is currently at 3.0 and these countries are building the infrastructure as well as the mechanism to move to 4.0. Southeast Asian countries, such as Malaysia and Thailand, once at similar development level to Vietnamare, have been actively improving their national education to welcome Industry 4.0. Meanwhile, Vietnam national education is still at 2.0 [1].

To be able to adapt to the rapid changes in the labor market and to the need of addressing complex multidisciplinary issues with which intelligent systems such as robots are unable to deal, higher education needs to build a compatible environment, based on the goal of inspiring individual creativity. This environment should integrate both school systems where faculty exchanges and direct tutorials with students and the online system to meet the needs of self-study wherever students are and whenever they are ready for their study. The envirronment should facilitate them to confidently communicate, criticize, connect and collaborate. It encourages students to actively maximize their potential in the journey to apporach and apply knowledge of creativity [36].

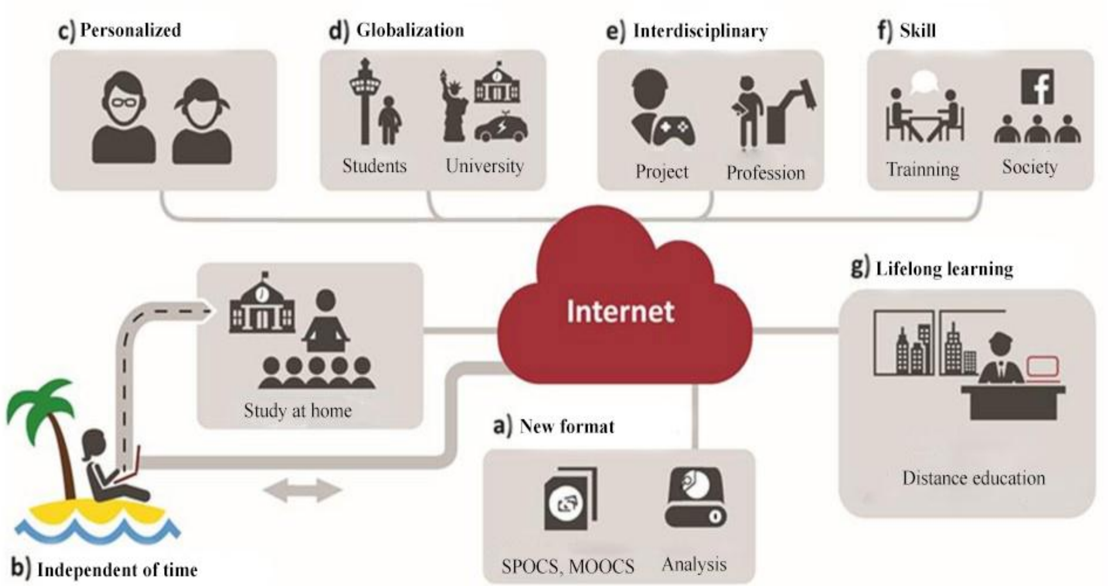

Figure 6. Education 4.0 [40]

Apart from self-study, the ability to unlearn the old theretical knowledge that is now obsolete or contradictory to operating principles of new technology, is essential to keep up with the pace of technology change. Unleraning skills are important issues that many educational systems have not mentioned yet. In addition, soft skills such as teamwork, negotiation, emotional intelligence, and service spirit will become increasingly important.

Qualifications will be assessed by the level of creativity and the ability to solve a multidisciplinary problem at a complex level according to each student's competence but not by the ability to acquire a certain amount of knowledge, such as the number of credits or subjects of a particular discipline.

There will be no longer a bachelor's degree in economics, a bachelor's degree in languages or a bachelor's degree in physics but a bachelor’s degree. Nor will there Bachelor’s degrees in software engineering, in computer engineering, or in mechanical engineering, but an engineering degree. The academic training will be personalized according to indivisual preferences, abilities and passions. Like vocational training, enterprises will be an indispensable part of the university training environment. Businesses will accompany the faculty to create conditions for students to improve their knowledge and maximize their skills and solve practical problems to integrate into the progress of the world [41] [42] [8].

Training human resources for the labor market at any given moment requires time. It takes a person at least 16 years to obatin a college degree from child to adult. Re-training of human resources to meet the needs of the market takes at least two to four years on condition that the educational system for this purpose is existing.

III. COMPARING CDIO FRAMEWORK WITH INDUSTRY 4.0

A current lack of a framework for addressing educational needs to meet sectoral requirements of Industry 4.0 is illustrated in previous sections. Cheah (2018) [43] noted that the lack of research in this area may be due to the technical core of Industry 4.0; and so technical challenges and participants are emphasized on in most of the work related to CDIO Framework. As a contributor to CDIO, we are interested in finding out if the CDIO Framework we have applied for nearly 10 years can serve the purpose of guiding us in redesigning our engineering curriculum [44].

When looking at the CDIO Syllabus, we found that the initial syllabus was built in 2001 and it was later updated in 2011, with missing skill addition and nomenclature clarification to make the Syllabus more explicit and consistent with national standards [7]. We know that that the new knowledge under the request of Industry 4.0 can be presented in Part 1 of the Disciplinary Knowledge and Reasoning of the CDIO Syllabus v2.0. Subjects on IoT, CPS, Cloud Computing, Data Analytics, etc can be updated in Part 1. As stated by Smulder [5]: “The placement of this item at the beginning of the Syllabus is a reminder that the development of a deep working knowledge of technical fundamentals is, and should, be the primary objective of undergraduate engineering education.” It is found that most parts of the Syllabus are familiar to engineering professions, except Part 1. Approximately the same set of personal and interpersonal skills are used and the same generalized processes are followed by engineers of all types. This is a neat arrangement as it allows educational institutions adopting the CDIO Framework to customize the programs to include new knowledge brought about by Industry 4.0 into the CDIO Syllabus without altering the overall general format of the document. Thanks to all mentioned above, it can be concluded that all the skills required for Industry 4.0 have been sufficiently covered in the present CDIO Syllabus [43].

Next, it is known that Parts 2, 3 and 4 of the CDIO Syllabus are shown in the category types. In each part, skills and attributes are divided into sub-categories down to X.X.X.X level. The number of entries increased from the version 1.0 to the version 2.0. We have encountered some challenges when executing the authentication files of the required skill sets with key industry stakeholders [45]. We need significant amount of time to invest in “educating” industry counterparts firstly on the CDIO Syllabus in general, and secondly in the knowledge that underpins each skill. The relationship between the skills and attitudes is also problematic. Industry 4.0 will be possibly applied by different sectors at different degrees [46].

Industrial engineering and process automation which are the leading fields experience widespread implementation of various Industry 4.0 solutions on the factory floor. The chemical treatment industry has adopted a consistent management and control system in its day-to-day operations, and can see Industrial 4.0 applications in streamlining operations through the complete value chain. The skills and attributes required by process technicians in the chemical processing industry may not be much changed, compared to one involved in shop floor automation.It is therefore important for program owners to seek the validity with relevant industry stakeholders on revised educational goals in any redesigned curriculum. We found that Profiles skills approach mentioned in the previous section is more useful and manageable approach for the authentication process and would like to suggest that an evaluation proposal be implemented by the CDIO collaborators. Program designers should cluster main and key capabilities based on one's job role in a job defined function.

Other organizations such as OECD use the same approach within their capacity [4]. Next we pay attention to the CDIO standards. Using information from our reviews of Industry 4.0 and its implications on technical education mentioned previously, we set out each study of the CDIO standards, carefully review the "Description" and "Reason" of each standard, and view them through the lens of Industry 4.0 to determine the suitability of each standard. Where appropriate, each "Description" and "Reason" is reinterpreted with specific reference to major topics in Industry 4.0 [45]. Each CDIO standard and its brief note are displayed in gray boxes and the level of conformity of that standard for Industry 4.0 is shown below the gray boxes, with brief explanations on how standards can grasp the elements of Industry 4.0.

CDIO Standard 1 - The Context*: Acceptation of the principles of development and deployment of product lifecycles, processes and systems - Awareness, Design, Deployment and Operation – are the context for technical education.*

Relevance to Industry 4.0: This is clearly still relevant in the context of Industry 4.0, but with new emphasis on the importance of working in multidisciplinary teams; Because the nature of the product, process, or system is different and therefore the development and deployment of the life cycle is likely to be shorter. An example can be taken from the field of biomedical devices.

CDIO Standard 2 – Learning Outcomes: *Program stakeholders should validate detailed learning outcomes, which must be consistent with program goals, for personal and interpersonal skills, and production, processes and systems development, as well as disciplinary knowledge.*

Relevance to Industry 4.0: When assessing the relevance of the CDIO Syllabus, we can see that the learning outcomes mentioned in the CDIO syllabus are still relevant, but confirmation with stakeholders is vitally important and a review of the process using a Skill Profile is recommended instead of rating each skill one by one.

CDIO Standard 3 – *Integrated Curriculum:* *In Integrated Curriculum supporting disciplinary courses are included to integrate personal and interpersonal skills, and product, process, and system building skills.*

Relevance to Industry 4.0: According to this standard, new knowledge on topics in Industry 4.0 such as Internet of Things (IoT) and data analysis should be addressed in appropriate modules, the depth of which depends on the needs of each discipline. and the school year. For example, specific information on the performance of critical equipment (eg, catalytic reactors) may be a brief introduction to IoT for chemical engineering sophomore year, while detailed data analytics is a necessary skill in the course of network security or consumer behavior. Similarly, skills such as virtual collaboration should be integrated into the appropriate module (s) to develop the required competencies throughout the learning period.

CDIO Standard 4 – Introduction to Engineering: This is an *an introductory course that provides learners with engineering practice in product, process, and system building, and essential personal and interpersonal skills are also introduced over the duration of the course.*

Relevance to Industry 4.0: In order to meet Standard 4.0, the introductory syllabus of engineering majors must include an introduction to industry 4.0 and its role in the discipline. This means that students must be involved in assignments, exercises, and projects related to Industry 4.0 such as Big Data, data analysis, and management of resources and data.

CDIO Standard 5 – Design-Implementation Experiences: *A training program includes at least two design-implementation experiences, covering one at basic level and the other at advanced level.*

Relevance to Industry 4.0: It must be recognized that current training programs for the technical disciplines of both domestic and regional universities do not meet the requirements of the Industrial revolution 4.0. Schools are staggered in building a flexible and effective curriculum for students in the trend of training human resources for this fourth industrial revolution. Therefore, we are not advocating the addition of design-implementation experiences at advanced level. Instead, universities should carefully consider the development of experiential projects that currently derive from the ideas and applications of the industrial revolution 4.0. To do that, schools need to collaborate with the industrial units that they are associating with and provide human resources for a variety of experiential and practical projects for students. Particular attention should be given to promoting multi-disciplinary projects in such a way that students can demonstrate their competences in various CDIO skills, including the new set of skills required in Industry 4.0.

CDIO Standard 6 – Engineering Workspaces: *Technical workspaces and laboratories support and encourage hands-on learning in product design, processes, and systems; specialized knowledge; and social learning.*

Relevance to Industry 4.0: To focus on Industry 4.0 in Standard 5, the concept of workspace should be extended beyond the University campus. The space must include shops, complex and processing factories so that students can complete their internships with real-world experience. In addition, students need a virtual space (virtual learning environment or VLE) to simulate experiments, especially those related to virtual reality (AR / VR). Such working environments, especially cyberspace, can enhance "hands-on" with "minds-on" learning. For example, with the AR / VR environment, students can try out different combinations of products, processes or systems that require excessive costs.

CDIO Standard 7 – Integrated Learning Experiences: *Integrated learning experiences lead to the acquisition of specialized knowledge, as well as personal and communication skills, product, process, and system building skills.*

Relevance to Industry 4.0: As mentioned in standard 6, the fact that students are learning and practicing in an online environment such as cloud data that may promote personal skills, interaction and communication. The AR / VR environment may not be as realistic as factories and workshops, but it is safe and facilitates the upgrading of new skills of the present time, such as dealing with a problem in the process to minimize the risk of harm. Moreover, Industry 4.0 is capable of allowing simulations to be performed in a more realistic environment such as 24/7 real-time reflection and adult learner work cycle.

CDIO Standard 8 – Active Learning: *Teaching and learning is based on active learning approaches*

Relevance to Industry 4.0: Cloud, IoT, role playing environments in AR / VR, etc. all provide opportunities for learners to engage in active learning, in a new way; especially in online collaboration among colleagues, or in the implementation of real-world tasks such as emergency response to a chemical accident, which would be extremely dangerous if it occurs in the experimental and practice spaces in the university campus. This also means that high-level thinking skills (exploring different scenarios or outcomes) will be well-trained and in-depth. Current positive learning methods such as pair-work, group-work, quick notes, etc. will still be used but they are more effectively implemented by using innovative technology, notably through the tools of EdTech.

CDIO Standard 9 – Enhancement of Faculty Competence: *Capacity building actions for trainers in personal and interpersonal skills, product design, process, and systems skills.*

CDIO Standard 10 – Enhancement of Faculty Teaching Competence: *The actions enhance the faculty's capacity to provide integrated learning experiences, in the use of active learning approaches, and in the assessment of student learning.*

Relevance to Industry 4.0: The changes in student learning in the trend of 4.0 industry as previously discussed have set the faculty's requirements for selecting teaching methods and adapting to the new learning environment. Faculty should equip themselves with new ways to engage students through online data such as the cloud, EdTech tools, use of AR / VR, etc. They need to integrate new skills identified in the requirements of Industrial 4.0 into the modules they are teaching. Faculty also needs to be trained in how to use and analyze data that can analyze the student's experiences in real time and take timely corrective action. In particular, faculty need to be equipped with digital training skills and solve common problems in virtual worlds.

Finally, faculty members need to update their knowledge of the 4.0 industries that is affecting the industry they are serving. This requires a thoughtful strategy and plan for engaging faculty members among universities, especially during times of manpower crisis.

CDIO Standard 11 – Learning Assessment: *Student assessment of personal and communication skills, and product, process, and system building skills, as well as specialized knowledge.*

Relevance to Industry 4.0: How will the impact of the industrial revolution 4.0 affect the way students learn, and how does this govern the way of assessing student learning? For example, the ability to analyze data will bring about changes in the way students are evaluated. More focus is needed to assess the formation of data when they are available in real time to address the challenges of specific learning situations (such as misconceptions, wrong assumption) in the classroom. High-level or more difficult assessments can be made based on real-world "What-If" scenarios (see Standard 8) based on emergency situations simulated in AR / VR.

CDIO Standard 12 – Program Evaluation: *A system for evaluating programs in accordance with these 12 standards, and providing feedback to students, faculty, and other stakeholders for continuous improvement.*

Relevance to Industry 4.0: This standard is extremely important because it will motivate for continuous improvement. As noted in Standard 1, the application of Industry 4.0 will directly affect the formation of new skill sets. Moreover, advances in technology will continue to impact on the development of new skills. Therefore, the most important thing is that the training program must be regularly evaluated, for example, within 3 years instead of the accepted time of 5 years.

In summary, when comparing the CDIO curricular and standards, we found that the CDIO curriculum framework is closely linked to industry 4.0. However, the curriculum and future learning styles will have to change to meet the requirements of the practice. In particular, the curriculum needs to be broader to provide more opportunities for interdisciplinary projects, expanding cross-disciplinary subjects such as data analysis or CPS through optional modules. These topics can be provided by industry experts or by those with the most up-to-date knowledge in fast-changing industries. In addition, the length of study at the workplace is extended, for example by extending the 6-month or longer practice period. To achieve this goal, universities need to actively expand their links and deepen their collaboration with the relevant industry. We would think that we need to add two more criteria: Firstly, educational institutions need to be more actively involved in cooperation with business partners and public institutions, notably potential employers; Secondly a detailed guide needs providing for the institution in the management of student learning at work and internships. Therefore, we would propose two criteria that will be presented in the next section.

IV. RECOMMENDATIONS

The first additional Standard that we propose, namely Standard 13, is Industry Engagement, defined as “Actions that education institution undertake to actively engage industry partners to improve its curriculum”. The aim of any curriculum improvement is to prepare graduates for industry. Some of the learning outcomes specified in the program aim at or articulated in the organization's graduate attributes can only be attained in real world workplaces.

Supportive industry partners can help deliver such learning experience to students.

Students find the real world context meaningful and engaging to them, it not only helps to connect between what is learned in campus and what is being practiced in the industry, but can also help improve understanding of the expectations of the real world and shape their minds, making them be ready for work and be ready for the world. The CDIO Standards have been recognized as useful involvement of stakeholders in the sector. The importance of industry engagement in the study field is huge and it can address the requirements raised in most, if not all, of the 12 existing CDIO standards.

Industry partners play a crucial role in the training of students to be the professionals in their field, for example, by providing them opportunities to experience real-world work environment via industrial attachment or internship (Standards 1, 7). Students can also work on real-world projects while on industry attachment or internship, or in campus working on industrysponsored projects (Standards 5, 6). Industry partners can serve as judges evaluating the work done by students (Standard 11). Even routine, office-type work is authentic and experiential for students (Standard 8). Industry partners can also complement students’ academic studies by taking up teaching role as adjunct professor, as speakers for course seminars, or as members of a program’s advisory panel. They can also partner with academic staff to jointly develop curriculum that is directly relevant, up-to-date and useful to the industry. In addition, industry partners can also support the educational institution’s continuous professional development program by offering staff placement opportunities for teaching faculty to upgrade his/her technical know-how (Standards 9, 1 0). Of course, the issue of industry engagement is not new, and it may be argued that industry engagement is already implied in Standard 1 (CDIO as Context) and Standard 12 (Industry partners and stakeholders).

However, we believe that the advent of Industry 4.0 has brought to the fore its importance. We believe that having a new standard specifically aimed at Industry Engagement has its merit, to make explicit the necessity of actively seeking industry feedback not just in designing of our curriculum, but also in delivering them for example through co-teaching and co-supervision of projects.

The second recommended standard, which is temporarily labeled as Standard 14 Workplace. Traditionally, the term "learning" is related to formal education, i.e. in classes in institutions. More and more people are interested in workplace learning, driven by unprecedented changes brought by recent technological developments, most recently under the banner of industry 4.0. Recent research on the outcomes of higher education has provided evidence of the gap between the knowledge and skills needed at work and those produced through formal education.

Workplace learning can enhance in-campus learning by providing students with opportunities to apply classroom knowledge in real-world setting, and in some cases, to deepen that technical capability. It can also add value to the development of desired graduate attributes such as professional and ethical responsibility, appreciation of social, cultural and environmental context of engineering practice, etc. – the sorts of abilities that cannot be acquired by sitting in lecture halls.

In various literatures, the terms like work-based learning, work-integrated learning, and work-related learning were used to show the plenty of definitions for the terminology “Workplace Learning”. In the present context, we define workplace learning as “A curriculum that includes students working in a real-world work environment with the aims of strengthening in campus learning and developing their professional identity” [1]. While implementing workplace learning have faced many challenges, such as maintaining consistent desired learning outcomes among students attached to different companies, the pedagogical convergence between work-based learning and campus-based learning was made possible thanks to technological advances. Designing a more authentic learning experience for students is a necessary skill for faculty and should be guided in existing CDIO Standards supplemented with a separate standard on workplace learning.

V. CONCLUSION

This article provides a brief introduction to the 4.0 industry, and shares the results of a study of the relevance of the CDIO Framework to industry 4.0. It concludes that the CDIO Framework - both the Syllabus and the Standards - is still relevant as a reference to guide the redesign of engineering education. For the CDIO curriculum, it is proposed that skill sets be validated with key stakeholders using the "Skills Profiling" method rather than the listed ones when the framework is firstly constructed. For the CDIO standards, it is proposed that their interpretation be extended to take into account the specific features brought about by Industry 4.0, notably the real-world learning through industrial and environmental projects, virtual learning and collaboration. Finally, it also suggests that two new standards - namely, Industry Engagement and Workplace Learning – be introduced. It is believed that the ideas presented and recommendations will prove to be valuable for program owners on how to use CDIO Framework to modify their curricula for better preparing graduates for the world of Industry 4.0. The authors also suggest that the proposal in this paper be considered as the first draft, to be further explored by the CDIO community for its recognition and acceptance.

REFERENCES

[1] H. Karre, M. Hammer, M. Kleindienst, and C. Ramsauer, “Transition towards an Industry 4.0 state of the LeanLab at Graz University of Technology,” Procedia Manuf., vol. 9, pp. 206–213, 2017.

[2] S. D. Göker, “Reflective models in teacher supervision introduced by education 4.0: the teacher in the mirror,” 2017.

[3] A. M. Harkins, “Leapfrog principles and practices: Core components of education 3.0 and 4.0,” Futur. Res. Q., vol. 24, no. 1, pp. 19–31, 2008.

[4] T. Hyland, J. Buckley, N. Seery, S. Gordon, and D. Canty, “Assessing Design Activity in Engineering Education: A Proposed Synthesis of Adaptive Comparative Judgement and the CDIO Framework,” in ASEE Engineering Design Graphics Division 72nd Mid-Year Conference, 2018.

[5] Y. SHIMIZU, S. THOLLAR, Y. ANADA, and N. HAYATA, “The Application of CDIO Standards to Clinical Engineering Education,” 2018.

[6] R. F. Mustapa, A. F. Z. Abidin, A. A. N. M. Amin, A. H. M. Nordin, and M. N. Hidayat, “Engineering is fun: Embedded CDIO elements in electrical and electronic engineering final year project,” in Engineering Education (ICEED), 2017 IEEE 9th International Conference on, 2017, pp. 1–6.

[7] F. Smulders, A. Kamp, and C. Fortin, “The CDIO framework and new perspectives on technological innovation,” 2018.

[8] S.-M. Cheah and H. Leong, “Relevance of CDIO to Industry 4.0–Proposal for 2 New Standards,” 2018.

[9] A. Benešová, M. Hirman, F. Steiner, and J. Tupa, “Analysis of Education Requirements for Electronics Manufacturing within Concept Industry 4.0,” in 2018 41st International Spring Seminar on Electronics Technology (ISSE), 2018, pp. 1–5.

[10] J. Brach, “Mobility 4.0, Commercial Vehicle 4.0 and Transport 4.0 Theoretical and Practical Aspects,” Res. J. Univ. Gdańsk. Transp. Econ. Logist., vol. 74, pp. 31–45, 2017.

[11] A. T. Hoang, “Waste heat recovery from diesel engines based on Organic Rankine Cycle,” Appl. Enery, vol. 231, pp. 138–166, 2018.

[12] Viet Dung Tran, Anh Tuan Le, Van Huong Dong, Anh Tuan Hoang. “Methods of operating the marine engines by ultra-low sulfur fuel to aiming to satisfy MARPOL Annex VI,” Adv. Nat. Appl. Sci., vol. 11, no. 12, pp. 34–40, 2017.

[13] V. V. Le, D. C. Nguyen, and A. T. Hoang, “The potential of using the renewable energy aiming at environmental protection,” Int. J. Latest Eng. Res. Appl., vol. 2, no. 7, pp. 54–60, 2017.

[14] A. T. Hoang, M. M. Noor, and X. D. Pham, “Comparative Analysis on Performance and Emission Characteristic of Diesel Engine Fueled with Heated Coconut Oil and Diesel Fuel.,” Int. J. Automot. Mech. Eng., vol. 15, no. 1, 2018.

[15] A. T. Hoang, “The Performance of Diesel Engine Fueled Diesel Oil in Comparison with Heated Pure Vegetable Oils Available in Vietnam,” J. Sustain. Dev., vol. 10, no. 2, p. 93, 2017.

[16] A. T. Hoang and V. T. Nguyen, "Emission Characteristics of a Diesel Engine Fuelled with Preheated Vegetable Oil and Biodiesel," Philipp. J. Sci., vol. 146, no. 4, pp. 475–482, 2017.

[17] T. A. Hoang and V. Van Le, "The Performance of A Diesel Engine Fueled With Diesel Oil, Biodiesel and Preheated Coconut Oil.," Int. J. Renew. Energy Dev., vol. 6, no. 1, 2017.

[18] A. T. Hoang and V. V. Pham, "Impact of jatropha oil on engine performance, emission characteristics, deposit formation, and lubricating oil degradation," Combust. Sci. Technol., 2018.

[19] A. T. Hoang, Q. V. Tran, and X. D. Pham, "Performance and Emission Characteristics of Popular 4-Stroke Motorcycle Engine in Vietnam Fuelled with Biogasoline Compared with Fossil Gasoline," no. 2, 2018.

[20] Anh Tuan Hoang et al., "An absorption capacity investigation of new absorbent based on polyurethane foams and rice straw for oil spill cleanup," Pet. Sci. Technol., vol. 36, no. 5, pp. 361–370, 2017.

[21] A. T. Hoang, V. V. Pham, and D. N. Nguyen, "A report of oil spill recovery technologies," Int. J. Appl. Eng. Res., vol. 13, no. 7, pp. 4915–4928, 2018.

[22] A. T. Hoang, X. L. Bui, and X. D. Pham, "A novel investigation of oil and heavy metal adsorption capacity from as-fabricated adsorbent based on agricultural by-product and porous polymer," Energy Sources, Part A Recover. Util. Environ. Eff., vol. 40, no. 8, pp. 929–939, 2018.

[23] A. T. Hoang and M. Q. Chau, "A mini review of using oleophilic skimmers for oil spill recovery," J. Mech. Eng. Res. Dev., vol. 41, no. 2, pp. 92–96, 2018.

[24] A. T. Hoang, N. X. Chu, and T. Van Tran, "The Environmental Pollution In Vietnam: Source, Impact And Remedies," Int. J. Sci. Technol. Res., vol. 6, no. 2, pp. 249–253, 2017.

[25] A. T. Hoang and V. V. Pham, "A study of emission characteristic, deposits, and lubrication oil degradation of a diesel engine running on preheated vegetable oil and diesel oil," Energy Sources, Part A Recover. Util. Environ. Eff.

[26] A. T. Hoang and L. Anh Tuan, "A review on deposit formation in the injector of diesel engines running on biodiesel," Energy Sources, Part A Recover. Util. Environ. Eff., 2018.

[27] X. D. Pham, A. T. Hoang, D. N. Nguyen, and V. V Le, "Effect of Factors on the Hydrogen Composition in the Carburizing Process," Int. J. Appl. Eng. Res., vol. 12, no. 19, pp. 8238–8244, 2017.

[28] A. T. Hoang, L. H. Nguyen, and D. N. Nguyen, "A Study of Mechanical Properties and Conductivity Capability of CU-9NI-3SN ALLOY," Int. J. Appl. Eng. Res., vol. 13, no. 7, pp. 5120–5126, 2018.

[29] X. D. Pham, A. T. Hoang, and D. N. Nguyen, "A Study on the Effect of the Change of Tempering Temperature on the Microstructure Transformation of Cu-Ni-Sn Alloy," Int. J. Mech. Mechatronics Eng., vol. 18, no. 4, pp. 27–34, 2018.

[30] D. N. Nguyen, A. T. Hoang, X. D. Pham, M. T. Sai, M. Q. Chau, and V. V.

Pham, "Effect of Sn component on properties and microstructure Cu-Ni-Sn alloys," J. Teknol., vol. 80, no. 6, pp. 43–51, 2018.
[31] A. T. Hoang, D. N. Nguyen, and V. V. Pham, "Heat Treatment Furnace For Improving The Weld Mechanical Properties: Design and Fabrication," Int. J. Mech. Eng. Technol., vol. 9, no. 6, pp. 496–506, 2018.
[32] T. N. Le, M. K. Pham, A. T. Hoang, and D. N. Nguyen, "Microstructures and elements distribution in the transition zone of carbon steel and stainless steel welds," J. Mech. Eng. Res. Dev., vol. 41, no. 3, pp. 27–31, 2018.
[33] T. N. Le, M. K. Pham, A. T. Hoang, T. N. M. Bui, and D. N. Nguyen, "Microstructure change for multi-pass welding between austenitic stainless steel and carbon steel," J. Mech. Eng. Res. Dev., vol. 41, no. 2, pp. 97–102, 2018.
[34] M. R. Cabrita, V. Cruz-Machado, and S. Duarte, "Enhancing the Benefits of Industry 4.0 from Intellectual Capital: A Theoretical Approach," in International Conference on Management Science and Engineering Management, 2018, pp. 1581–1591.
[35] K. Edström and A. Kolmos, "PBL and CDIO: complementary models for engineering education development," Eur. J. Eng. Educ., vol. 39, no. 5, pp. 539–555, 2014.
[36] M. Götting et al., "Methodology and case study for investigating curricula of study programs in regard to teaching industry 4.0," in Industrial Informatics (INDIN), 2017 IEEE 15th International Conference on, 2017, pp. 533–538.
[37] A. A. Galushkin, A. G. Nazarov, E. N. Sabyna, and T. V Skryl, "The Institutional Model of Formation and Development of Industry 4.0 in the Conditions of Knowledge Economy's Formation," in Industry 4.0: Industrial Revolution of the 21st Century, Springer, 2019, pp. 219–226.
[38] M. Elbestawi, D. Centea, I. Singh, and T. Wanyama, "SEPT Learning Factory for Industry 4.0 Education and Applied Research," Procedia Manuf., vol. 23, pp. 249–254, 2018.
[39] A. T. Hoang and V. V. Le, "Marine pollution and remedies of Vietnamese Government," Int. J. Recent Eng. Res. Dev., vol. 2, no. 4, pp. 51–55, 2017.
[40] J. Kovar, K. Mouralova, F. Ksica, J. Kroupa, O. Andrs, and Z. Hadas, "Virtual reality in context of Industry 4.0 proposed projects at Brno University of Technology," in Mechatronics-Mechatronika (ME), 2016 17th International Conference on, 2016, pp. 1–7.
[41] R. A. Ramirez-Mendoza, R. Morales-Menendez, H. Iqbal, and R. Parra-Saldivar, "Engineering Education 4.0:—proposal for a new Curricula," in Global Engineering Education Conference (EDUCON), 2018 IEEE, 2018, pp. 1273–1282.
[42] A. Shukla, R. Singh, R. Agarwal, M. Suhail, S. K. Saha, and S. Chaudury, "Development of a Low-Cost Education Platform: RoboMuse 4.0," in Proceedings of the Advances in Robotics, 2017, p. 38.
[43] G. Wu, "Based on complex learning theory CDIO Project Master of Management education model Research," Learn. Educ., vol. 6, no. 2, 2018.
[44] K. V Vodenko, M. A. Komissarova, and M. M. Kulikov, "Modernization of

the Standards of Education and Personnel Training Due to Development of Industry 4.0," Ind. 4.0 Ind. Revolut. 21st Century, vol. 169, p. 183, 2018.

[45] J. Malmqvist, K. Edström, and R. Hugo, "A Proposal for Introducing Optional CDIO Standards," in Proceedings of the 13th Intl. CDIO Conference, 2017, pp. 21–36.

[46] S. Junaid, P. C. Gorman, and L. J. Leslie, "Deliberate Practice Makes Perfect! Developing Logbook Keeping as a Professional Skill through CDIO," Time Chang., p. 80, 2018.