COMPARING THE CDIO STANDARDS WITH THE WORK-INTEGRATED LEARNING CERTIFICATION

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ABSTRACT

Improving the quality of higher education is an important responsibility of universities and colleges. Several approaches have been developed with the goal of improving the quality of university study programs. In this paper we compare the CDIO (Conceive, Design, Implement, Operate) and the work-integrated learning (WIL) initiatives based on recently completed WIL certifications at University West. Through a series of workshops, the CDIO standards are compared with the aspects and criteria of the WIL certification guidelines, to identify overlapping areas and differences between the two initiatives. The results show that both initiatives overlap but also differ in several aspects. These differences could be useful to strengthen the WIL certification process at University West as well as clarifying the connection between CDIO and work-integrated learning.

KEYWORDS

AIL, WIL, Engineering education, Quality in higher education

INTRODUCTION

Higher education institutions (HEIs) need to continuously improve their quality to prepare students for the society of the 21st Century. One important quality aspect is to develop efficient ways of collaborating with various partners in the surrounding community. For the quality of HEIs to develop, the society must be viewed as a valuable resource. Close ties with business and industry, and diversity among staff and students are necessary, especially within engineering education. An engineering degree should prepare students to develop a wide range of knowledge and skills. These range from scientific and mathematical to technical knowledge, but also include soft skills (Schulz, 2008) such as teamwork, business skills and critical analysis. These soft skills are also central sustainability competences (Swedish Regeringskansliet, 2018; UNESCO, 2017). It is vital that learning for engineers takes place in the context of authentic engineering problems and processes, to develop these skills and to put theory into practice (Mitchell, Nyamapfene, Roach, & Tilley, 2019).

Several initiatives focused on incorporating these skills in higher education exist. CDIO (Conceive, Design, Implement, Operate) is one of the most prominent initiatives within engineering education (CDIO, 2021). It targets the typical tasks an engineer performs when bringing new systems, products and services to the market or to society. The CDIO initiative was created to strengthen active and problem-based learning and improve students' communication and professional skills. CDIO focuses on improving practical and work-related skills to better prepare engineering students for their future professional life.

At University West in Sweden, another initiative, Arbetsintegrerat lärande (AIL), has been adopted as the main philosophy in all education programs. “Arbetsintegrerat lärande” normally translates to work-integrated learning (WIL). However, the meaning of the term WIL at University West differs slightly from the common definition. Outside University West, WIL often refers to activities where students spend periods working at a company, for example in the form of co-op, cooperative education (Cooper, Orrell, & Bowden, 2010). At University West, WIL includes a broader set of activities targeting practical skills, such as project work and lab exercises using realistic cases, tools, and environments (Lundh Snis & Smidt, 2021).

Currently at University West, all education programs, for example, in engineering, economics, nursing, and psychology are undergoing a WIL certification process. According to the authors' perspective, WIL shares much of the same philosophy as CDIO for engineering educations, however the relation between these two initiatives is currently not clear. The goal of this study is therefore to map similarities and differences between the CDIO initiative and the WIL certification. Specifically, the following questions were asked:

- What are the similarities between CDIO and the WIL certification?
- What is unique to CDIO and unique to the WIL certification?

The comparison between the CDIO and the WIL initiatives is based on recently completed WIL certifications at University West and was carried out through a series of workshops, where the CDIO standards (Malmqvist, Edström, & Rosén, 2020) were compared with the aspects and criteria of the WIL certification guideline (Lundh Snis & Smidt, 2021) to identify overlapping areas and the differences between the two initiatives. The results of the study show that there is indeed a large overlap between the initiatives but also several unique aspects, which could be of interest to the CDIO and the WIL communities.

The remaining part of the paper is structured as follows. In “Educational framework initiatives”, the CDIO initiative, the WIL certification and other approaches to improve higher educations are described. Then, related work and the method used in this study are presented. In section “Results”, the comparison between the CDIO standards with the WIL certification are described, followed by an overlap analysis. Finally, conclusions and future work are presented.

EDUCATIONAL FRAMEWORK INITIATIVES

Several frameworks for improving higher-education programs have been created during the last decades, here we describe the most well-known.

The CDIO initiative

The Conceive, Design, Implement, and Operate (CDIO) initiative (CDIO, 2021) is one of the most prominent initiatives within engineering education. It focuses on the typical tasks an engineer performs when bringing new products, systems and services to the market or society. CDIO is an innovative framework for educating the next generation of engineers. Students are taught engineering fundamentals within the context of real-world systems and products.

Having engineers be able to engineer is the goal. CDIO is an initiative aimed at fostering active learning and problem-based learning as well as improving students' communication and professional skills. It helps engineers prepare for the workplace by improving practical and work-related skills (Crawley, Malmqvist, Östlund, & Brodeur, 2007).

Academics, industry, engineers, and students were involved in the development of the CDIO initiative, which was specifically designed to be adaptable for all engineering schools at universities. Since CDIO is an open architecture, it can be adapted to meet the specific needs of any university engineering program, and it is being adopted by a growing number of engineering educational institutions around the world. CDIO is currently used in, for instance, college aerospace programs, applied physics programs, electrical engineering programs, and mechanical engineering programs.

The CDIO proposes a set of standards (Malmqvist, Edström, & Rosén, 2020) that serve as the guiding principles (or best practices) for implementing CDIO in an engineering program. The twelve CDIO standards address:

- program philosophy (Standard 1),
- curriculum development (Standards 2, 3 and 4),
- design-build experiences and workspaces (Standards 5 and 6),
- new methods of teaching and learning (Standards 7 and 8),
- faculty development (Standards 9 and 10), and
- assessment and evaluation (Standards 11 and 12).

These standards describe a program's defining traits, serve as educational reform standards, allow for comparability with other programs, and give a mechanism for self-evaluation to assist ongoing progress. Furthermore, they enable benchmarking with other programs and provide a tool for self-evaluation to support continuous improvement.

The WIL certification at University West

“Arbetsintegrerat lärande” normally translates to work integrated learning (WIL). At University West WIL is defined as a pedagogical practice where students' learning takes place through the integration of theoretical and practical knowledge and experiences. This knowledge is taken from educational contexts within the framework of both college and university and working life and civil society and where internship-related elements in higher education are designed and implemented in collaboration with working life (Lundh Snis & Smidt, 2021). WIL includes a broader set of activities targeting practical skills, such as project work and lab exercises using realistic cases, tools and environments. This view is similar to Billets definition: **“**Work-integrated learning is a pedagogical practice whereby students come to learn from the integration of experiences in educational and workplace settings” (Billet, 2009).

Outside University West, WIL often refers to activities where students spend periods working at a company, for example in the form of co-op, cooperative education (Cooper, Orrell, & Bowden, 2010). According to Schedin and Hassan (2016), from a socio-cultural standpoint, the WIL model can be seen as a process of interaction between students in the educational environment and in a practical setting such as a company. This interaction gives students the option to work with tools, such as machines and experimental equipment, doing laboratory demonstrations, and participating in projects at a company. Learning and growth are shared responsibilities that take place in universities and companies, integrating theory and practice.

The WIL certification of education programs at University West has the purpose to ensure that work-integrated learning in a systematic way permeates the educations, and that all students are given the opportunity to critically reflect on the relationship between theory and practice. Besides WIL, the creators of the certification process chose to also include sustainability. This could have been a separate activity but was decided to be merged with the WIL certification. Several aspects and criteria are defined and need to be fulfilled by an education program to get a WIL certification (see Table 1).

Table 1. The aspects and criteria used when evaluating an education program for the WIL certification.

The WIL certification	**Aspects**
1 Integration	How WIL and sustainable development is *integrated* into the programme as a whole/the common thread that places work-integrated learning in a context – focus on organisation, planning, implementation, and follow-up of the programme
2 Pedagogy	The application of WIL educational theory – focus on teaching practices, models, methods, and activities
3 Collaboration	Forms of *collaboration* with prioritised partners and other actors in the surrounding community
4 Communication	How the WIL and sustainable development perspective in the degree programme is *communicated* clearly and intelligibly for the benefit of students and colleagues as well as for collaboration partners and the surrounding community
The WIL certification	**Criteria**
A Pedagogical theory	The programme rests on an educational philosophy in which the link between theoretical and practical knowledge is justified and discussed in relation to the goals and content of the programme.
B Theory and practice	The integration of theory and practice at a general level systematically permeates and supports progression in the programme and prepares the students for working with and driving sustainable development/change in society.
C Activities	Through practice-related activities, the student is given the resources to develop educationally, learning to problematise, challenge, and integrate practical/experience-based and theoretical knowledge, and to do so through analytical reflection.
D Participation	The degree programme is composed of practice-related activities/modules that are shaped and carried out in collaboration with actors in the surrounding community, and that these are developed in a way that strengthens integration of theoretical and practical knowledge.

When applying for the WIL certification, program managers write an overall program description for the education program, where they describe and justify with concrete examples how WIL in a systematic way permeates the education and how to achieve sustainability aspects through WIL elements. To describe this, the aspects and criteria listed in Table 1 are applied (Lundh Snis & Smidt, 2021). There is no assessment rubric or maturity scale used.

Other frameworks

Among other approaches to improve education programs is the Framework for Improving Student Outcomes (FISO) which is the continuous improvement framework for all Victorian government schools, used in Australia (FISO, 2021). In USA there is the Accreditation Board for Engineering and Technology (ABET) that is a type of quality assurance that is used in a variety of fields, including computing, engineering, and science (Rashideh, Alshathry, Atawneh, Al Bazar, & Abualrub, 2020). However, these approaches are not considered further in this work.

RELATED WORK

Several earlier research studies have looked at the connection between CDIO and WIL. Schedin and Hassan (2016) present a learning model for WIL and the relation of this model to CDIO standards 7 and 8. This learning model is based on collaboration with industry partners to guarantee an internship position to students. Industry based projects and final thesis are also integrated onto the learning model. This is then connected with standard 7 of CDIO, since the standard supports the learning of disciplinary knowledge integrated with personal, interpersonal, and product and system building skills. The learning model proposed by Schedin and Hassan (2016) promotes critical thinking and problem-solving activities, and this relates to standard 8 which support active learning.

Brodie, et al. (2014), investigate the possibility of implementing the CDIO framework for distance and online education. In this context, there is little support from industries for practical activities and project work. Therefore, the authors suggest complementing the implementation of CDIO in online education with WIL. The advantage of this would be to receiving input from industry with respect to formulating real world design problems and engaging students in the design and construct phases of CDIO.

Einarson et al., (2016), present a set of learning outcomes, inherent to Demola and based on CDIO and WIL. Demola is a platform for collaborations between academy and industry with focus on multi-disciplinary student projects. The authors underline the connection between WIL and standards 7 and 8 of CDIO, similarly to Schedin and Hassan (2016). The authors mention that universities are still struggling to implement WIL because of several problems like, establishing sustainable industry academic contacts, strategies for project ownership and intellectual property rights and guarantees regarding the fulfilment of academic goals. The Demola platform helps in implementing WIL since it includes templates for academic-industry contracts and process models. In an extension of their work, Einarson and Saplacan, (2016), compare the set of learning outcomes from CDIO Standard 2, which is part of Demola, with the national Swedish higher education ordinance (Högskoleförordning, 1993) to show how Demola may adapt to national goals.

METHOD

The purpose of this study was to compare all standards of the CDIO initiative to the WIL certification and is based on recently completed WIL certifications at University West. To accomplish this, we chose to conduct a series of workshops where we compared the CDIO standard documents (Malmqvist, Edström, & Rosén, 2020) with the guideline document for the WIL certification (Lundh Snis & Smidt, 2021). Participating in the workshops were the four authors of this paper. Two participants have previous experience of CDIO activities at different universities, one participant was involved in approving the WIL certification criteria and certification of programs, and all authors participated recently in the WIL certification process of a program at University West.

To structure our process of identifying overlapping areas and mapping differences, a table with the CDIO standards along rows and the aspects and criteria of the WIL certification along columns were used. Going through the CDIO standard consecutively, the texts were interpreted, analysed, and reflected upon for each of the WIL aspects and criteria. All common traits and reflections, or the absence of them were noted in the matrix. The matrix provides a good overview for the presentation of the results. A Venn diagram was used to illustrate overlaps and differences. Finally, based on feedback from presenting an abstract of the draft work at a local conference at University West, the main findings were summarized and developed in more details (Loconsole et al, 2021).

RESULTS

To structure our main findings from the comparison of the CDIO standards and the WIL certification, we chose to map all standards, aspects, and criteria using a Venn diagram (see Figure 1). In the left-hand circle we find the CDIO standards and on the right-hand side, the WIL certification aspects and criteria. The matrix from our comparison of the CDIO standards with the WIL certification can be seen in Table 2. The filled circles indicate strong overlap, the striped circles medium overlap, the dotted circles weak overlap, and empty squares no overlap.

A general observation, when going through all material, is that the CDIO standards are clear and well defined. On the other hand, the WIL certification guidelines were harder to interpret because they were wordier and more complex. This made it necessary, for the comparison, to rely more on our own interpretations and experiences with the WIL certification.

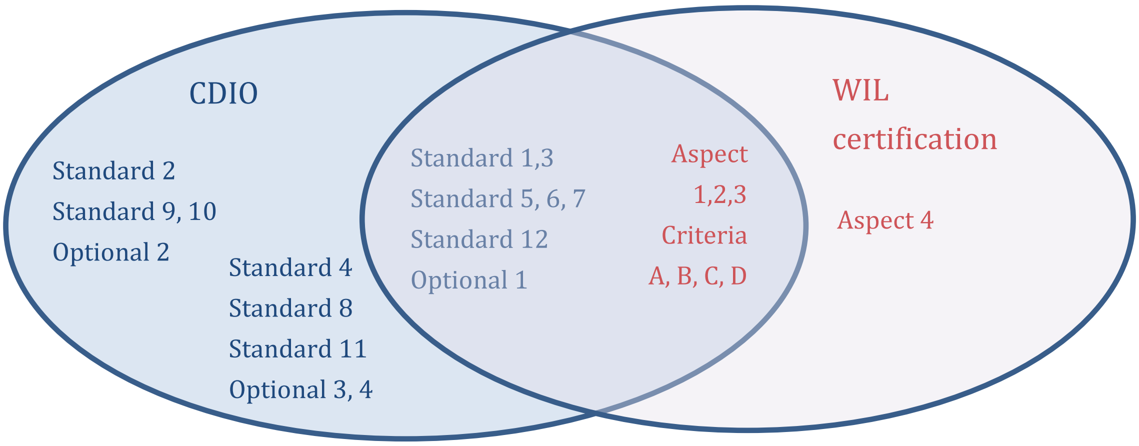

Figure 1. Venn diagram showing the overlapping and non-overlapping areas between CDIO and the WIL certification.

Table 2. Resulting mapping of the CDIO standards and the AIL certification guidelines.

	WIL aspects				WIL criteria			
CDIO Standards 3.0	1 Integration	2 Pedagogy	3 Collaboration	4 Communication	A Pedagogical theory	B Theory and practice	C Activities	D Participation
1 Context	Strong	Medium			Strong	Strong	Strong	
2 Learning outcomes			Weak	Weak	Weak			Weak
3 Integrated curriculum	Strong		Medium			Strong	Strong	Medium
4 Introduction to engineering	Weak					Weak		
5 Design-implement Experiences		Strong				Strong	Strong	Strong
6 Learning workspaces		Strong			Weak	Weak	Weak	Weak
7 Integrated learning experiences	Medium	Medium			Medium	Strong	Strong	
8 Active learning		Medium					Medium	Medium
9 Faculty competence			Weak					
10 Teaching competence								
11 Learning assessment							Weak	
12 Program evaluation	Strong			Weak				
Optional standards								
1 Sustainable development	Strong					Strong		
2 Simulation-based maths								
3 Entrepreneurship			Weak				Weak	Weak
4 Internationalization & mobility		Weak	Weak				Weak	
Strong	Strong overlap. Similar description and meaning. CDIO supports the WIL certification and vice versa.							
Medium	Medium overlap. Similar meaning but not as clear connection.							
Weak	Weak overlap. Frameworks support each other somewhat.							
	An empty square means no overlap.							

Analysis

The following standards were found to be unique to CDIO:

- **Standard 2, Learning outcomes**. The WIL certification has no explicit learning outcomes. This is a major difference since CDIO includes an extensive syllabus defining detailed learning outcomes (Crawley, Malmqvist, Lucas, & Brodeur, 2013). However, during our analysis, we realized that the WIL certification implicitly relies on the learning outcomes defined by the Swedish national higher-education goals (Högskoleförordning, 1993). Although the connection between these high-level national goals and WIL are unclear.

- **Standard 9 and 10, Faculty competence and teaching competence.** Teachers' disciplinary and pedagogical competence development are not considered in the WIL certification. A faculty competence focus would have been a valuable thing for the WIL certification since not only students should experience WIL but also teachers doing, for instance, a sabbatical or a practical experience period in industry to improve their competences.

The following standards were found to be stronger in CDIO:

- **Standard 4, Introduction to engineering.** The WIL certification has no similar requirement. Although the WIL certification does not require an "introduction to engineering" course, such a course would support the WIL integration (aspect 1).
- **Standard 8, Active learning.** Active learning is not explicitly mandated by the WIL certification. On the other hand, active learning often comes naturally from the focus on work integration since activities involving practical experiences and learning are commonly active by nature.
- **Standard 11, Learning assessment.** Learning assessments in the WIL certification are not included. This is not surprising since the WIL certification is also lacking learning outcomes making it hard to evaluate aligned assessments.

The following aspect was found to be stronger in the WIL certification:

- **Aspect 4, Communication.** Communication is an important aspect in WIL certification which is not emphasised as much in the CDIO standards. The idea with communication in the WIL certification is to spread awareness and teach the pedagogy behind WIL to students, colleagues, collaboration partners, and the surrounding community.

During the analysis, a weak point in both initiatives were discovered:

- **Research as a profession.** Several students will, after graduating, end up in a research-related position, for example, as a Ph.D. student. This is especially true for programs at the master's level. Neither the CDIO initiative nor the WIL certification include this aspect. Doing research is also a profession with some specific knowledge and skills required.

For the optional standards; Sustainable development is included in both initiatives. Simulation-based math is very engineering specific; hence it is not applicable to the broader WIL certification. Entrepreneurship and internationalization are not explicitly mentioned in the WIL certification but are valuable WIL activities.

DISCUSSION

An interesting observation is that the WIL certification is broader than the CDIO initiative. For example, at University West, nurse educations are also being WIL certified. These educations also target a specific profession although they do not include all the conceive, design, implement, and operate activities. This indicates that the CDIO standards and syllabus may be seen as two parts. One part focusing on good pedagogical practices for profession-oriented educations and another part specific for engineering educations.

Communication was found to be a weak point in CDIO since there is no standard focusing on communication explicitly. Nevertheless, looking closer, one could argue that communication is implicit in many of the standards. For example, in the assessment rubrics for several standards, the highest level (5) mandates evaluation and feedback from students, instructors, and external stakeholders. In contrast, the WIL certification sees this as important enough to include as one of the aspects. The reason for this can be found in the pedagogical philosophy behind WIL, which we interpret as: (1) to integrate theory and practice, and (2) to acknowledge that external parties have knowledge and skills that staff at a university lack. Thus, focusing on communication encourages a greater exchange of knowledge.

One of the weak aspects found in WIL was the lack of learning outcomes. We believe that the WIL certification could be strengthened by adding learning outcomes. This would make the WIL certification easier to understand, more concrete and specific. The WIL certification also lacks an explicit focus on active learning even if active learning is common in practice. Active learning would also be good to include as an explicit aspect in the certification.

CONCLUSIONS

This paper has presented a comparison between the CDIO standard documents and the guideline and criteria documents for the WIL certification at University West, Sweden. The comparison identified some overlapping areas and differences between the two initiatives. The results can be summarised as follows:

1. The two initiatives have similarities. As can be seen in the Venn diagram in Figure 1 and in Table 2, the standards 1, 3, 5, 6, 7, 12, and optional standard 1 of CDIO are overlapping with aspects 1, 2, 3 and criteria A to D of the WIL certification.
2. Unique aspects are present in both initiative: Standard 2, learning outcomes, standards 9 and 10, faculty and teachers' competence development (both pedagogic and disciplinary) are unique to CDIO while aspect 4 communication is unique to the WIL certification.
3. Both initiatives lack focus on the research profession. None include the connection to continued (academic) studies and research.
4. The CDIO standards are well structured and easy to understand. The WIL certification guideline uses complex, hard to interpret language that could be simplified.

The results clarify the relationship between CDIO and WIL and can be useful when implementing the CDIO standards or the WIL certification. Especially if the educational program already complies with the CDIO standards or have obtained a WIL certification, then, some standards or aspects might already be fulfilled.

One interesting extension of this work would be to clarify the implicit learning outcomes of the WIL certification and investigate the connection with the learning outcomes defined by the Swedish national higher-education goals (Högskoleförordning, 1993). Another possible extension of this study is that part of CDIO could be adopted towards education programs outside engineering.

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Andreas de Blanche (PhD) is an associate professor in computer science and engineering at the department of engineering at University West in Sweden. He was vice chair of University Wests board on Research and Education when the WIL certification was developed. The board determined the WIL certification criteria and certified the first ten programs. His main interests include engineering education, high performance computing and blockchain technology.

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