CDIO AS BLUEPRINT FOR COMMUNITY SERVICE ENGINEERING EDUCATION

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ABSTRACT

This paper is a case report of why and how CDIO became a shared framework for Community Service Engineering (CSE) education. CSE can be defined as the engineering of products, product-service combinations or services that fulfill well-being and health needs in the social domain, specifically for vulnerable groups in society. The vulnerable groups in society are growing, while fewer people work in health care. Finding technical, interdisciplinary solutions for their unmet needs is the territory of the Community Service Engineer. These unmet needs arise in local niche markets as well as in the global community, which makes it an interesting area for innovation and collaboration in an international setting. Therefore, five universities from Belgium, Portugal, the Netherlands, and Sweden decided to work together as hubs in local innovation networks to create international innovation power. The aim of the project is to develop education on undergraduate, graduate and post-graduate levels. The partners are not aiming at a joined degree or diploma, but offer a shared short track blended course (3EC), which each partner can supplement with their own courses or projects (up to 30EC). The blended curriculum in CSE is based on design thinking principles. Resources are shared and collaboration between students and staff is organized at different levels. CDIO was chosen as the common framework and the syllabus 2.0 was used as a blueprint for the CSE learning goals in each university. CSE projects are characterized by an interdisciplinary, human centered approach leading to inter-faculty collaboration. At the university of Porto, EUR-ACE was already used as the engineering education framework, so a translation table was used to facilitate common development. Even though Thomas More and KU Leuven are no CDIO partner, their choice for design thinking as the leading method in the post-Masters pilot course insured a good fit with the CDIO syllabus. At this point University West is applying for CDIO and they are yet to discover what the adaptation means for their programs and their emerging CSE initiatives. CDIO proved to fit well to in the authentic open innovation network context in which engineering students actively do CSE projects. CDIO became the common language and means to continuously improve the quality of the CSE curriculum.

KEYWORDS

community service engineering, interdisciplinary, blended, education, open innovation, CDIO standards: 1, 2, 6, 7, 8, 9, 10

INTRODUCTION

Technology plays an important role in facing societal challenges. Engineers can contribute to the development of solutions, provided that they are aware of the context and willing to amplify their participatory skills. In 2010 a UNESCO report (Unesco, 2010) already affirms the role of engineering as the driver of social and economic development and innovation. However, it also stresses the need to transform engineering education, both curriculum and teaching methods, to emphasize user relevance and a stronger problem-solving approach.

In Lifelong Learning Project 539642 'Community Service Engineering (CSE), ('Community Service Engineering', 2015) five Higher Education Institutions (HEIs) have teamed up with the non-governmental organization RVO Society to collaborate in engineering curriculum development focusing on the social domain. The project partners are the University of Applied Sciences Thomas More (coordinator), RVO Society and KU Leuven from Belgium, The Hague University of Applied Sciences from the Netherlands, the University of Porto from Portugal and University West from Sweden. The RVO Society aims to interest youth (aged five to twenty-five) in socially relevant technology and science, and connects businesses and clients who have unmet needs to young educational and informal learning groups who want to develop solutions. Through their Cera Award RVO Society launches a call for projects to the social sector three times a year. They do this by mailings to the Flemish social profit organizations, and via umbrella organizations in the sector. Social sector organizations can formulate any technical scientific problem from within their organization. This covers a wide rage of topics such as energy, ICT, communication, mechanical or electrical problems, design projects etc. Working with their client the young developers co-create new technological applications that fulfill the needs and thus create a sustainable and more inclusive society. Every year the most promising project receives the Cera Award. A collaboration between Thomas More and the Cera Awards showed that even very motivated engineering students often struggle to create solutions that truly fit the needs of their clients. The world of engineering students and the engineering education context surrounding them is different from the organizational structure and issues playing within the social sector. This makes it difficult for engineering students to bridge that gap with empathy and really get to the bottom of the problems and needs of the social sector. This insight was the inspiration for the European CSE project. The main goal of this project is to develop, pilot and offer an international (postgraduate) course in Community Service Engineering, worth 30 European credits, with a translation to graduate and undergraduate education.

Community Service Engineering

CSE is defined as the engineering of products, product-service combinations or services that fulfill well-being and health needs within the social domain, and specifically those of vulnerable groups in society such as elderly, intellectually-, physically- or sensory disabled, chronically ill people, people with an addiction, youth at risk, detainees, people living in poverty, and people from a different migration background (Dekelver, Vervoort, Cosemans, Van Petegem & Rombouts, 2013; Hallenga-Brink & Vervoort, 2015). The vulnerable groups in society are growing, and so are their special needs. In the EU however, policies and social institutional structures are directed towards self-sufficiency and longer independence of the population, including these vulnerable groups, as fewer people will work in health care due to the ageing population (Van den Bosch, Heij, & Volberda, 2013). Finding technical solutions for the unmet needs that result from this tendency, both for the vulnerable groups and their formal and informal caretakers, is the domain of the Community Service Engineer. Formal healthcare technology and projects for newly developing countries (international humanity programs) are not part of the core of CSE, although cross links with such projects can occur. The enterprises that CSE works with are primarily non-profit or social profit organizations. In

some cases, it can be profit organizations as well, as long as the products and services are developed for improving the quality of life of vulnerable groups in an ethical way. The CSE domain covers many different sectors: sheltered workplaces, special youth care, organizations working with people with disabilities, family care, youth welfare, child & family services, centers for social and general welfare, special education and housing, rehabilitation centers, community development, socio-cultural sector, social workplaces, employment, home care services, residential and care centers etc. Engineers can work with a variety of technologies depending on the needs they are addressing.

In need of a new approach

The Unesco report (Unesco, 2010) suggests transforming engineering education, curricula and teaching methods to emphasize relevance and a problem-solving approach to engineering including challenges such as poverty reduction and social development. Young people are likely to be more attracted to make a difference in the world through an engineering career than by the challenge of mathematics and science skills (National Academy of Engineering, 2008). Young people worldwide are motivated by the prospect of getting a job that fits their attitudes and values (Sjøberg & Schreiner, 2012). The results from Sjøberg and Schreiner's Rose project confirm the importance of values, attitudes and meaning. Girls especially, in all cultures, seem to value these aspects more than boys do. Yet, the contributions engineers make to a better society do not come to mind when young people think about studying engineering. Traditional engineering education does not offer a lot of opportunities and time for engineering students to get to know the social sector. Most of their education focuses on the acquisition and development of technological, disciplinary knowledge. Even if project work is an important part of education, it is often technology-driven instead of user-need driven.

As the general image of the engineering profession does not reflect social and societal components, there is a need for a new approach. This approach should offer (future) engineering students a vision of a profession that makes a difference in people's lives and operates in a meaningful context. CSE aims to offer this context in a curriculum that is based on educational concepts that match this ambition. The question is which engineering education blueprint or framework best fits the authentic open innovation network context in which undergraduate, graduate and post-graduate engineering students can learn by doing and preferably realizing CSE projects within their HEI or even in collaboration with other HEIs, and in collaboration with stakeholders.

THE EDUCATIONAL VISION OF COMMUNITY SERVICE ENGINEERING

First of all, combining engineering with the social domain requires not just a multidisciplinary, but rather an interdisciplinary approach of education. In order to learn to understand and be able to be an actor in the social domain, engineers must learn to speak the language of its professionals, end-users, educators and fellow students of social studies, and thus interact with them. This goes further than being able to do research on the requirements of stakeholders in the design phase, and then proceed with engineering, which is the multidisciplinary approach we see more often in current (project-based) engineering education. So although CSE focuses primarily on engineering students, students from other departments are seen as co-creators, together with stakeholders from both the social and technical domain and educators.

The knowledge generated by HEIs is commonly presumed to 'find a way to society', but dissemination is not always timely, complete or effective (Chesbrough, 2003). In the open innovation approach that Chesbrough suggests all stakeholders involved become experts by collaborating and together they generate feasible, desirable and viable innovative design. In this set-up knowledge generated at a HEI is disseminated right when and where it is applicable and in case of the social domain, often highly needed (Amsterdam University Press, 2013; Beumer, Kips, & Mulder, 2011). Moreover, the primary role of a HEI at undergraduate and graduate level is typically considered to be 'creating a good learning experience for students' and 'preparing students for a career in research or a professional position with more responsibilities'. With changes in Western society such as the shifting demographical distribution of age and the resulting decreasing size of our workforce, especially in government and healthcare (Van den Bosch et al., 2013) gaps in innovation and R&D power could be filled up by HEIs in Chesbrough's co-creational approach. In the near future higher education needs to provide for a sustained power of innovation for the organizations they collaborate with and for society in general.

The perspective on authentic learning changes considerably in that sense. Not only is it a very stimulating environment for learning effectiveness and to enhance student creativity and empathy (Nicholl, Flutter, Hosking, & Clarkson, 2013), it will also become a necessity to solve real life problems. In the next ten to fifteen years the focus of engineering student internship or graduation projects will shift towards truly solving societal (sub)problems, even as a small contribution to a bigger and longer open innovation process the student's HEI is involved in on the long-term. This adds transformation research and transformation design to the mix of open innovation and co-creation. The term "transformation design" is used for work within communities for socially progressive ends, introducing a human-centered design approach (Burns, Cottam, Vanstone, & Winhall, 2006). Transformation research starts with activating the agents (stakeholders), defining intervention at community scale, and building capacities and partnerships. By re-distributing power and enhancing imagination and hope, ideas can be made concrete and infrastructure and enabling platforms can be built. Success and impact should always be evaluated at the end of the cycle, and new partnerships can be formed based on the outcomes (Sangiorgi, 2011). Based on experiences at THUAS, it takes six to eight years before the fruits of such projects can be truly harvested. But plenty of learning opportunities in a real context are present within this timespan for students.

Role of the teacher

Amongst others, safeguarding the long term interests and expectations of network partners within an open innovation project and not having students reinvent the wheel year after year are stakeholder management skills that teaching and research staff must (learn to) master. There will be a new and challenging role for teachers in an international learning environment, that will function as a lifelong learning environment. Traditional teaching competences may not be enough. Teaching staff needs support to redefine their role in open innovation projects and the 21st century skills they need for it. Engineering educators and the social domain partners do not typically speak the same language either, which leaves a lot of innovation potential within student projects untouched. The HEI functions as a facilitator of the learning process for all. It can integrate long-term projects in fragments in education, making students work on in between tasks in the authentic context, while guarding the continuous learning of the overall process for all the stakeholders (client, users, researchers, students). In this way the client (and user!) will not be left without a tangible result. The teachers' role will thus have different dimensions: facilitators of lifelong/network learning environments, connectors between the social profit sector, businesses and students,

coaching students in their self-directed learning, supporting students in the acquirement of international-intercultural and transversal competences, providing insights or inspiration (technologies, case studies, needs of social profit sector) at pivotal, just-in-time moments, and formulating cases out of the students' projects and making learning material out of it. Much more reciprocal learning will take place. Teachers could have an additional role to link the different fields of study and faculties within the HEI, providing insights in recurring needs in the social profit sector (and thus having market potential), and providing insights in existing technology in the market and companies looking for market potential in the social profit sector (and thus providing possible solutions for formulated needs).

Design Thinking

In the CSE project this demand-driven, authentic educational vision is applied, and unmet needs are actively searched for in the social domain, via the networks around the participating HEIs and in collaboration with the RVO Society in Belgium. Students that follow a CSE course develop solutions in co-creation for the unmet needs in the social domain: they learn to interact with clients and users in a human-centered, design thinking approach and let them participate in the creative process. To structure this process, design thinking methods are used from IDEO (IDEO, 2015), including blended materials such as online templates.

Razzouk and Shute (2012) list a number of characteristics of a design thinker: human- and environment-centered, able to visualize, predisposed towards multi-functionality and multiple angles, systemic approach, able to use language as a tool, a team player, and able to deal with the uncertainty of delaying choices and combining new configurations first. These characteristics give insight into the nature of design thinking. An innovative design process is iterative, exploratory, and sometimes chaotic. It starts from a certain need or problem, captured in the first stages in a design brief, and results in the description of a product while gradually refining its sometimes conflicting, changing specifications. Innovative design follows cycles of mutual adjustment between specifications and solutions until a final solution is reached (Hatchuel & Weil, 2009). At all times the user and stakeholders are involved.

Design thinking is key to the community service engineers to prepare them to deal with difficult situations and solve the complex problems in the social domain, without losing overview. Enhancing students' design thinking skills may be achieved through incorporating authentic and intriguing tasks (Razzouk & Shute, 2012) and providing them with many opportunities to apply design processes.

International context in undergraduate, graduate and post-graduate CSE education

It is a challenge within the CSE project to set up such an interdisciplinary, open innovation, human-centered, design-thinking approach in an international context. The benefit of an international setting is that it can help to enlarge the sometimes small, local markets within the social domain. The actual implementation of the CSE curriculum differs per partner, depending on the existing institutional and education constraints. An online platforms can be of support by offering project databases, online course elements and social interaction between students (Hallenga-Brink & Vervoort, 2015). It is not the aim to form one joined degree or diploma. Instead Community Service Engineering will be an element of engineering education programs at the partner universities. Resources will be shared and collaboration between students and staff is organized at different levels. CSE is offered on post-graduate, graduate and undergraduate level within the partners, but this does not mean cross-fertilization cannot take place when students are dealing with similar design

challenges. Other options are to implement elements of shared resources and educational concepts into the existing curricula of engineering education at the different partner institutions. The option to translate the post-master's curriculum into undergraduate curricula are implemented at Thomas More, The Hague University of Applied Sciences and University West. At Thomas More, students receive a diploma supplement "Socially Ingenious" at the end or their 3 years of study if: (1) they take an extra course "socially ingenious" (3 additional credits); (2) choose during the 1st or 2nd phase of their studies assignments that carry the label 'socially ingenious' and (3) add to that a bachelor thesis project with a clear social dimension ('Socially Ingenious | Thomas More', 2015). At the University of Porto Community Service Engineering is integrated into the master program of engineering education. At KU Leuven (Belgium) the 30 credit post-graduate course "Community Service Engineering" is open to all international (life long learning) students with a Master's degree in Engineering.

In this light an experiment with a joint database of projects is being carried out, which provides information on possible collaborations and types of projects done at the partner universities. Different tools and technologies are selected for effective blended learning, including (pedagogical) models and scenarios for multi-campus education and successful e-coaching methods. For the international transfer and sharing of knowledge, experiences and results within the CSE projects, a virtual learning context has been set up in FeedbackFruits, where co-creation networks can be in digital dialogue with each other during projects, share documents and movie clips, have access to the CSE repository of knowledge clips and sources that are built up, and share experiences and good practices with each other and students. This virtual context is by no means a replacement for the authentic learning environment in which the CSE students will truly learn how to work in the social domain and find solutions. But it is a valuable support system, fit for the 21st century, making it easier to obtain still scant knowledge in socially engaged engineering's niche markets.

DRIVERS FOR ADOPTING CDIO IN CSE

In order to fit the different courses in CSE at the partner universities to one another in a way that exchange is possible, an educational framework was sought to function as a blueprint. The KU Leuven offered a competence set for international exchange students, which could fill in part of the framework. The University of Porto uses EUR-ACE as the framework for all their engineering education, and cannot abandon it. The engineering programs at The Hague University of Applied Sciences are all CDIO member. University West is in the middle of applying for CDIO. Thomas More suggested to look into these last two frameworks. CDIO is described to be flexible and adaptable (Crawley, Brodeur, Malmqvist, Östlund, & Edström, 2007), able to respond to forces in education and society such as described above. It also emphasizes the importance of fitting education to the needs of industry. Multiple cases can be found where CDIO is used as a blueprint outside the direct context of an existing engineering program or department (Malmqvist, Kohn, & Lindquist, 2015). EUR-ACE is a widely spread authorized quality label for engineering programs in Europe. First a combination of the two was considered. However, a complete conversion between EUR-ACE and CDIO is not possible (Falcao, 2011). EUR-ACE and CDIO have a different approach, and four of the CDIO standards (4, 5, 7, and 8) define educational elements which are not explicitly discussed in the EUR-ACE accreditation requirements (Malmqvist, 2009). The CDIO syllabus reflects a more encompassing view of engineering than EUR-ACE's, by considering the full product/system/process lifecycle, including the implementing and operating life phases, which is important for the open innovation. Also, an evaluation process based on a rating scale, such as the CDIO self-evaluation model, was considered more

useful for guiding the continuous improvement processes for CSE than a threshold value scale, such as used in the EUR-ACE accreditation.

The University of Porto adopted the CDIO scales for the 12 standards for the CSE course for communication purposes with the other partners. At Thomas More and KU Leuven the comparison exercise led to the decision to reformulate the existing CSE syllabus for the post-masters course in CDIO terms by next semester, see figure 1.
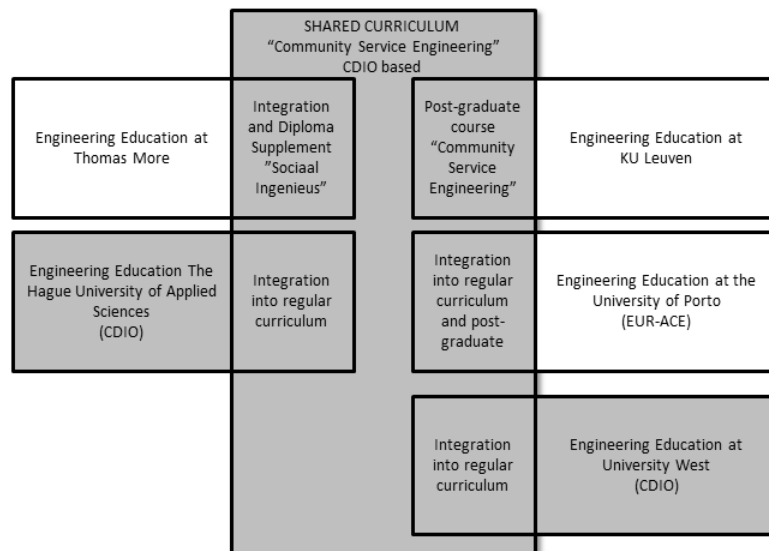

Figure 1. The shared CSE curriculum and use of CDIO, adapted to the local situations.

The area in gray indicates how CDIO is adopted. The areas in white do not implement CDIO. For instance: at Thomas More, CDIO is only implemented in the courses that lead to the diploma supplement "socially ingenious" (gray area) and that is a part of the shared curriculum of the 5 partners involved. The rest of engineering education at Thomas More does not use CDIO. At The Hague University of applied Sciences, CDIO is adopted throughout the curriculum already, as well as in the CSE curriculum, and in the near future this is expected to be the case at University West as well.

Given the aims of the CSE curriculum and the existing differences between the partners' approaches, the CDIO framework proves to fit well as a basis for the curriculum of CSE. First of all, in standard 1 CDIO (Crawley et al., 2007) describes the context of engineering education in the same professional setting as the open innovation approach of CSE: a focus on the needs of customers (the human-centered approach mentioned in the CSE vision above), delivery of products processes and systems and meaningful incorporation of new inventions and technologies (delivering real products and innovative power), focus on the solution instead of disciplines (interdisciplinary approach), working and effectively communicating with others (co-creation), and dealing with the available resources (feasibility, viability, desirability). In standard 2 the personal, professional and interpersonal skills are as important as the disciplinary knowledge and reasoning, and the possible learning goals within CSE courses cover most of the CDIO syllabus list, see table 2. The first column shows the main CDIO syllabus learning goals or competences, including the added competences 4.7 and 4.8. of the 2014 version of the CDIO book. Each competence is divided into several

sub-competencies, and the table shows if all or some of these are covered in the CSE education provided by the different partners of CSE. The table makes clear none of the main categories in the syllabus are left uncovered. Communications in foreign languages seems least represented, but for all programs English counts as a second language (3.3.1), so a foreign language is taken into account. It is interesting that both personal and interpersonal skills are within the core of CSE education, as is the integrated project line of box 4. And also for each CSE program entrepreneurship is an important element of the projects. In that sense CDIO is clearly a good fit. Not all CSE programs deal with operating (4.6) in the education equally, only the applied sciences programs do.

Table 2: Use of the CDIO Syllabus in CSE education: which sub-sub competences are included per partner university.

CDIO Syllabus (Crawley et al, 2014)	THUAS	Thomas More	U Porto	KU Leuven
1 Disciplinary Knowledge And Reasoning	All	All	All	All
2 Personal And Professional Skills And Attributes				
2.1 Analytical Reasoning And Problem Solving	All	All Minus 2.1.4	All	All Minus 2.1.4
2.2 Experimentation, Investigation And Knowledge Discovery	all	All	All	All
2.3 System Thinking	All	All Minus 2.3.4	All	All
2.4 Attitudes, Thought And Learning	All	All	All	All
2.5 Ethics, Equity And Other Responsibilities	All	All	All	All
3 Interpersonal Skills: Teamwork And Communication				
3.1 Teamwork	All	All	All	All
3.2 Communications	All	All	All	All
3.3 Communications In Foreign Languages	Only 3.3.1	Only 3.3.1	All	Only 3.3.1
4 Conceiving, Designing, Implementing &Operating Systems in Enterprise, Societal, and Environmental Context – The Innovation Process				
4.1 External, Societal, And Environmental Context	All Minus 4.1.3 and 4.1.6	All	All	All
4.2 Enterprise And Business Context	4.2.1, 4.2.2 and 4.2.7	4.2.1, 4.2.2 and 4.2.7	All	All
4.3 Conceiving, Systems Engineering And Management	All	All	All	All
4.4 Designing	All	All Minus 4.4.6	All	All
4.5 Implementing	4.5.1 and 4.5.6	Only 4.5.1	All	All
4.6 Operating	4.6.1, 4.6.3 and 4.6.5	none	All	none
4.7 Leading Engineering Endeavors	All minus 4.7.5	All minus 4.7.10	All	All
4.8 Entrepreneurship	4.8.2, 4.8.5, 4.8.6, 4.8.8	4.8.5, 4.8.6, 4.8.8	All	4.8.5, 4.8.6, 4.8.8

The integrated, active approach of learning the CSE profession coincides with standards 3 and 8. Requirements for the learning workspaces mentioned in standard 7 such as collaborative design projects, extracurricular design projects, test and operate possibilities, and linked projects between departments have to be both physically and digitally covered in CSE. And last but not least standards 9 and 10 about staff (teaching) competence development are certainly important factors of success for real CSE innovation to become reality.

CONCLUSIONS AND RECOMMENDATIONS

To get a better understanding of the quality and characteristics of CSE education at the four partner universities, a template document was prepared upholding the twelve CDIO standards. All partners described their implementation status and current situation with regards to these standards in their CSE endeavors, in a mini-self-evaluation. Table 3 shows the status of CDIO implementation in CSE per partner, using the rubric of CSIO. The scale from 1-5 builds up from 'knowing it's important (1)' to 'doing it and checking it regularly with important stakeholders' (5). A score of 3 means a start has been made. At the time of this writing, information about University West was not yet known, because they are in the process of applying for CDIO membership. This exercise gave insights into the strengths and weaknesses. The difference between implementation status among partners can be explained to some extend in relation to figure 1, and to the direct link of CSE to CDIO principles or other principles. From the table it can be concluded that the implementation scores are solid and close to one another in standards 5, 7 and 8. This means that all partners support the design-implement experience in the social domain, by means of an integrated learning experience, scaffolded by active learning didactics is seen as the core of the CSE curriculum.

Table 3: implementation levels of CDIO standards for CSE partners in their CSE curricula or courses.

Standard	Thomas More – post masters CSE course	University of Porto – CSE integrated in current graduate curriculum	The Hague University of Applied Sciences – CSE integrated in current undergraduate curriculum
1: The Context	3	1	4
2: Learning Outcomes	2	3	4
3: Integrated Curriculum	3	NA	NA
4: Introduction to Engineering (CSE)	3	1	2
5: Design-Implement Experiences	3	4	4
6: Engineering Workspaces	4	2	4
7: Integrated Learning Experiences	3	4	4
8: Active Learning	4	3	3
9: Enhancement of Faculty CDIO Competence	0	2	3
10: Enhancement of Faculty Teaching Competence	0	1	2
11: Learning Assessment	3	2	3

12: Program Evaluation	1	0	5, but not 4

It can also be concluded that, as one of the work packages of the project deals with the role of the teacher, standards 9 and 10 certainly need attention. As discussed the role of the teacher changes considerably in an open innovation set-up. Guidelines and approaches are discussed and auxiliary tools experimented with. Also the introduction to (Community Service) Engineering, especially the social domain, is an important priority. For this purpose, online knowledge and experience clips are made at the time of writing to fill the CSE repository and the project database is being revised.

One thing that did not come out of the CDIO self evaluation was how CSE was doing on international collaboration. It comes back in the CDIO syllabus as one of the learning goals for students, but not as an organizational aim. This is the third priority for the project. None the less, the CDIO framework offers all partners a common understanding in defining the content of their CSE curricula, and offers insights for the quality cycle for continuous improvement for the future of this project.

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