Learning results of first year's students Dee Larbboonsarp, Mathijs Nieuwenhuijsen, and Victor Montero Constantino, summarized after The Basics of IDE Introduction week, September 2017

10. Designing an Integrated, Futureproof, and Flexible Curriculum

The Transition of the IDE Curriculum Supported by CDIO

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This chapter is based on the publication:
Hallenga-Brink, S.C., & Sjoer, E. (2017). Designing a Flexible, Choice-Based, Integrated, Professionally Challenging, Multidisciplinary Curriculum. *Proceedings of the 13th International CDIO Conference, University of Calgary*. Calgary.

Introduction: The need for a flexible, integrated curriculum

Industrial Design Engineering [Open] Innovation (IDE) is a 3-year, English taught, VWO entry-level, undergraduate programme at The Hague University of Applied Sciences (THUAS). The IDE curriculum focuses on the fuzzy front end of (open) innovation, sustainable development, and impact in the implementation phase of product-service design. The work field of Industrial Design Engineering and Open Innovation, like many other domains, is growing increasingly more complex (Bogers, Zobel, Afuah, Almirall, Brunswicker, Dahlander, Frederiksen, Gawer, & Gruber, 2017). Not only have the roles of designers changed considerably in the last decades, they continue to do so at increasing speed. Therefore, industrial design engineering students need different and perhaps more competencies as young professionals in order to deal with this new complexity. Moreover, in our transitional society, lifelong learning takes a central position (Reekers, 2017). Students need to give their learning path direction autonomously, in accordance with their talents and interests.

IDE's Quality & Curriculum Committee (QCC) realized in 2015 there is too much new knowledge to address in a 3-year programme. Instead, IDE students need to learn how to become temporary experts in an array of topics, depending on the characteristics of each new project they do (see Textbox 1). The QCC also concluded that more than just incremental changes to the current curriculum were needed; thus, the idea for a flexible, choice-based semester approach in the curriculum was born: 'Curriculum M' (Modular). A co-creational approach was applied, in which teaching staff, students, alumni, prospective students, industry (including the (international) social profit sector), and educational advisors collaborated to develop a curriculum that would allow students to become not just T-shaped (wide basis, one expertise) professionals, but U- or W-shaped professionals, with strong links to other disciplines.

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"… From the evaluation of our first cohorts of graduates' work it becomes clear entrepreneurship is the poor relation of the three pillars of our programme - Design, Research and Entrepreneurship." "So, let's teach entrepreneurship more prominently." "But… I don't see how we can give entrepreneurship more attention without scratching something else important."

"Instead of scratching courses, let's begin from scratch: Let's list what we think are THE important subjects for our profession in the near and far future, and go from there."

Twenty minutes of brainstorming later:
"I think our list has just grown way beyond 180 credits!"

Textbox 1. Quotations from the Quality & Curriculum Committee (QCC) Meeting at IDE,2015.

Using the CDIO framework for curriculum innovation

The Faculty of Technology, Innovation, & Society (TIS) is a member of CDIO (Conceive, Design, Implement, Operate), a worldwide engineering education network. CDIO is a learning community of higher engineering education lecturers, managers and educational scientists in close collaboration with industry, sharing knowledge to deliver 'engineers who can engineer'. It offers a grounded framework of twelve standards of good practice (see Table 1) and a detailed syllabus of competencies formulated with international industry (Crawley, Malmqvist, Östlund, Brodeur, & Edström, 2011) to continuously improve towards practical, future proof education.

CDIO Standard	Explanation
Standard 1 The Context	*"...Beginning engineers should be able to Conceive--Design--Implement--Operate complex value-added engineering products, processes, and systems in modern team-based environments. They should be able to participate in engineering processes, contribute to the development of engineering products, and do so while working to professional standards in any organisation."*
Standard 2 Learning Outcomes	*"...In the CDIO syllabus, professional engineering organisations and industry representatives have identified key attributes of beginning engineers both in technical and professional areas. These detailed learning outcomes for personal and interpersonal skills, and product, process, and system building skills, as well as disciplinary knowledge help to ensure that engineering students acquire the appropriate foundation for their future."*

Standard 3 Integrated Curriculum	*"...A curriculum designed with ... an explicit plan [of integrated learning experiences that lead to the acquirement of integrated personal and interpersonal skills, and product, process, and system building skills. An explicit plan identifies ways in which the integration of skills and multidisciplinary connections are to be made... [and which corresponding pedagogical approaches are used]."*
Standard 4 Introduction to Engineering	*"...Students usually select engineering programmes because they want to build things, and introductory courses can capitalize on this interest. In addition, introductory courses provide an early start to the development of the essential skills described in the CDIO Syllabus."*
Standard 5 Design-Implement Experiences	*"...A curriculum that includes two or more design-implement experiences, including one at a basic level and one at an advanced level."*
Standard 6 Engineering Workspaces	*"... Engineering workspaces and laboratories that support and encourage the hands-on learning of product, process, and system building, disciplinary knowledge, and social learning."*
Standard 7 Integrated Learning Experiences	*"...Integrated learning experiences that lead to the acquisition of disciplinary knowledge, as well as personal and interpersonal skills, and product, process, and system building skills. [This] can be realized only if there are corresponding pedagogical approaches that make dual use of student learning time."*
Standard 8 Active Learning	*"...By engaging students in thinking about concepts, particularly new ideas, and requiring them to make an overt response, students not only learn more, they recognize for themselves what and how they learn. This process helps to increase students' motivation and form habits of lifelong learning."*
Standard 9 Enhancement of Faculty Competence	*"...Actions that enhance faculty [teaching staff] competence in personal and interpersonal skills, and product, process, and system building skills."*
Standard 10 ENHANCEMENT Faculty Teaching Competence	*"...Actions that enhance competence in providing integrated learning experiences, in using active experiential learning methods, and in assessing learning."*

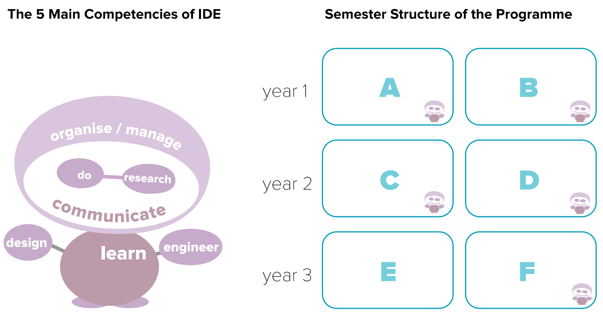
Standard 11 assessment	*"...Assessment of student learning in personal and interpersonal skills, and product, process, and system building skills, as well as in disciplinary knowledge... Different categories of learning outcomes require different assessment methods. These methods may include written and oral tests, observations of student performance, rating scales, student reflections, journals, portfolios, and peer and self-assessment."*
Standard 12 Programme Evaluation	*"...A system that evaluates programmes against these twelve standards, and provides feedback to students, faculty, and other stakeholders for the purposes of continuous improvement."*

Table 1. Short descriptions of the 12 standards of CDIO (Crawley et. al., 2011)

CDIO's syllabus has served as a blueprint for the reformulation of the competency profile of IDE in 2015, and its standards as guideline in the Curriculum M development. The programme started its first run in September 2017. What didactic choices did the programme take, congruent with the CDIO framework? And when and where did the ambitions to future-proof its curriculum take IDE even beyond the innovative CDIO guidelines? Based on a more elaborate paper published in the Proceedings of the 13th CDIO Conference (Hallenga-Brink & Sjoer, 2017), we reflect upon these two questions in this chapter.

Curriculum M in a nutshell

In Curriculum M, students learn in a societal, authentic context, together and reciprocally with (a hybrid) teaching staff and stakeholders, including users, while working on challenging projects in teams. After completing the mandatory first semester, 'the Basics of IDE' (Boi), they choose four semesters from a menu, based on their experiences and aroused interests, see Figure 1. Their rationale for choice can be to continue to develop talents or work on weak spots, to deepen or widen their knowledge and expertise, and/or to steer their experience in the thematic direction fitting their emerging professional identity. Throughout the semesters, students work on developing the competencies of IDE except during one minor-semester in C, D or E (semester E in Figure 1). Semester F is the individual final project for graduation, where the students prove all competencies on the highest level. The semester menu is dynamic and may change per year, based on the needs of students, number of enrolments, but also societal and technological developments.



Semester Menu Choices:

A:	Basics of IDE	ExCrEn
B/D:	Design Aesthetics & Perception	ExCr
	Product Engineering	CrEn
	Strategic Product Design	ExEn
C/D/E:	Responsible Design	ExEn
	Smart Objects	ExCr
	Prototyping & Craftmanship	Cr
	Exploring New Technologies	Ex
	International Insights Research	Ex
	Economics of Mass Production Design	En
	Entrepreneurship	En
	Design with Nature	Cr
	Design Agency	ExCrEn
	Service Design/Design Thinking	ExCrEn
C/D/E:	Minor/Exchange/Internship (max. once)	-
F:	Final Project (graduation)	ExCrEn

Figure 1. The basic structure of Curriculum M of IDE.

Semesters are 20 weeks each, of which 15 weeks are directed at the challenging project and its supportive workshops with an expo of all results at the end, and the last 5 weeks are so-called 'portfolio weeks'. The latter are allocated to extracurricular projects (students' own bedside table projects, *free space* projects from teachers, special excursions or international exchanges), concluded with a portfolio event where students get feedback from industry. There should be no entry barriers to a semester for a modular curriculum approach to work (Sinke, Zondervan, Kessel, Theeuwes, & Rouwhorst, 2015). Therefore, the only requirement is to have passed the Basics of IDE in semester A. After that, all semesters can be chosen in any order. Organisationally, the minimum and maximum number of students who can enrol for a semester is predefined. Students submit their first and second choices. The programme cannot always guarantee first choice placement. Because of the parallel menu choices, students each create their own integrated path through the curriculum.

The twelve CDIO standards in curriculum M

Future-Proof Learning Outcomes

In 2015, together with the Dutch twin IPO-programme at THUAS, IDE has reformulated its competency profile into a comprehensible set of 5 main competencies that students need to master, see Figure 1 once more. This visualisation of the competencies shows where each is nested: 1. Doing research provides glasses to look through. 2. Designing and engineering is hands-on. 3. For organizing and managing, students need to develop the frontal lobe in their brains. 4. Communication is always important: your words, arguments, presentations, teamwork skills etc. 5. Learning is a matter of the (motivated) heart. Each competency has several sub-competencies, 24 sub-competencies in total (see Figure 2). Lawson & Dorst (2009) recognize distinct levels of

expertise in undergraduate design students, from a novice who can apply strict rules, via an advanced beginner who relies on general truths and can make connections, to a competent graduate who is a problems solver, learner and reflector able to adopt when needed. The sub-competencies are described on these three levels in a programme-wide rubric. The active verbs of Bloom's taxonomy (Felder & Brent, 2004) are used in the rubric-cells. There are three integrated, individual assessment moments per semester only: in weeks 5, 10 and 15. Each time, students individually proof a self-chosen selection of five or six of the 24 sub-competencies on the next level based on their project and workshop work, which they collect in their portfolio library.
At the end of Semester F, they will have proven all sub-competencies on the 'Competent' level.

Design Expertise levels:	ENTRANCE level	NOVICE (apply strict rules)	ADVANCED BEGINNER (general thruths)	COMPETENT (problem solver)	THE MASTER (post bachelor)
Competencies IPO/IDE:	Linear processing, guessing and assuming	Checking the boxes, following steps, explaining	Connecting design steps, reflecting	Judging, self-evaluating, reflecting, adapting, solving	developing and opening new ways, creating new domains
1. Do Research					
1.1. (Re)define problems and reason analytically	Student retells client's and user's input literally	Student lists client's and user needs and problems, based on general arguments	Student determines stakeholder needs and problems, based on relevant arguments	Student constructs the problem definition, based on triangulated arguments	Student adapts problem definition with client based on logical, experience-based analytical arguments
1.2. Discover knowledge by investigating and experimenting	Student finds existing general knowledge	Student investigates by given methods	Student discovers by experimentation, combining appropriate methods of the design/innovation process	Student constructs knowledge by selecting the valuable outcomes of his/her experiments, investigation and discovery	Student dives deep for each new project by investigating and experimenting by prefered methods
2. Design & Engineer					
2.2. Use an iterative process with diverging and converging methods and techniques	Student considers the design process to be a 'straight line' process from A to B	Student iterates when requested to do so, and uses basic (given) diverging and converging techniques	Student selects proper methods for the diverging and converging phases in the design process	Student selects proper methods for an iterative, diverging and converging design process	Student compiles, executes and adapts an iterative design process, and evaluates along the way
2.4. Consider desirability, viability, and feasibility while designing and engineering	Student defines desirability, viability and feasibility	Student classifies desirability, viability and feasibily issues in their project	Student keeps desirability, viability and feasibily issues into account	Student evaluates desirability, viability and feasibily factors of his/her design, weighing their relative importance	Student creates desirable, viable, feasible designs
3. Organise & Manage					
3.2. Collaborate within a design team in a multidisciplinary (international) setting	Student (occasionaly) takes part in team work	Student actively participates in group work and gives team members in project group constructive feedback	Student collaborates with team members from the perspective of a co-established specific role	Student iteratively evaluates his/her role within the team and adapts where and when needed	Student combines several signature roles as a designer in team work
3.3. Show resourcefulness, flexibility and willingness to make decisions in	Student makes decisions when asked to	Student lists available argumentation and takes decisions based on that list	Student follows decisions made earlier in the design process and integrates new	Student iteratively evaluates decisions made during the design process and dives deep when	Student formulates a decision making strategy for an iterative design process

Figure 2. Part of the programme-wide competencies rubric, with examples of sub-competencies.

The IDE competency-rubric covers all learning goals of the CDIO Syllabus. This includes the later additions in version 2.0 of the syllabus: learning goals Leadership and Entrepreneurship. Two elements in IDE's competency set go beyond what standard 2 advises. First, the CDIO Syllabus asks for team work, centred on a team of equals (fellow students). At IDE students learn how to work in co-creation teams with real stakeholders, including industry partners and users. And secondly, as most students are communicating daily in a foreign language (English), the learning goals for working in an international setting are more elaborate. They focus on taking cultural diversity into account both in process and results as a team, and not just practicing a second language.

Integrated Learning and Assessment

Each IDE semester is an integrated learning experience with project tutoring and practicing in workshops, social and autonomous learning activities, formative and summative feedback and dialogue with the programme.
An IDE student has a conceive-implement, design-implement, or design-operate experience every semester of the major programme, following standards 3, 4 and 5 (see Table 1). A big question in the development of Curriculum M was how to gradually increase the authenticity and complexity of the professional learning tasks, and the autonomy and self-direction of the student. It is not enough to merely offer the authentic, professional context following John Dewey's theory of experiential learning (Fransen, 2005) and restore reflection in engineering education (Buch & Bucciarelli, 2015). When one 'throws students in at the deep end of the pool', as a Dutch saying goes, with minimally guided instructions for 'increased authenticity', this does not fit the cognitive architecture of our students' brains when they come in at age 17-19 (Kirschner, Sweller, & Clark, 2006). Kirschner found evidence for a higher effective learning by guided, just-in-time instruction, in order to deal properly with critical cognitive load. This led to a standard semester structure where workshops offer just-in-time supportive theory and skills to the project groups which are fully integrated with the project, and structure to work on the challenging project by weekly tutoring sessions, see Figure 3. Also, regular coaching sessions are provided, so the students are scaffolded in learning to define their own professional profile and in proving their mastery of the competencies along the way.

Figure 3 shows the first, mandatory, Basics of IDE semester. Each unit has a focus on one of the four stages of CDIO. In four units of 5 weeks, all three profiles of IDE 'explorer', 'designer' and 'entrepreneur' are addressed within one complex group project (in 2017 on Micro-mobility). This is where both introduction and selection take place. During the introduction week, students build a prototype of their first intuitive design right away. They continue with the same design challenge in units 1, 2 and 3 focusing on different aspects and phases of the project, presenting it at their first expo. In Unit 4, the portfolio weeks, they design and build the first version of their personal digital portfolio and ask feedback on it from professionals.

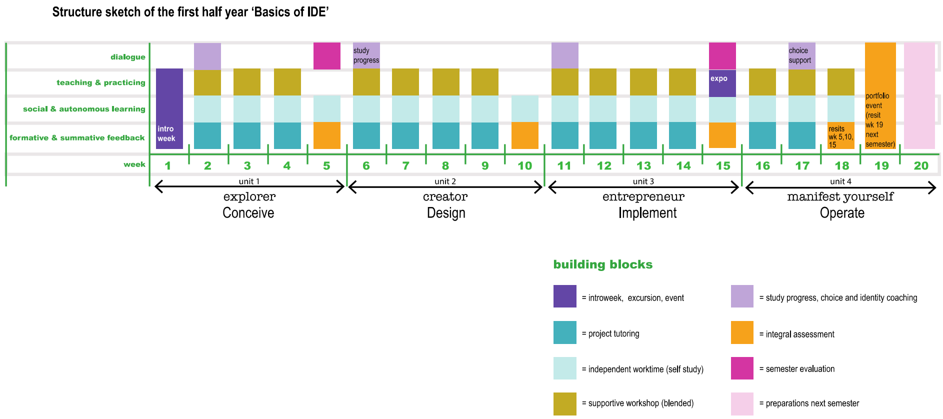


Figure 3. The Basics of IDE Semester, the first compulsory 20 weeks of the IDE programme.

In all following semesters of choice, in line with CDIO, students are taught beyond conceiving and designing in a theoretical setting by working on real projects, including implementation and operation activities such as manifesting themselves in the work field and sometimes even launching products in the market. Clients can be industry partners, design agencies, but also social domain partners and non-governmental organisations. For instance, students think up solutions for refugee camps for Doctors Without Borders, or design smart technology products for the blind and visually impaired for social enterprise Wunder People. That being said, implement and operate are less often touched upon in typical educational design projects. For that reason, some of the new semesters in Curriculum M focus on those two phases, using concept/design results of other more strategic design semesters. This will empower innovations within the programme. Students can also set up their own enterprise during their studies (during the Entrepreneurship and Final Project semesters) around one of their designs from former semesters.

What IDE added to standard 5 is to offer students international and multi-disciplinary design-implement experiences during these semesters to prepare them even better for their future jobs. Because of the international classroom at the IDE programme (over 80% of students come from abroad), every semester can be seen as an international experience, but students also have the opportunity to go abroad to do a design or design research project, an exchange, or a minor elsewhere. The semesters are open to incoming exchange students from partner universities as well. Some projects will be undertaken by IDE students together with students from other disciplines such as mechanical engineering or non-engineering disciplines (health, social work, business etc.). This ensures an actual multidisciplinary context for our students already during their studies.

Didactics in teaching and assessment
Because of the design-focused engineering education at IDE experiential learning has been the focus in teaching methods, standards 7, 8 and 10. However, next to active learning there are other important didactical choices to encourage the lifelong learning abilities of our students. One is familiarizing them with blended learning during their studies. Another is giving room for autonomy. When students can show autonomous behaviour, they voluntarily take on working or learning tasks (Gagné & Deci, 2005). In a lifelong learning setting, which will not always have grades and credits as extrinsic motivators, this is vital. IDE likes to give students the chance to tap into their personal drivers, by letting them choose their own path and build up their own professional identity. Meijers et. al. (2010) identified three main conditions for developing a professional identity: learning should take place in an authentic setting, students should have the opportunity to choose part of their study activities according to their personal development goals and there should be a professional, reciprocal dialogue between students and teachers about their development. Curriculum M provides for this dialogue during coaching, workshop feedback, and the 5-weekly summative assessments. Cohen-Schotanus (2010) shows that students typically start preparing three weeks before the deadline and study hardest for the first test they have, to the disadvantage of the remaining ones in the same period (Schmidt, Schotanus, & Arends, 2009). Therefore, Curriculum M semesters purposefully have the 5-week unit structure; see Figure 3, concluded with one single individual, integrated oral assessment with two independent assessors. Within this assessment the focus is on what the student has learned instead of on what is lacking. The grading is done in dialogue, where ideally student and assessors agree at the end of the session what sub-competencies indeed have been proven, and the student summarizes the received feedback in an action plan. There is no competition of other exams or classes during the assessment weeks.

Faculty Competences and Facilities
Society sees a changing role of the 21st century teacher, not as an expert on a certain specialisation only, but as a coach or perhaps even a co-designer in an open innovation network setting, facilitating innovations by reciprocal learning of all stakeholders including the students (Hallenga-Brink & Vervoort, 2015). Thus, necessary competencies of teaching staff change, standards 9 and 10. Part of the lecturers is hybrid, designing or doing research next to teaching, which increases competency. Choosing a co-creation approach for Curriculum M brought along the opportunity to enhance competency even more. During co-creation sessions reciprocal learning takes place. Also, training for the new curriculum has been in focus. Teaching staff has

taken part in several CDIO workshops, working on constructive alignment of teaching, learning, and integrated assessment. Also training and calibration sessions for the integrated assessment and coaching on professional identity have started and will continue to be planned throughout the semesters.

Because CDIO is integrated in Curriculum M, the evaluation automatically takes CDIO-principles along, standard 12. Instead of developing plans and implementing them and then asking industry to evaluate this, IDE has taken the route to co-create the new curriculum in a group of teaching staff, (prospective) students, alumni, industry, educationalists, and other stakeholders. During the semesters evaluations (one in week 6 and one in week 19) students and clients will help teaching staff to adapt while teaching and planning for the next run. This co-creation setup results in not only *feedback* afterwards, but also *feedforward* and *feedduring*. This kind of input was for instance used in the reconstruction process TIS is currently in, to make sure facilities such as project group landscapes instead of traditional classrooms, professional meeting spots with clients, and of course the workshop and 3D protolab are going to be on par with the learning activities of the IDE students, standard 6.

All these results are summarized in Table 2.

Very valuable	Standards 9 & 10	Attention to (hybrid) faculty competence improvement, training and support during the implementation of an innovative curriculum design
	Standard 6	Input to make our (near-)future workspaces future-proof
Valuable + Beyond	Standard 2	Learning Outcomes *also on international and co-creation competencies*
	Standard 5	*International, Multi-disciplinary* Design-Implement Experiences
	Standards 8 & 11	*Student-owned and Lifelong* Active Learning and *less but fully integrated* assessment
	Standard 12	Programme Evaluation *as part of the curriculum (design) cycle*

Table 2. The highlights of IDE's experience using CDIO as blueprint and guideline for curriculum redesign

Conclusion: Reciprocal learning and iterative 'beta'testing

What kind of didactic structure do you need to future-proof your programme in higher education? In innovating the IDE curriculum towards a flexible, choice-based, integrated, professionally challenging, and multidisciplinary curriculum, the CDIO framework has proven to be a match to our ambitions. As the terms conceive, design, implement and operate are closely related to the realms of an open innovator, they were effortlessly found back in the structure of the curriculum. The CDIO syllabus 2.0 also fitted to the competencies of an industrial design engineer, with some minor additions. And the CDIO standards offered welcome reminders and guidance on staff development, the organisation of the programme, and the needed facilities. This has ameliorated the chances of a successful implementation of Curriculum M.

In other standards, Curriculum M found a match but also went beyond the CDIO framework: taking teamwork to the next level of co-creation and add intercultural competences beyond communicating in a different language compared to the Syllabus; and by advancing on several standards (2, 5, 8, and 11), for instance by co-creation with all stakeholders instead of thinking something up first and then checking if they would be willing to support in hindsight. Also, ownership of the student of his own learning and assessment was taken to the next level, with a fully integrated assessment system. This proves to have a positive influence on study progress and self-directed learning instead of underachieving. And last, the flexibility of the semester menu to respond to changes in the work field and society is an important starting point for a future-proof curriculum. These opportunities of growth for the framework are brought back to the CDIO learning community via conference papers and workshops.
In the meantime, using the CDIO framework has made it possible to collaborate with CDIO partners to offer students the multidisciplinary context they will find in their professional life already during their studies. The next step is to involve our work field network in our CDIO endeavors. Overall, we can recommend using the CDIO framework for curriculum innovation. We feel we can now truly educate designers who can design within their future professional context, and we have a concrete tool to continuously enhance our efforts to do so.

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