ACADEMIC DEVELOPMENT SUPPORT FOR IMPLEMENTING CDIO

Kärt Kase, Tiina Kasuk, Tiia Rüütmann

Tallinn University of Technology, School of Engineering, Centre of Teaching Excellence

Kaimo Sonk, Raivo Sell

Tallinn University of Technology, School of Engineering, Department of Mechanical and Industrial Engineering

Ivar Annus

Tallinn University of Technology, School of Engineering, Dean's Office at School of Engineering

ABSTRACT

Inducing changes in the management of education can be challenging, especially in the field of engineering. In the School of Engineering in Tallinn University of Technology (TalTech) being a member of the International Society for Engineering Pedagogy (IGIP) and CDIO, the Centre for Learning Excellence was established recently to provide academic staff with more support in teaching and learning development. In the last decade, the IGIP curriculum for engineering educators has been available for all teaching staff.

Therefore, in this paper, it is evaluated how the newly updated IGIP curriculum covers basic pedagogical knowledge used in the CDIO framework. A survey was conducted for teachers of the Product Development and Robotics programme, to evaluate the current state before starting to implement CDIO principles. One teacher from the programme shared his vision of support needed from a teacher who is planning to implement CDIO. The aim of this paper is to analyse what is the current situation in teacher training in TalTech and what kind of specific support is needed by the teachers who start implementing the CDIO framework in their courses. Three different analysis methods pointed out various aspects that should be considered in planning how to support teachers in the process of implementing CDIO.

KEYWORDS

IGIP curriculum, Faculty Development, Course Development, CDIO implementation, Standards: 3, 7, 8 and 10

INTRODUCTION

Graduates of Tallinn University of Technology (TalTech) are valued highly for their professional knowledge. The industry expects more independence in analysing and solving real engineering problems. Therefore, TalTech's School of Engineering sought for experiences and solutions of making engineering education more connected with real life. The CDIO Initiative has created a framework that provides students with an education that sets fundamentals of engineering to the context of Conceiving - Designing - Implementing - Operating real-world systems and products. The CDIO Network is a worldwide community with knowledge and a wide variety of well-working examples in engineering education. The first study programme with interest and readiness to start using CDIO principles in TalTech was bachelor´s programme Product Development and Robotics. The programme director initiated collaboration with Estonian Centre for Engineering Pedagogy (ECEP) to provide teachers with needed help when implementing the framework. ECEP, with International Society for Engineering Pedagogy (IGIP) accreditation since 2003, has been the prime provider of pedagogical training in TalTech for years. In the last decade, the IGIP curriculum for engineering educators has been available for all teaching staff.

Up to 2020, pedagogical training in TalTech has been provided centrally through the personnel department. Changes in determining the role of the University in society has led to understanding that there is a need for a field-specific approach for course development. According to the Strategic Plan 2021-2025, TalTech launched school-based didactics and pedagogy centres to enhance and improve the quality of teaching. The School of Engineering established the Centre for Teaching and Learning Excellence, where teachers get support with analysing and developing their courses, inspiration from colleagues, and the latest studies of engineering education. The School of Engineering sees great potential in implementing the CDIO framework to provide students with real-life engineering experiences. The Centre for Teaching and Learning Excellence should become a beneficial collaborator for teachers and program directors who start engaging CDIO principles in their courses and programs.

Dirksen (2015) in her book "Design for how people learn" empathizes the need to understand the gap between learners’ current knowledge level and the expected level in order to professionally succeed. Most training programs start to solve the knowledge gap, but there may also be a gap in motivation, skills, habits, and/or environment. Felder and Brent (2016) have brought out the problem that sometimes teachers have to teach skills they haven't learned nor experienced and are not sure in their competencies in those skills. Especially integrating professional skills in core courses may be a problem accompanied by the fear of using new instructional methods that may take too much time away from the main subject.

Collaborators of CDIO Network have suggested methods on how to support teachers starting to implement CDIO principles in their courses. Usage of the mentoring approach has been proved to work successfully as a teaching competence enhancement model (Loyer & Maureira, 2014); (Papadopoulou, Bhadani, Hulthén, Malmqvist, & Edström, 2019). Teacher training programs should take a holistic approach with CDIO case studies, active engagement, and direct usefulness to get teachers to know and use active learning methods (Papadopoulou, Bhadani, Hulthén, Malmqvist, & Edström, 2019); (Kontio, 2009). Using a learning-centered approach in training programs may help teachers to overcome uncertainty and provide new viewpoints for the role of a teacher and tools for assessment with active teaching and learning (Kontio, 2009).

Therefore, a compliance analysis of IGIP curriculum and CDIO standards was performed to understand how the IGIP curriculum covers the pedagogical competencies that support implementing CDIO principles in TalTech. A survey was conducted among teachers of the Product Development and Robotics program, to map how teachers evaluate their courses before starting to implement CDIO principles. Most of the teachers in the program have participated in one or two CDIO workshops. One teacher conducted an analysis of his challenges (described in detail in Case-study section) with starting to implement CDIO principles in his course and what kind of support teachers may need when developing their courses. He has participated in CDIO workshops and several courses from the previous IGIP curriculum. Based on the results, the current situation was identified and will be used for planning specific training and individual support.

The aim of this paper is to understand the current baseline and potential gaps in teacher training in TalTech and the specific support needed by the teachers who start implementing the CDIO framework in their courses.

COMPLIANCE ANALYSIS OF IGIP CURRICULUM AND CDIO STANDARDS

International Society for Engineering Pedagogy (IGIP) was established in 1972 in Austria. IGIP aims to develop practice-based curricula, engineering pedagogical competencies, contemporary methods for teaching and assessment for engineering education. IGIP accredits training centres for engineering pedagogy at institutions delivering courses conforming with the IGIP prototype curriculum with a minimum amount of 20 ECTS credits. In 2021 IGIP reaccredited TalTech updated in-service micro-credentials program for engineering faculty continuing education in engineering pedagogy (24 ECTS). IGIP maintains a list of accredited individual engineering educators who are awarded the title „International Engineering Educator" certifying IGIP's required level of engineering pedagogical competencies for effective teaching engineering. (International Society for Engineering Pedagogy, 2022)

Engineering educators who redesign their courses for the implementation of CDIO principles need pedagogical competencies and students participating in newly redesigned CDIO courses need supervision and support in reflection and self-regulation. The newly updated program gives the needed competencies for engineering faculty for effective teaching and supervision.

In the framework of the present research, a compliance analysis was carried out to analyse whether the updated pedagogical program meets the CDIO standards (CDIO Standards 3.0, 2022), thus supporting the smoother implementation of CDIO principles. In Appendix 1 the structure of the updated TalTech engineering-pedagogical curriculum is presented.

Course name in IGIP curriculum / CDIO Standard	Engineering Pedagogy	Laboratory didactics	Curriculum theory	ICT tools	Effective communication	Educational Psychology	PBL	Analysis of studies	Final project	Internship	Standards	New technologies	Coaching	Multicultural	Practice	Sustainable dev	Learning lab	Management	Excursions	Product dev
Standard 1	■	■		■			■	■	■	■	■	■	■		■	■	■	■	■	■
Standard 2	■	■	■	■				■	■				■				■			■
Standard 3	■		■					■	■								■			■
Standard 4							■		■	■						■			■	
Standard 5				■			■		■		■					■			■	■
Standard 6				■			■		■	■		■		■			■			■
Standard 7				■	■	■	■	■	■	■	■	■				■		■	■	■
standatd 8	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Standard 9	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Standard 10	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Standard 11	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Standard 12	■		■					■	■											

Figure 1. Results of compliance analysis of IGIP curriculum courses that include guiding principles of CDIO Standards

According to the compliance analysis presented in Figure 1, all modules of the engineering-pedagogical program support the implementation of *CDIO Standard 1 "The Context"*, Standard 8 - "Active Learning", Standard 9 - "Enhancement of Faculty Competence", Standard 10 - "Enhancement of Faculty Teaching Competence", Standard 11 - "Learning Assessment" are guaranteed by all subjects of the curriculum.

CDIO Standard 2 "Learning Outcomes" is ensured by following courses of the curriculum: "Engineering Pedagogy", "Laboratory Didactics", and "Curriculum Theory and Practice", "ICT tools supporting interactive e-learning", "Analysis of the study process. Ethical problems in education", "Final Project", "Coaching and Mentoring", "Learning Lab" and "Product Development and Innovation".

CDIO Standard 3 "Integrated Curriculum" is covered by courses "Engineering Pedagogy", Curriculum Theory and Practice", "Analysis of the study process. Ethical problems in education", "Final Project", "Learning Lab" and "Product Development and Innovation".

Principles of the *CDIO Standard 4 "Introduction to Engineering"* are covered by the learning outcomes of courses "Final Project", "Internship in a company. Cooperation projects with partners", "Problem-based and meaningful learning ", "Sustainable development", and "Excursions to Companies", "Product Development and Innovation".

CDIO Standard 5 "Design-Implement Experiences" is implemented in courses "Problem-based and meaningful learning ", "Final Project", "Standards and Quality", "Sustainable Development", "Excursions to Companies", and "Product Development and Innovation".

CDIO Standard 6 "Engineering Learning Workspaces" is ensured by learning outcomes of the courses "ICT tools supporting interactive e-learning", "Problem-based and meaningful learning", "Final Project", "Internship in a company. Cooperation projects with partners", “Standards and Quality”, “Multicultural Learning Environment”, “Product Development and Innovation” for engineering educators and “Learning Lab” for engineering students.

CDIO Standard 7 “Integrated Learning Experiences is afforded by integration learning outcomes of the courses “ICT tools supporting interactive e-learning”, “Educational Psychology and sociology”, “Effective Communication”, “Analysis of the study process. Ethical problems in education”, “Problem-based and meaningful learning”, “Final Project”, “Internship in a company. Cooperation projects with partners”, “Standards and Quality”, “New Technologies”, “Sustainable Development”, “Management”, “Product Development and Innovation”, and “Excursions to Companies”.

Standard 12: Program Evaluation is guaranteed by the courses “Engineering Pedagogy”, “Curriculum Theory and Practice”, “Final Project”, “Analysis of the study process. Ethical problems in education”.

Results of the compliance analysis of IGIP curriculum and CDIO standards present solid proof that IGIP engineering-pedagogical curriculum ensures and contributes to the effective implementation of CDIO principles by supporting engineering faculty members with needed pedagogical competencies.

SURVEY

A survey among teachers of the Product Development and Robotics programme was conducted, to map how teachers evaluate their courses before starting to implement CDIO principles.

Method

The survey consisted of 16 statements and 2 background questions. 16 statements were based on the 12 standards of CDIO. There were 2 statements for Standards 2, 6, 8 and 11, that consider several different aspects. Using separate statements allowed responders to answer according to each aspect. All statements were answered on the Likert scale, where 1 meant “disagree,” 5 meant “agree” and 0 meant “don´t know.” One question was about respondents role in the course (main teacher or assistant) and one was for comments. The survey was anonymous and conducted in Estonian. Translated survey questions can be found in Appendix 2. The online survey was sent out to 41 teachers of the Product Development and Robotics program.

Results

The self-evaluation survey was conducted by 18 (44%) teachers. All respondents marked themselves as main teachers.

Figure 2. gives an overview of the results. Standards 11, 6, 2 were evaluated highest. For Standard 2 there were two statements about learning outcomes: consistent work with learning outcomes (average 4,35) and considering feedback from stakeholders (average 4,12). Standard 6 consisted of two statements: there is a physical engineering workspace where students can evolve their knowledge through hands-on activities (average 3,78); digital learning materials are available to students all time (average 4,94). The highest rating for the second statement of Standard 6 is related to the e-support project in TalTech, where the minimum level of e-learning should be ensured in compulsory courses in I and II levels by the year 2021 (TalTech E-Learning, 2022) For Standard 11 there were two statements about

learning assessment: whether professional skills are developed during course (average 4,33) and learning outcomes are specified and understandable for students (average 4,53).

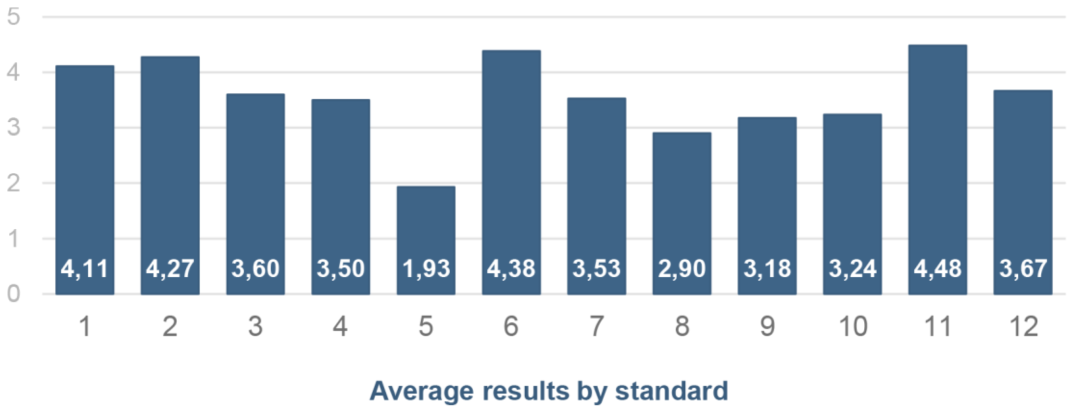

Figure 2. Overview of the survey results

Standards 5, 8, 9, 10 were evaluated lowest. In Figure 3 it is illustrated how responses were divided for each statement. Standard 5 stated that design-implement experiences are used in the course (average 1,93). It is important to take into account, that all respondents were not teachers of engineering subjects. Standard 8 (average 2,90) consisted of two statements about active learning: using active learning methods in lessons (Statement 1, average 3,40) and using peer assessment to evolve professional skills (Statement 2, average 2,40). Standard 9 stated that the enhancement of disciplinary knowledge and professional skills are well supported by the university (average 3,14). Standard 10 stated that the enhancement of teaching skills are well supported by the university (average 3,24).

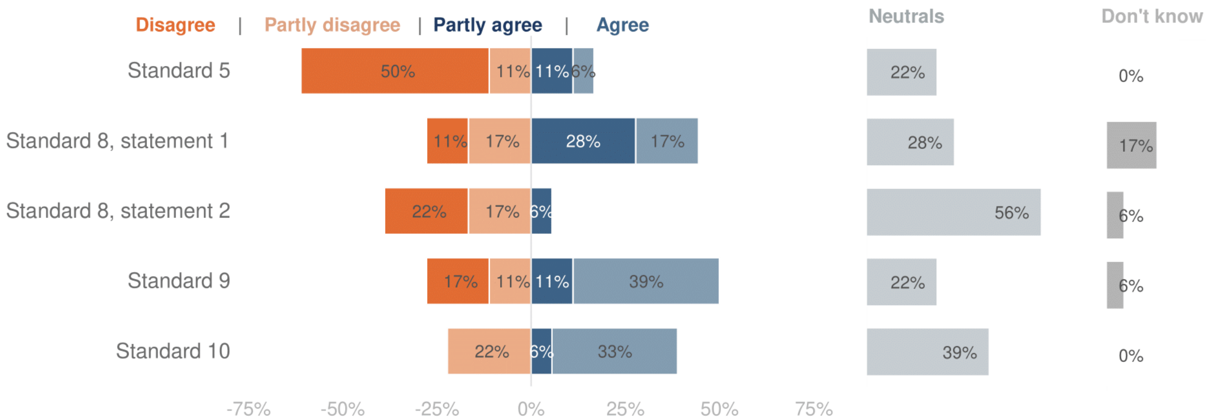

Figure 3. Distribution of answers for statements with lowest average rate

Four respondents added comments to their self-evaluation. One stated that the course is not engineering-subject and supports evolving transferable competencies. One respondent brought up the problem that the level of students' (especially international students) for knowledge and skills is uneven, some students are not able to understand the essentials needed to pass the course. Based on the CDIO Standard 6 one possible solution would be to use digital content repositories from prerequisite courses to enable students to acquire needed knowledge.

One comment was about Standard 3: “At the moment there is no collaboration nor integration with other courses, every teacher works by themselves. Hopefully, program directors see the big picture.” The average rate for the statement about Standard 3 was 3,60: 22,2 % answered “agree”, 33,3% “partly agree”, 16,7% “didn’t know”, 5,6% were neutral, 16,7% “partly disagree” and 5,6% “disagree”. The survey was sent out to all teachers of the program but there were no questions about whether they teach speciality subjects or general courses. Teachers of speciality subjects may have rated this statement higher as they may have a better overview of how their course is related to other courses.

The last comment was a proposal for improving the used survey with comments for all statements to clarify the meaning of the statement or CDIO standard.

Conclusions of survey results

The results of the survey pointed out Standards 5 (Design- Implement experiences) and 8 (Active learning) that need more attention. Also, Standard 3 should be one focal point for supporting the implementation of CDIO. Answers for the statements about Standard 9 (Enhancement of Faculty Competence) and Standard 10 (Enhancement of Faculty Teaching Competence) refer that both need a new approach. To get a more adequate view of compliance of the programme to CDIO standards, it should be distinguished between teachers of general and speciality studies.

CASE-STUDY AND DISCUSSION

This section describes the need for support on a university level to implement CDIO aspects to a course in TalTech. The needs are listed from a teacher’s point of view who has some prior knowledge of CDIO but has not yet implemented these principles in a course. The teacher also participated in the survey and his answers were consistent with overall results with one major difference – the lowest score in self-evaluation was for Standard 5 Design-Implement but for this course it was evaluated much higher as it’s project-based course.

CDIO methods will be implemented in a course for 5th semester Bachelor engineering students in Product development and robotics curriculum. The course title is Integrated Product Development, and its workload is 6 ECTS credits. It’s a project-based course where students develop a new product, often resulting in a physical prototype. About 60 students are taking the course each semester and projects are done in groups. The maximum limit of students per group is 5, but it’s recommended to have groups of 3 as this keeps the vagueness of responsibility in check. Each group has an individual project topic that has been confirmed with the teacher. The course ends with an exam (30% of final grade) and submitting the project documentation (70% of final grade). The exam is in written form, with multiple-choice questions and individual so that every student’s knowledge of the course materials can be checked. The project documentation grade is communal.

The problem lies in the individual project topics and the amount of documentation created that needs to be checked and given feedback. On average the group size is 3 which means about 20 projects. Each project documentation is about 50 and sometimes up to 90 pages long. That means about 1000 pages to read, process, and give feedback to. The amount of work is somewhat mitigated by discussion and questions from the students throughout the semester, so the teacher already knows the project quite well but usually, these are projects from the more active students who make more effort to pass the course with a good grade.

To solve this problem a principle from CDIO can be implemented – including the students in the review and feedback process. This is related to Standard 8 Active learning and the fact that this approach hasn't been implemented before is consistent with the survey results described in the previous section. The survey shows that the self-assessment score for this standard is one of the lowest.
The feedback is organized in the middle of the semester (8th week) and it's a pre-requisite for attending the exam and getting the final grade. The following is a description of the support required at the university level.

The solution will be implemented in an e-learning environment Moodle. This affects some of the decisions how the feedback process is set up.

The main benefit of this approach is the increase in learning quality and quantity. Reviewing other students' projects will give perspective on how well they themselves are doing, what can they improve, add or do differently.

Support before implementation
Don't fix what's not broken. On a teacher level it is often argued why should one change something if the majority of students are happy, they pass the course, they learn the required material and the feedback is positive? Everything new is always daunting, especially if the amount of work required is unknown and the usefulness questionable.

From the teacher's perspective the support before implementation of CDIO methodology should focus on helping teachers understand the benefits of improving their courses. This can be done by using examples of successful changes in other courses. The examples must be similar to the course in question. If a math course teacher is shown examples of a biology course, then the potential impact might not be reached as the teaching methodologies are different and not transferrable.

The second support aspect before implementation is to show mathematically how the invested work hours by the teacher pay off in the long run. By spending x number of hours, one will reduce the amount of work at the end of the semester by y. A simple multiplication should demonstrate the benefits from the teacher's point of view. Time saved was one really important factor in the Integrated product development course because it significantly reduces the amount of complicated and lengthy feedback for groups that are not active during the semester. Reviewing good projects is easy and quick, 80% of the time giving feedback is spent on low-quality projects.

The third aspect where the university can offer support is where to start from. If the teacher is unfamiliar and inexperienced then starting from nowhere can be difficult. Most of the academic staff just need a nudge in the right direction and everything else will follow naturally. The establishment of Centres for Teaching and Learning Excellence in TalTech is expected to provide such support in the coming years.

Support during implementation
There is a need for technical support during the implementation of CDIO methods. In the analysed case, the peer review is to be added to the Integrated product development course.

The exact set-up is not defined yet but because all activities related to learning should be in one location, a learning management system (Moodle) is to be used.

The first aspect that requires support is not knowing the technical possibilities of the Moodle. The teacher in the course is well versed in computers but not knowing that a specific functionality exists will result in inefficient solutions. For example, the peer review could be organized in a standard forum, but this would create a lot of confusion and extra work for the teachers. The second option is to use “Group self-selection” which allows the groups to work together, keep their files in the same place, and give access to other groups for peer review. But this solution has the same problems as using a forum. The third option is to use the special activity “Workshop” where peer review is organized into four phases. The “Workshop” activity is rarely used and may be hard to find.

The second aspect of technical support is setting up the CDIO activities themselves. There are 11 different categories that all have several options on how to set up the peer review. The support provided does not have to go into details with every option, but some basic recommendations would reduce the amount of time required from the teacher. Also, it’s not visible how the projects for reviews will be distributed and how to avoid getting your project for reviewing (randomly getting your own group members' project).

The third aspect is the best practices. To avoid just learning from mistakes there could be recommendations on what usually works best. One of the concerns for Integrated product development was whether to use anonymous feedback. Being able to be brutally honest vs. knowing how seriously to take the feedback based on the person making the comments. The second concern was the number of reviews per student. Are 2 reviews enough to get a comprehensive overview or would 3 be better? Also, how many reviews per student would be too much work? This kind of support would also mean that the teachers can talk to somebody about the course and brainstorm for ideas. For example, the “compliment sandwich” was proposed to be used in the review method where it starts with a compliment, then things that can be improved and finish with something positive.

Support after implementation

The support from the university after implementation should focus on measuring the results and improvements based on the experience. Measuring the effects of implementing peer review can be challenging because there is not an objective baseline to compare it to. Students and their skills vary each year and just a comparison to the previous year's results/grades might give a biased result. Proposing suitable KPIs would increase the teachers’ morale if it is shown how the students’ learning experience and inquired competences have improved. Or in case of negative feedback what can be done differently in the future.

At the end of the course, teachers should always conduct self-evaluation to recognize positive and negative aspects of used methods. It is recommended to create a tool for the self-evaluation to make the practice more convenient. It could be a list of important aspects to think through or an evaluation form that can be saved for comparison for the following years.

CONCLUSIONS

Three instruments used in the present research pointed out various aspects that should be considered in planning teacher training and support for implementing CDIO principles.

Compliance analyses of the IGIP curriculum and CDIO Standards proved that the IGIP curriculum can be used as the base of pedagogical training for engineering teachers implementing CDIO approaches. To introduce CDIO principles and get more effect out of training programs, suitable CDIO principles should be used in training programs. Design-implement experiences and Active learning should be considered as the first topics for training. The case study pointed out the need to collect use cases of implementing CDIO principles, spread the inspiration and learn from best practices. Mentoring could be used for providing support for those who are starting to implement CDIO principles. The method of covision is also suitable for group mentoring teachers with similar challenges in close fields. The second point that came out from the case study was the technical support needed with Moodle. Finding the best possible solution for the learning process should be worked out in collaboration with teachers and specialists from the Centres for Teaching Excellence. Support on how to set up activities in Moodle is provided by the Educational Technology Centre at TalTech.

To support the sustainability of implementing CDIO principles in courses, the tool for self-evaluation should be developed and researched. Training programs should be modified using the CDIO approach to give teachers experience in active learning and impact their teaching. In contemporary education, students can give us valuable input to enhance the impact on faculty and course development.

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BIOGRAPHICAL INFORMATION

Kärt Kase is an Academic Development Officer at the Centre of Teaching Excellent at Tallinn University of Technology (TalTech).

Tiina Kasuk is an Academic Development Officer at the Centre of Teaching Excellent at Tallinn University of Technology (TalTech).

Tiia Rüütmann Ph.D. is an Associate Professor of Engineering Pedagogy at Tallinn University of Technology. She is head of the "Centre for Teaching Excellence" and "Estonian Centre for Engineering Pedagogy. She is a Programme Director of a Master Programme "Vocational Teacher". She is the president-elect of the International Society for Engineering Pedagogy (IGIP).

Kaimo Sonk Ph.D. is a Senior lecturer at the Department of Mechanical and Industrial Engineering

Ivar Annus Ph.D. is a Tenured Assistant Professor and leader of the Urban Water Systems research team in the Department of Civil Engineering and Architecture at Tallinn University of Technology. He is a Vice-Dean for Academic Affairs at the School of Engineering

Raivo Sell Ph.D. is a Tenured Assistant Professor Department of Mechanical and Industrial Engineering. He is a Programme Director of "Product Development and Robotics".

Corresponding author

Kärt Kase
Tallinn University of Technology
School of Engineering
Centre of Teaching Excellence
Ehitajate tee 5, Tallinn
Estonia
kart.kase@taltech.ee

APPENDIX 1: STRUCTURE OF TALTECH MICRO-CREDENTIAL PROGRAM OF ENGINEERING PEDAGOGY

Module	**Subjects/ECTS**
Compulsory Module 1 – „*Course Design*“ 6 ECTS	1.1 Engineering Pedagogy (2 ECTS)
	1.2 Laboratory didactics (2 ECTS)
	1.3 Curriculum theory and practice (2 ECTS)
Compulsory Module 2 – „*Design of Learning Process*“ 6 ECTS	2.1 ICT tools supporting interactive e-learning (2 ECTS)
	2.2 Effective communication (2 ECTS)
	2.3 Educational Psychology and sociology (2 ECTS)
Compulsory Module 3 – „Analysis of Learning Process“ 6 ECTS	3.1 Problem-based and meaningful learning (2 ECTS)
	3.2 Analysis of the study process. Ethical problems in education (2 ECTS)
	3.3 Final project. Portfolio design (2 ECTS)
Elective Module - Minimum 6 ECTS to be elected	4.1 Internship in a company. Cooperation projects with partners (2 ECTS)
	4.2 Standards and quality (1 ECTS)
	4.3 New technologies (1 ECTS)
	4.4 Coaching and mentoring (1 ECTS)
	4.5 Multicultural learning environment (1 ECTS)
	4.6 Teaching practice (2 ECTS)
	4.7 Sustainable development (1 ECTS)
	4.8 Learning Lab (1 ECTS)
	4.9 Management (1 ECTS)
	4.10 Excursions to companies (1 ECTS)
	4.11 Product development and innovation (2 ECTS)
Total	**24 ECTS**

APPENDIX 2: TRANSLATED SURVEY QUESTIONS

Standard	Question
	1. I´m : a. Main teacher b. Assistant (teaching in practicum, laboratory, exercise)
1: The Context	2. Students work with real-life problems or conceive, design and analyze the lifecycle of different products, processes or systems.
2: Learning Outcomes	3. I consistently work with / develop/ review learning outcomes of my course 4. The feedback from key stakeholders (program manager, colleagues, students, and Industry) is considered during the process of developing course learning outcomes and content
3: Integrated Curriculum	5. I know how my course content aligns with skills and knowledge taught in other courses in the same program
4: Introduction to Engineering	6. In the first lesson of the semester, I explain to students, how the course is related to other courses in this program or engineering in general
5: Design-Implement Experiences	7. My course follows a design-implement approach - students develop products, processes, systems or services
6: Engineering Learning Workspaces	8. There is a learning environment that supports and encourages hands-on learning 9. Digital learning materials are available for students all the time
7: Integrated Learning Experiences	10. In my course, professional competencies like personal and interpersonal skills are developed as well as disciplinary knowledge
8: Active Learning	11. There is active learning in my lessons, for example, group work, discussion, case analysis, etc 12. I think that peer assessment is a valuable experience for students, and I use it in my teaching
9: Enhancement of Faculty Competence	13. The enhancement of my disciplinary and professional competencies is well supported by the university
10: Enhancement of Faculty Teaching Competence	14. The enhancement of my teaching competencies (integrated, active, and experimental learning methods, assessment) is well supported by the university
11: Learning Assessment	15. I think that it is essential to enhance student disciplinary knowledge and skills as well as professional competencies (communication, leadership, analyzing, motivation, time management, critical thinking etc) 16. Learning outcomes for my course are written in a way that students can understand what they need to be able to do and how it is assessed
12: Program Evaluation	17. My course is continuously evaluated in the context of the program, and results are introduced to key stakeholders
	18. Comments (other ideas in connection with the CDIO framework)