Tracks for change, flexibility, interdisciplinarity and creativity in engineering education

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TRACKS FOR CHANGE, FLEXIBILITY, INTERDISCIPLINARITY AND CREATIVITY IN ENGINEERING EDUCATION

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ABSTRACT

This paper describes the early stages of the developments of Tracks, an initiative to create, implement and evaluate a new educational model where the structure of the education is developed to give students the opportunity to create multi- and interdisciplinary competencies, meet their expectations and need for a more individualized study plan and shorten the lead times for changing the education to embrace new technologies. The new education model is based on the creation of tracks with different themes lying between existing programs not belonging to a specific department or school. The idea is to create individual and flexible study opportunities by introducing Track-courses within the themes. These courses address specific challenges that may be broad societal and profound research-driven. Tracks also include large investments in Chalmers' learning environment. The paper focuses on Tracks as a large change initiative, strategies to manage the complexity of this change as well as development philosophy and working methods in the early phases of the initiative. Change at universities has been discussed previously, but this is a unique opportunity to study how large change may be managed over time, including both the content of the education and the learning environments. Through action research, where interventions may be done to influence the initiative, it is possible to develop practical contributions for other universities in need of similar development. The research has been conducted over approximately a year and includes data from interviews and action research, where the authors are the main people working with this initiative. The close contact with the data gives a unique understanding of how different activities within the initiative influence the outcome. Thus, this paper will contribute to the understanding of how large institutional change initiatives are facilitated by a flexible and agile approach contrasting the traditional and somewhat slower university culture.

KEYWORDS

Educational change, multidisciplinary, agile, flexibility, educational management, Standards 1, 5, 7, 8

BACKGROUND

In 2017, Chalmers University of Technology (hereafter Chalmers) decided, in discussion with its owner foundation, to invest in three large flagship initiatives to make sure that the university would be at the forefront of education, research, and utilization in ten years. As a university, Chalmers has a strong reputation but realized that although a long history and successful work

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within these three main areas, it is also important to dare to develop into the future requirements of both research, education, and utilization. An open call for all employees at the university encouraged people to suggest large programs that would develop Chalmers accordingly. From the over 60 suggestions that were submitted, a process to sort out three main candidates was initiated in 2018. This process included several workshops, meetings, discussion etc. with relevant stakeholders within each focus area. Finally, the boards of the university and the foundation made the decision to implement the initiatives Tracks, Chair (Chalmers AI Research Center), and Genie (Gender initiative for excellence).

An important part of the anchoring of the ideas was to make a trend analysis and connect the suggestions both to the current issues in society but also to try to understand where the university needs to be in the future. For the educational development, it was concluded that there are new and different requirements on the students graduating. Additionally, there are new demands and expectations from the young people starting their educations at the university. The lead times at the university are long compared to technology development. Moreover, to solve current issues, there is a significant need for a multidisciplinary understanding and competence to collaborate around solutions for complex issues, see, *e.g.*, Kamp (2019) and references therein. The proposal for developing the education was finally a combination of two different ideas that had been submitted on developing the education and the learning environments at Chalmers.

Although Tracks also includes a significant investment in learning environments, this paper focuses on the educational part of Tracks. The aim of the paper is to contribute with perspectives of how, with which strategies, a large educational change initiative may be managed over time.

TRACKS INITIATIVE

The idea behind Tracks is to work with a new educational model, including opportunities for students to develop multi- and interdisciplinary competencies, possibilities for the students to create more individualized study plans, and to decrease the lead time for changing the education. Such a model should also be implemented, evaluated, and adjusted within the initiative. This initiative is created as a complement to the existing education, which means that it is an opportunity for both teachers and students to work differently and include other aspects than possible in the current rather strict educational program based format. The organizational residency for the students is still the educational program they are admitted to, and they still get their ordinary degrees. Students take Tracks courses as parts of their electives or as extra-curricular activities.

The main idea is to create tracks between existing programs, see Figure 1, to make sure that they do not belong to any specific department or school at the university. This is to avoid disciplinary barriers and to ensure that the Tracks initiative is open to all students and teachers regardless of organizational affiliation. Each track has a theme, and theses themes change regularly to make sure that the content of Tracks is connected to current societal issues and contemporary research. Moreover, within each track, there are several courses within each specific theme. It gives students an opportunity to either take one Tracks course with a specific project or follow more courses within one of the tracks to get a specialization within that theme and to gain skills for solving real societal challenges (Alpay & Jones 2012) The Tracks courses are also changed regularly and updated to meet the fast changes of the world of today (Mazzucato 2018).
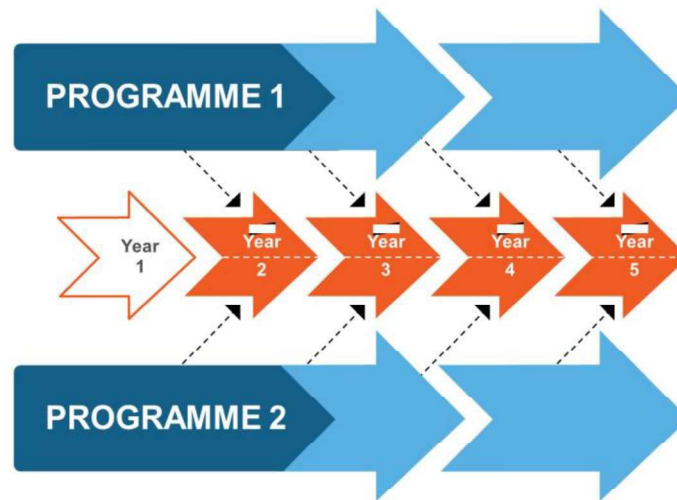
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Figure 1. Students with different educational backgrounds study together in tracks laying between existing educational programs.

Tracks Courses

National and local regulations state that the educational offering (programs and courses) must have established and approved program and course plans at least six months before the start of the academic year. In order to comply with this, "umbrella courses" with general course plans, aims and learning outcomes are created in the study administrative systems. The courses' general learning outcomes deal with abilities to identify and master problems with open solutions spaces, handle uncertainties and limited information, lead and participate in the development of new products and systems, work in multi- and interdisciplinary teams, communication, and ethical aspects etc. Tracks courses' specific content and learning outcomes are defined in connection with course start. Thus, umbrella courses allow for flexibility and are used to develop and teach Tracks courses without having to create a whole new course in the course administrative system.

The basic educational idea of Tracks is to offer project-centered learning supplemented with short courses (modules), on-line learning, self-study and mentoring to obtain necessary technology and scientific knowledge and skills, *cf.* the New Engineering Education Transformation (NEET) at MIT (Crawley, Hosoi and Mitra 2018). In addition, the courses are supplemented with teaching and training of professional skills covering project management, work in multi- and interdisciplinary teams, ethics, and equal opportunities. Tracks courses include the entire process, from needs and ideas to a model or prototype in an implementable condition that can be evaluated. Such a model or prototype may consist of a service, an algorithm, or a product that can be physical or digital. The courses are, thus, platforms for a training development methodology, developing professional engineering skills as well as to deepen science, math, and technology knowledge throughout the education (Alpay &Jones 2012).

Currently (academic year of 2019/20), there are three Tracks themes in a first pilot;
•   Sustainable Transportation,
•   Health & Sports Technology and
•   Artificial Intelligence.
Examples of courses within these themes are; Structural battery composites: Realization and multifunctional performance, Optimize subsystems for electric vehicles, Design of sustainable infrastructure and urban transformation, Projects in Music engineering: Awareness of sound and AI Ethics through Fiction. These courses range from 10 weeks to one semester and correspond to 7.5 ECTS. The development costs are funded by Tracks while the ordinary course budget model covers the delivery, including assessment.

Teaching support

An important part of Tracks is to create support for teachers and faculty teaching diploma (certificate) courses on challenge-driven education, multidisciplinary team projects, and teaching in modern physical and digital learning environments for experiential learning.

Tracks is also an initiative to develop Chalmers' learning environment. In order to meet the needs of Tracks, a prominent and flexible learning environment is created with project spaces both physically and digitally. The environment will include computer resources for artificial intelligence, such as machine learning, workshops, and hybrid virtual-physical environments where students can build, test, and evaluate prototypes.

The goal of the second stage of Tracks is within three years to have five ongoing themes and about 60 courses during one academic year. This will include at least 500 students and around 200 active teachers as well as about five supportive professional skills modules and two faculty teaching diploma courses and major learning space of 1,500 square meters, including workshops, labs, project space, studios, and open creative spaces.

Management

The university management decided to have team leadership for Tracks consisting of an experienced educational leader and a skilled and well-thought-of project manager. The leadership was appointed in February 2019 and focused immediately on early incremental developments, implementations and refinements. Consequently, the first Tracks courses were launched in the summer and fall of 2019.

The initial strategy was to set up a flexible and agile structure to manage the response from different groups of stakeholders such as faculty, students, and management. In this structure, there are different levels of flexibility where the teachers are enabled the most freedom to create other opportunities than they are used to when developing their teaching. Initially, the focus has been on teachers who have engaged in activities organized as part of Tracks such as workshops to propose themes and, later, to develop courses within the themes. Teachers teamed-up and suggested courses that were reviewed with feedback and after minor revisions approved. The Tracks' management has put a lot of trust in the teachers. If the courses fit into the themes, attract students from many educational programs (disciplines), and address the professional learning outcomes, teachers have had great freedom to design and teach courses. At the same time, teachers received extensive help in managing the administration around the courses from advertising and informing students to registering and posting grades. The Tracks leadership has a continuous dialogue with teachers and administrators to develop the framework around the courses. This includes the development of courses, managing them in

the Chalmers study administration system and support with the regulations. In short, the strategy has been to manage Tracks in a similar way as the students are trained within the Tracks courses, *i.e.,* agile, with openness and flexible in time and place.

The response from the ambassadors is important feedback for the development of the initiative. However, to make sure the change process is not only driven by such feedback, but a thorough evaluation and reflection process is also developed. Moreover, when the Tracks pilot courses had started, and the scope increased, it was realized that management needed to be strengthened. A management team was then established consisting of the two leaders, a blended learning expert, a secretary of studies, a professional skills teacher, and a faculty training specialist developing the teacher pedagogical diploma courses.

External stakeholders are involved in development to provide advice, provide input, and verify that development is in line with plans. Furthermore, external stakeholders are important to ensure that the courses are relevant to the industry and that students are given opportunities to develop skills that are in demand. The major body for external stakeholder involvement is the advisory board, which consists of expertise in engineering education from academia and industry. External stakeholders are also directly involved in the courses, *e.g.,* as clients or external mentors.

PREVIOUS RESEARCH

Discussions related to the content and development of universities may include several different aspects. This paper, more specifically, studies how a large change initiative with the aim of keeping the university at the forefront of education is managed. The initiative includes both the content of the education and learning environments. Thus, management has to consider several stakeholders and their views on the change process. Moreover, studying change at universities could include several interesting aspects. Previously, It has been noted that universities are traditional organizations (Snow Andrade 2018). Despite changes in society, universities have managed to keep a traditional profile for a long time. Such a profile has also been used as an advantage to build on history and traditions. An additional aspect relates to research-intense universities where there are often tensions between teaching and research (Alpay & Jones 2012).

However, there are also discussions around the need for change and updates to the traditional way of running higher education (Graham 2018). Such updates can include several things from pedagogy to the actual content of the education. In 2011 the concept of Industry 4.0 was coined in Germany, and soon after, Universities 4.0 was developed as the necessary complement from the educational sphere. Universities 4.0 is about meeting the need for specific skills from Industry 4.0. Moreover, it is about rethinking the traditional way of teaching and expanding the opportunities for life-long learning, as discussed by (Hallenga-Brink & Sjoer 2017). Cheah and Leong (2018) further discuss that the things included in the education today, such as project work, will be both complex and multidisciplinary to a new extent in the future.

The problem is not only the fact that it has become necessary to develop universities, but the issue is also how it may be done in the best way strategically. It is not only the university organizations that are traditional, it may also influence the way of thinking within the university. The faculty delivering the education needs to be convinced that the change is necessary and see why it is important. The motivation may be different for different faculty members (Hallenga-Brink & Kok 2016), which makes it even more important to facilitate the process of

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understanding the opportunities created by the change. That could be difficult to accept if such change is not aligned with the faculty's viewpoints, regular activities, or expectations (Rouvrais & Landrac 2012). Typical issues previously discussed are the inbuilt resistance to change and how to manage such resistance in an optimized way.

Other sources of resistance that may apply to higher education are, for example, "unwillingness to change habits, structural inertia such as embedded policies and procedures and group norms that influence individuals" (Snow Andrade 2018). Depending on the type and extent of change, it may be suitable with a bottom-up approach, a top-down approach, or a mix of these. It becomes a challenging management issue with conflicting and restraining forces. And one strategy to avoid that is to include industry partners and students to act as change agents (Rouvrais & Landrac 2012).

There are successful examples of changes in the education where universities have started with either a course or a program to be able to step by step adjust the education (Rouvrais & Landrac 2012). Recent developments show that both engineering and management practices will need a more agile approach to how decisions are made and projects managed in the future (Audunsson, Fridgeirsson & Saemundsdottir 2018). Consequently, both industry and universities need to adjust. Examples from Industry and Education 4.0 include, for example, peer-to-peer learning, active learning, flexibility in both time and place learning, project-based learning, actual experience learning, and responds to the needs of Industry 4.0 (Truong & Le 2018).

METHOD

Action research has become a method that may include a relatively broad number of approaches. As described by Coghlan and Brannick (2019), there are some characteristics that are especially interesting for conducting action research within your own organization. The cornerstones of action research are to do "research in action instead of about action; a collaborative partnership; concurrent with action; and a sequence of events and an approach to problem-solving" (Coghlan & Brannick 2019 p. 3). Conducting action research also follows four phases, including planning, taking action, evaluating the action, and finally, further planning based on the previous phases.

Furthermore, it is important to work in collaboration with the studied participants in contrast to keeping the studied participants as objects. This creates a partnership around the research that is continuously influenced along with the studied action. The third cornerstone is that the research should be "concurrent with action," meaning that the purpose is to make the action more effective at the same time as scientific knowledge is created. Finally, the method of action research gives an opportunity to work with the four phases mentioned above and, at the same time, solve practical problems occurring during the work. In collaboration with the members of the action research and the organization, it is possible to find information and experiment to learn and solve issues within the process. Such issues may be both intended and unintended, depending on the situation. However, all the collected data is contributing to building up scientific knowledge and theory around the learning outcomes.

This paper is a study of the first pilot round of the Tracks educational part. The planning phase for the first year of the Tracks initiative has been rather short and effective. The guiding star has been the purpose of creating more flexible interdisciplinary courses open for all students at Chalmers. Because of the traditional structure of the university, the degrees of freedom are

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still limited also for this initiative, and creating new courses had to follow the ordinary organization and structure. This meant that to be able to create new courses for a first pilot-round, it was necessary to do this last-minute only weeks after the whole initiative started. This unintended quick start immediately led into action for the educational part of Tracks.

The phases of planning and action have then been run in parallel with somewhat overweight on the action because of the nature of the setup for the Tracks courses. To enable more flexibility, these courses can start at any time of the year with the result that there are courses in all phases, from planning to evaluation and further planning. Consequently, all these phases have been active in parallel. For every course that finished, it has been possible to evaluate, discuss with involved teachers, and reflect on the outcome. The input from stakeholders such as faculty, students, and management have been included in other ongoing courses and in the planning of new once.

However, although reflection and evaluation have been done continuously, there has also been more thorough work on an evaluation plan, including all stakeholders of the courses. This work includes ordinary course evaluations with specific questions regarding the Tracks model, including experiences from the interdisciplinary work and forms for teachers. Moreover, the Ph.D. student will conduct structured interviews with students and teachers to collect qualitative data. It has been important to not only adjust the planning based on stakeholder feedback, and the results from the evaluation plan have been discussed in the management of Tracks. The study year, and therefore also the first pilot of Tracks, ends by the summer of 2020, and the focused evaluation will primarily be conducted at the end of the spring semester of 2020. Based on the results from the evaluation, a more intense phase of further planning will be conducted between the two first pilot rounds of Tracks.

This paper reports on data collected over approximately a year with all phases of action research represented to some extent. Data includes evaluation questionnaires and interviews, but primarily information from the managers of the Tracks initiative. With such close contact with the data, there has been a unique opportunity to follow how different actions have influenced the outcome.

There are some limitations of this paper. Firstly, it is possible that the teachers and students engaging in the first pilot round of Tracks are so-called early adopters. With an open and flexible approach to the early suggestions, there may be a bias towards a group of teachers and students who appreciate flexibility. Consequently, the results from the following study years may be different because the people engaged and involved have different perspectives and understandings of flexibility and an organization that differs from the ordinary structures at the university. Secondly, the authors of the paper are close to the data and the initiative. There are advantages but could also be a bias in the reflections on the results

FINDINGS AND DISCUSSION

From the first pilot round of Tracks, there are three main findings. These findings are described and discussed below.

Firstly, although it is early to make any final conclusions, initial experiences are very encouraging. An agile and flexible management structure is found to be appropriate for the aim of the initiative. Considering the size of the initiative and the expected impact, important progress has been made over a short time period. This includes a thorough process where

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new courses and new educational content have been created within existing governmental and local university degree ordinances.

It is possible that the fact that Chalmers is well-functioning with established quality assurance systems and routines for educational management and developments actually facilitate change similar to what Graham (2018) noted for "current leaders" in engineering education. Thus, it has been possible to create the necessary flexibility for Tracks within the existing framework. Furthermore, Chalmers has a history of educational developments including development and implementation of CDIO, educational for sustainable development and entrepreneurial learning, ethics and constructive alignment (Malmqvist, J. et al. 2010, Enelund, Knutson Wedel, Lundqvist, & Malmqvist 2013, Kohn Rådberg, Lundqvist, Malmqvist, & Svensson 2018). Because faculty and administration have been through such initiatives previously, there exists a sense of understanding for this type of change. On the other hand, several large educational initiatives may create resistance and resignation.

Secondly, teachers have been very active in proposing, developing, and running courses. They have appreciated the opportunity to do something new. Moreover, they have been able to realize ideas about teaching students in solving the major challenges and working with the students on research-related challenges. Students are equally enthusiastic. About 100 students follow the courses in this first pilot round. Students are satisfied, and Tracks is mentioned positively in the student body. Moreover, Chalmers' industry partners are positive and already participate in several courses.

Tracks have mostly attracted teachers who have taught team projects and/or teachers that are previously known for their openness to educational reforms. For continuous development, it will be important to build on role models and successful examples. One important part of Tracks is to create support for teachers who will be involved in Tracks courses. The idea is that this support includes faculty teaching diploma courses, which will be part of the teachers' pedagogical portfolios and, thus, merits in their careers. Moreover, the support aims to enable Tracks to reach a wider group of teachers.

Thirdly, there has also been some resistance within the organization. The experienced resistance has been related to administrative procedures. Still, it has been possible to find flexible solutions around necessary adjustments in the administrative systems. Such solutions have meant that support staff cannot follow ordinary procedures and templates. Initially, these solutions have, therefore, resulted in additional work. This has created concerns in the organization and unwillingness to change habits.

Educational development is often a slow process with many bureaucratic obstacles ranging from government and university regulations to academic traditions and disciplinary protectionism. The success lies in having a management structure that allows for innovation, change, and flexibility. Moreover, the structure needs to be able to sustain an enduring long-term process as well as be able to continuously improve and set new goals.

The educational organization and content need to be structured and on a well-known format to make sure that all stakeholders have relevant information and a common understanding of what the expected outcomes of the educations are. Consequently, the study administrative systems have developed over time to become stable and to have resistance to sudden changes. This has created an inflexible culture of how things should be done within the system. At the same time, there are increasing requirements from the industry and presumptive students for the educations to become more flexible and able to embrace new challenges and

solutions. Our findings have shown that it is possible to introduce this type of flexibility within the existing frameworks. However, the traditional administrative role has developed a competence for managing a stable study administrative system. Therefore, it will be necessary to also develop the management and the administrative roles to adapt a similar agile approach. If we aim to deliver an education that better prepares the students for addressing the current and future challenges, there is a need for the whole university to adapt similar skills and competences as provided through the education.

With this said, the findings also show that the development of Tracks has been dependent on certain individuals with an open mind and interest in change. This has been appropriate for the start-up phase when early success stories are important. However, in the longer perspective, the challenge will be to formalize the flexible perspectives asked for and, at the same time, keep the continuous development philosophy. As Snow Andrade (2018) discusses, there are several characteristics for keeping up successful transformation processes at educational institutions. Some of them have been applied in the early phases of Tracks, such as the long-term perspective of the initiative with leaders who adjust and work agile with input from the stakeholders. Giving the teachers freedom in their course development has been a deliberate way of establishing trust, which is also mentioned by Snow Aldrade (2018). For this initiative, it has been fruitful with a mix of a bottom-up and top-down approach. Top-down for establishing the importance of development and change and freedom in the bottom-up approach to engage the faculty. Reflecting on the method, it will be important with a continuous balance between these approaches to push and pull the organization forward in the development process.

CONCLUSIONS

Studying the Tracks initiative at Chalmers has shown how large institutional change initiatives are facilitated by a flexible and agile approach contrasting the traditional and somewhat rigid university culture. It will be continuously important to balance the new ideas with the known and established to reach the goals of the Tracks initiative.

Reflecting on the Tracks initiative in the light of the CDIO standards (CDIO Standards 2.1) focused on in this paper (1, 5, 7, 8) shows that through Tracks the students are trained in a multi- and interdisciplinary context which is also a real-world context (Alpay & Jones 2012). Such context improves the conditions for working with CDIO and developing an entrepreneurial mindset. Tracks is then an arena for their work with complex issues related to research, industry, and society. Simultaneously, the students' active work closely together with the faculty creates an understanding of engineering practice and learning, where the students recognize how and why they learn for the future. For the faculty, it also creates an opportunity for faculty competence development while working cross departments and in multidisciplinary teams that would not have had the opportunity to meet elsewhere.

Tracks give a unique opportunity to study and understand an example of implementing a CDIO-inspired curriculum at a university on a large scale. In this case, it was done by creating the same possibilities for all students at the same time to apply for these courses. It works as inspiration and opens up for change in general. During the duration of this initiative, it will be possible to develop and understand what are the most suitable improvements to make in education at large. All parts of Tracks will not be implemented broadly, but the most suitable developments are possible to integrate into the ordinary education offer. Instead of taking small steps, Tracks facilitates for the university to take larger steps in developing the educational

offer. In ten years' time, it is possible to be at the forefront of education without losing history, quality, and previous experiences in such a process.

REFERENCES

Alpay, E., Jones, M.E. (2012). Engineering education in research-intensive universities. *European Journal of Engineering Education*, Vol. 37:6, pp. 609-626.

Audunsson, H., Fridgeirsson, T., Saemundsdottir, I. (2018). Challenging engineering students with uncertainty in a VUCA situation. *Proceedings of the 14th International CDIO Conference* (pp. 9) Kanazawa, Japan: Kanazawa Institute of Technology.

CDIO Standard 2.1. (2020, April 17). Retrieved from CDIO Standard 2.1: http://www.cdio.org/content/cdio-standard-21

Cheah, S., Leong, H. (2018). Relevance of CDIO Industry 4.0 – proposal for 2 new standards. *Proceedings of the 14th International CDIO Conference* (pp. 17) Kanazawa, Japan: Kanazawa Institute of Technology.

Coghlan, D., Brannick, T. (2019). Doing action research in your own organization, SAGE Publications Limited.

Crawley, E.F., Hosoi, A., Mitra, A. (2018). *Redesigning Undergraduate Engineering Education at MIT – the New Engineering Education Transformation (NEET) initiative.* ASEE National Conference & Exposition. Salt Lake City, UT, USA

Enelund, M., Knutson Wedel, M., Lundqvist, U., & Malmqvist, J. (2013) Integration of Education for Sustainable Development in the Mechanical Engineering Curriculum, *Australasian Journal of Engineering Education*, vol. 19:1, pp. 51-62, DOI: 10.7158/22054952.2013.11464078

Graham, R. (2018). *The Global State of the Art in Engineering Education*, Technical Report, Massachusetts Institute of Technology, Cambridge, MA, USA.

Hallenga-Brink, S., Kok, O. (2016). Implementing CDIO in Twelve Programs Simultaneously: Change Management. *Proceedings of the 12th International CDIO Conference* (pp 13). Turku, Finland.

Hallenga-Brink, S., Sjoer, E. (2017). Designing a Flexible, Choice-Based, Integrated, Professionally Challenging, Multidisciplinary Curriculum. *Proceedings of the 13th International CDIO Conference* (pp 16). Calgary, Canada.

Kamp, A. (2019). *Science & technology education for 21st century Europe*. Discussion Paper Leuven. DOI: 10.5281/zenodo.3582544

Kohn Rådberg, K.,Lundqvist, U.,Malmqvist, M.Hagvall Svensson, O. (2018) From CDIO to challenge-based learning experiences – expanding student learning as well as societal impact? *European Journal of Engineering Education*, Vol. 43 pp. 1-16.

Malmqvist, J., Bankel, J., Enelund, M., Gustafsson, G., & Knutson Wedel, M. (2010) Ten Years of CDIO – Experiences from a Long-Term Education Development Process, *Proceedings of 6th International CDIO Conference* (pp 27). École Polytechnique de Montréal, Canada.

Mazzucato, M. (2018). Mission-Oriented Research & Innovation in the European Union. A problem-solving approach to fuel innovation-led growth. https://ec.europa.eu/info/sites/info/files/mazzucato_report_2018.pdf

Rouvrais, S, Landrac, G. (2012). Resistance To Change In Institutionalizing The CDIO Standards: From A Cascade To An Agile Improvement Model. *Proceedings of the 8th International CDIO Conference* (pp. 13) Brisbane, Australia: Queensland University of Technology.

Snow Andrade, M. (2018). A Responsive Higher Education Curriculum: Change and Disruptive Innovation. IntechOpen, DOI: 10.5772/intechopen.80443.

Truong, T., Le, B. (2019) The effects of Industry 4.0 on teaching and learning CDIO project at Duy Tan University. *Proceedings of the 15th International CDIO Conference* (pp. 15) Aarhus, Denmark: Aarhus University.

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