Educating for a building and construction industry in transformation, by creating a real-life case-oriented master's programme

Ole Jonny Klakegg, Synnøve Arntzen, Erling Onstein
NTNU, Faculty of engineering, Department of Manufacturing and Civil Engineering, 2821 Gjøvik, Norway

ABSTRACT:

NTNU has taken a leading position by developing a new generation master's specialization for digital transformation of building and construction. In August 2018, the first group of students where admitted to the new Digital Building Processes program at NTNU campus Gjøvik. This presentation will draw up the main lines in how this programme is developed and implemented with connected courses, the use of new didactical methods, tools and practices. We will explain how the education is supported by industry and integrated with real life case projects to secure a relevant and challenging education in line with the principles of CDIO.

Further, we present how the challenges of digitization are integrated in this programme in two ways: Firstly, the challenges of integrating and building on the real-life tools of digital construction, e.g. BIM, GIS and coordination technologies. The education for the digital future obviously needs to be digital. We also discuss the challenges and experiences in using digital pedagogical tools as means for developing an effective learning environment unlike any traditional construction programme seen at this level.

There is a serious need for education on future working methods and skills in the building and construction industry. Construction is one of the most important industries in society, both in terms of value created, employment and creating future built environment. It is also an industry with great challenges in terms of energy use, climate effect, high cost and low degree of innovation. The best players are well prepared for the future, but the big chunk of companies in construction are not even aware of what is happening. Even the university has been slow to notice the need for new education to meet this development. Not anymore.

1 INTRODUCTION

A digital shift now occurs in the building and construction industry. This shift means that new digital tools should be employed, new knowledge is needed, and this has consequences for the building processes and our day-to-day work in the industry. The construction industry needs to update their methods and skills required for the future. To meet this challenge for the industry, NTNU has introduced a new master's programme called Digital Building Processes. In this programme, the students meet the industry and real-life case projects, which they solve together in groups. The students have bachelor's degree from before and specializes to get a master's degree during four semesters. The focus is on the construction project manager's duties and responsibilities from start to end of digitally based building projects. In this study, the tools are all digital, the courses are connected, and the challenges the students meet are reflected upon throughout the course. The university needs to change its education to stay relevant.

2 METHODS

2.1 General

When we first do something new, we will change everything. This was the starting point for developing our master's programme called Digital Building Processes. We wanted practical studies, with learning and development in interaction. Where renewal of the construction process is the theme and renewal of the subject and teaching is the tool. The key principles when developing this programme were:

- Across NTNU campuses in Trondheim, Ålesund and Gjøvik – Based in Gjøvik
- Least possible lectures – most possible problem solving – using Flipped Classroom
- Education on a digital platform – actively using LMS (Learning Management System)
- Connections – two and two subjects tightly connected to extract synergy and ensure broader understanding
- No traditional exam – folder assessment.

The students work in groups actively solving real-life case scenarios that are relevant for the industry. This is according to the principles of CDIO (2019a), and the idea of what engineering students should learn, and which competences an engineer should possess.

CDIO is an innovative educational framework for producing the next generation of engineers. It is a methodology for engineering education reform, with a Syllabus and 12 CDIO standards. It follows the steps "Conceive-Design-Implement-Operate" as shown in Figure 1. The principles ensure to educate engineers that can engineer. The CDIO initiative has 120 universities as members worldwide (CDIO 2019a).

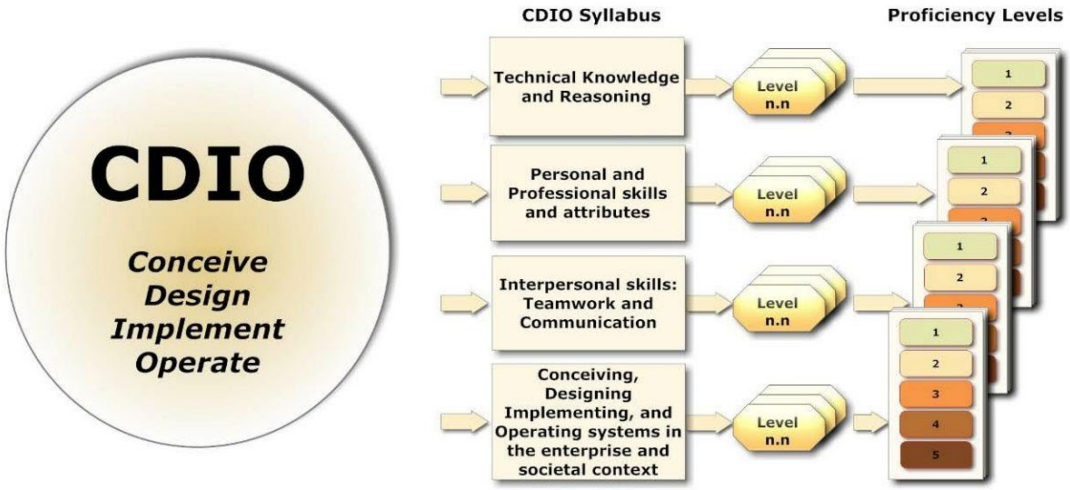

Fig. 1: CDIO overview (CDIO 2019b)

Another key point to include is The Golden Triangle of People, Process and Technology, shown in Figure 2 (Owen, 2009). The three aspects of the triangle need to interact, if not, none of them will work properly. There must be a certain balance between the three elements to ensure the right focus and coherence.

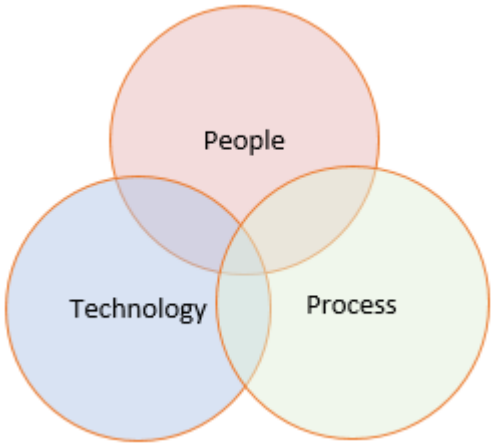

Fig. 2: The Golden Triangle; People, Process and Technology - IDDS whitepaper (Owen, 2009).

Digital tools are not enough to obtain the requested effect of digitization for project management and organisation in the construction industry. The digital shift is also a cultural transformation, which will require a change in mindset amongst people in the industry. The human factors and maintaining good dialogue with everyone involved in the project is still key elements of success, but at the same time, digital tools can enhance and ease the process – if we are able to understand and transform the workflow. It is crucial to make the changes necessary to stay competitive, and to work faster, more efficient and better.

Large companies have partly made such transition already. They need students to be well prepared and familiar with this new way of working. Most small and medium sized businesses are not that well prepared for the digital shift. Our candidates are preparing for both scenarios.

2.2 Developing a new master's programme

This presentation will draw up the main lines in how this programme is developed and implemented with connected courses, the use of new didactical methods, tools and practices.

The aim of the study is to understand the premises for an overall building process, where students will solve real problems with relevant digital aids. The industry poses as problem owners (with case projects), guest lecturers, accepting visits, evaluating results etc. We make software and digital platforms available, the students find out what they want to use and how to utilize digital aids. Sponsors have contributed financially so that the students are able to go on field trips. The students have also attended and presented on conferences for the industry.

This master's programme consists of concentrated and hectic seminars where we all meet and work together from day 1, combined with self-work during the interim periods. Knowledge tests and exercises are given along the way – and the final presentation is for both connected courses of each pair of courses.

When developing our Digital Building Processes master's programme, it was important for us to ensure that it is according to the principles of Constructive alignment (Biggs and Thang, 2011), where the teaching and learning activities, as well as the assessment tasks, addresses intended learning outcomes.

2.3 Teamwork

Teamwork is a main factor. The group of students registered for the study, are divided into teams. The students are working together with team contracts and team rules. Working life consists of teamwork, therefore this is one the main principles of our master's programme, to ensure a relevant education. Moreover, getting to know each other is essential for developing successful cooperation and thus we focus on establishing good relationships. Real life involves shifts in the team, and here as well. Team

membership rotates so everyone gets to know everyone. We want the student group to become a joint group! A key aspect of the teamwork is developing a sharing culture among the students, one of the things the construction industry will need to develop to utilize the available digital tools.

Exercises during the course is part of individual evaluation, but still the assignments demand discussions within in the groups. This way each group reflects upon each assignment from various angles to get other perspectives and to stimulate innovation and learning. Another example is oral presentations of scientific papers in front of the other students. They present selected papers for each other and has responded positively to this. They reflect on their own work and achievement as well as their peers.

2.4 Digital tools

Further, the future is teamwork supported by digital aids, and today knowledge of digital aids is still worth gold! The programme offers guest lecturers that highlight different perspectives on the building process; owners, engineering consultants, construction companies, suppliers and software developers support the study, share experience and ideas through guest lectures and access to realistic problems, data and tools. This way they secure relevance for the building and construction industry, as well as access to relevant and updated digital tools and software.

Since the programme is planned to hold students from several campuses, it is important to organise everything online and use different digital tools to support the learning process. The students can access all learning material in our Learning Management System, Blackboard. The mentoring is online at certain announced time and dates, using Blackboard Collaborate Ultra. The students use other professional digital tools, as BIM-tools and project planning tools, for the case-project and exercises.

Relevant software are both online collaboration software and software solving more isolated tasks related to specific steps in a building process. The goal is to let the students experience how the digital tools can fit together, and support the needed information management in a building process.

2.5 Connected courses

The master's programme is developed and implemented with connected courses, to create a synergy effect. These are indicated with a red dotted line in Figure 3. This means that two and two courses constitute a whole, to amplify the learning outcome. The blue courses in Figure 3 are all specially developed for this master's programme. Red and orange are selectable, and the yellow one is obligatory.

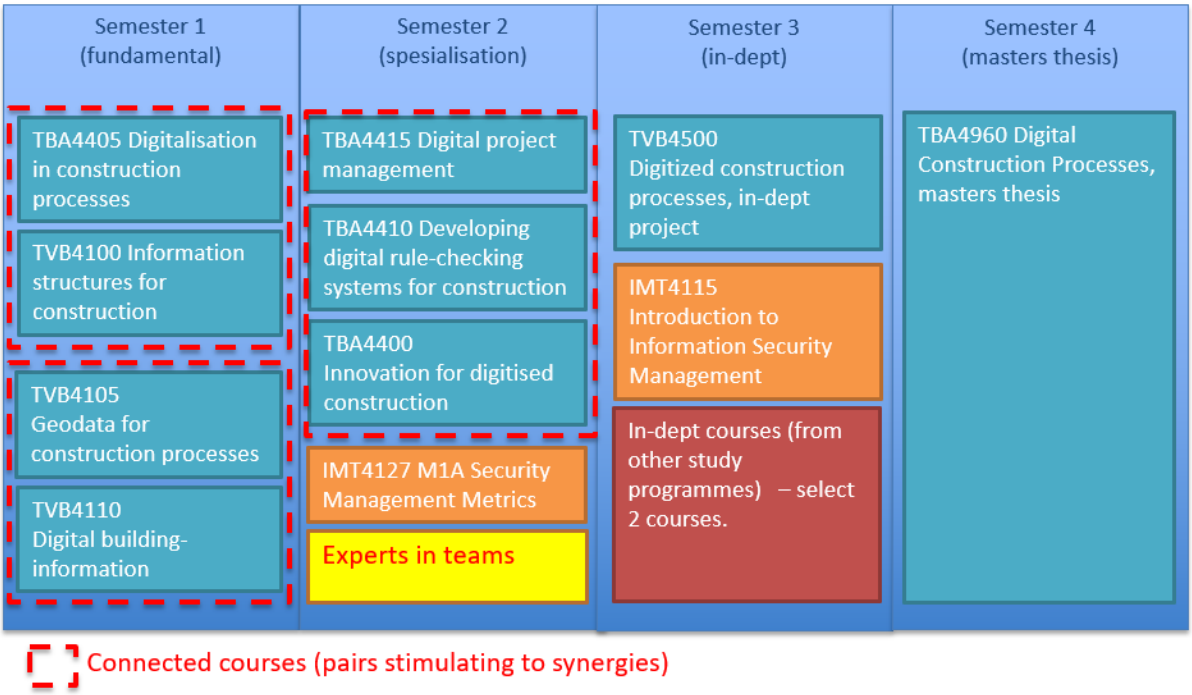

Fig. 3: Illustration of connected courses in Digital Building Processes master's programme.

2.6 Learning Management System

Our Learning Management System (LMS) organises all the learning material, as well as various learning activities performed individually and in teams (Blackboard Learn, 2019). Here the students can find all relevant information and announcements. The online mentoring is also in the same digital environment.

A wide range of learning materials and activities are used, here are some examples:

- Required curriculum (except books)
- Lectures and presentations for downloading, some lectures are streamed and recorded
- Podcasts
- Discussion forum, open for all students, a requirement to use for sharing
- Forum is also for handing in assignments, video presentations, or PowerPoint with audio
- After each module, the students get a knowledge test, with questions drawn automatically and randomly from a question bank
- A relevant selection of scientific articles and guidelines (for students to use as they want)
- After the course ends the students responds to a survey for evaluation and feedback, but also for the students to create awareness of their own learning process and outcome.

Outside the LMS: PeerWise (2019), which is a digital platform for peer review. The students give their ideas and questions as input on a given topic, and then give each other feedback and rate each other's questions. This is edutainment – meaning we use it as a competitive entertaining session – with a prize for the winner.

3 INDUSTRY AND REAL-LIFE CASE PROJECTS

The education is actively supported by industry and integrated with real life case projects to secure a relevant and challenging education in line with the principles of CDIO.

Real projects mean real issues, which requires real competence. Understand the problem, solve it - and show off the result! The courses in this master's programme are varied and active, includes company- and site visits, excursions and conferences to meet important and relevant industry representatives. The student group are assigned to one of two real-life projects. The group chooses and designs their own

task based on the introductory seminar with the project owner and their own interests. Then the group work with the assignment as a team for minimum five weeks. The result is presented as an "exam". Setting the theory and tools presented in the courses in a case frame will lead to the focus on relevant theories and tools.

The study programme has established collaboration with two real-life case projects; Skjerven Skog and Mustad Næringspark. Both are major property developments with industrial ambitions and a plethora of different construction challenges that will go on for years. Many classes of students will learn a lot from contributing to these developments. The owners also applaud the results and contributions from students. The results are useful, although maybe not directly.

Case 1: Skjerven Skog is a circular economic approach to creating a bio-based industrial symbiosis. The development of the business cluster around the new Hunton factory has resulted in the concept of "Bio-based Smart Industrial Park" or "BioSIP". Partners are Gjøvik municipality and NTNU.

Example student assignments (shortened):

- What information should Skjerven Skog and an arbitrary company X exchange to make the decision whether or not to include X in BioSIP?
- How can Skjerven Skog (the municipality) facilitate the use of BIM in the project, and in what stages and areas of use will they be able to benefit from BIM?
- How to use BIM as a tool for simulating future development of the industrial park?

Case 2: Mustad Næringspark has a long-term goal of becoming Gjøvik' s most attractive area for companies to establish in. Their business is renovating or building new buildings in historical industrial surroundings in Gjøvik. Their ambition is to create engaging work environments and an active business sector – really a whole new neighbourhood in the city close to the university campus. Currently Mustad Næringspark builds the Bright building, a brand new coworking space and Innovation House.

Example student assignments (shortened):

- How can the new construction project lifecycle model "Next Step" (Knotten et al., 2016) support strategic decisions from idea to final investment decision on Bright building?
- How to establish a concept for an experience forum that is appropriate and user-friendly for the business and industry, based on experience from Mustad Næringspark?
- How to develop digital models for design (3D BIM), planning (4D BIM) and cost estimation (5D BIM) for the next new university area in an existing industrial hall?

The students are challenged and motivated by these real-life case projects and training. This ensures the practical context and contribute to the students' professional and digital learning process.

4 EXAMPLE COURSE: DIGITAL CONSTRUCTION PROCESS

4.1 Content

The course deals with the construction process considering the digital shift that takes place in the construction industry now. The course focuses on project manager's new tasks and gives a basic understanding of a digital building process and the corresponding information flow. The course includes process modelling (BPMN) to understand processes and workflow. This topic is not primarily about Building Information Modelling (BIM) or other digital data tools. It is not about solving today's tasks, but about new ways to organize interaction and information flow throughout the whole construction lifecycle. Two main basis documents are Next Step (Knotten et al., 2016) and the international standard for information management; ISO 19650 (2018) Organization of information about construction works. Both frameworks concern the information flow in construction projects, principles and solutions for development and utilization of digital building models in project execution and building operation and asset management. The organization of the project to achieve optimal data security is discussed.

4.2 Learning outcome

After completing the course, the participants should have:

Knowledge about:
- The structure of digital building process from A to Z (ref. Next step).
- Terminology for digital building processes.
- Principles for digital information flow in the life of the building.
- The importance of digitization in the BAE industry.
- Information production and information process (ownership, responsibility, tasks).
- Detailed information needs in various stages of the construction process.
- Standards for digital interaction.

Skills to:
- Organize a project with appropriate roles that enable digital information flow.
- Set up appropriate requirements for digital information deliveries in a BAE project.
- Assess the building professional information in a BIM model.

General competence to:
- Understand the possibilities and limitations of digitization in the construction process.
- Plan organization for information management in the BAE industry.
- Evaluate the project manager's work tasks in order to carry out a fully digital construction process.
- Understand and have insight and conceptual tools to utilize BIM during the life of the building.

4.3 Teaching methods and activities

The course is carried out as project and problem-based learning. This includes lectures, exercises, self-study, group work and discussions, as well as case studies in real-life tasks in the building, construction and infrastructure industry. Great emphasis is placed on discussions and cooperation between the participants.

Computer tools, etc. software used: The available hardware and software for project management in the digital BIM lab at NTNU. The students in consultation with the course managers, selects software for the execution of the project assignment in relation to the current problem. For basic skills, we provide demonstration (exercises) of the following digital tools / techniques: Process modelling (based on BPMN supported by software: e.g. Bizagi or similar software free for students).

4.4 Grading

The folder should contain one project report and one presentation, three group assignments and the result from three passed knowledge tests, uploaded to Inspera Assessment (2019), NTNU's examination system by the students. Folder assessment provides the basis for the final grade in the course. The folder consists of:

- Group project report (60%)
- Group presentation (10%)
- Individual exercises (15%)
- Individual knowledge tests (15%).

The folder is evaluated by the course coordinator for connected courses and an external sensor. Grades for the entire folder is indicated by letter grade and given individually. In case of repetition, all reviews in the course must be repeated. A failed folder can be improved within the new submission deadline agreed with the course coordinator.

5 REFLECTIONS

We present how the challenges of digitization are integrated in this programme in two ways: Firstly, the challenges of integrating and building on the real-life tools of digital construction, e.g. BIM, GIS and coordination technologies. The education for the digital future obviously needs to be digital. Thus, we discuss the challenges and experiences in using digital pedagogical tools as means for developing an effective learning environment unlike any traditional construction programme seen at this level.

Just like the digital shift demands a change in mind set for the industry and the companies, it demands the same for the educational institution. We need to change our didactics according to today's world of knowledge and digital tools, but also according to the future skills and competencies needed. Today the teacher needs to work alongside the students, *guiding – not telling*. This means that the traditional lecture and learning material must change. We need the students to gain a higher level of knowledge, according to Blooms taxonomy (Bloom et al., 1956).

Therefore, in this programme, we have used a flipped classroom model, where all the material is available online all the time, but the seminars and hours spent together in a classroom or online, are for new relevant input from the industry, for discussions, reflections, analysis and mentoring. Flipped classroom also demands that students are prepared when showing up for seminars and mentoring. The students need to be active and participants in their own learning process, which again can increase their motivation, lead to a deeper level of learning and an augmented learning outcome (O'Flaherty et al., 2015).

Still we see that the students are not used to this way of teaching, so the majority still prefer traditional teaching. The main findings in a survey, "Pedagogisk virkemiddelbruk i TBA4405", conducted at the end of a course the first semester, shows that they are more comfortable with traditional lectures. Students were asked to agree or disagree to statements about the use of pedagogic means in the course. Example results are shown in Figure 4. Students are very content with teachers lectures and guest lectures and working individually. These are traditional and individual means of learning.

In our programme, we oblige the students to be active and to participate in their group, and this is challenging and demanding of all. Students say they like to work with process modelling, peer review, PeerWise, to give and get feedback, to use the discussion forum (visible for all students), and to present articles in front of their peers, group assignments with individual hand-ins, and folder assessment with "exam presentation". There were mixed responses to the LMS, individual studies and knowledge tests. The off-campus group strongly indicated they were dependant on group work to succeed.

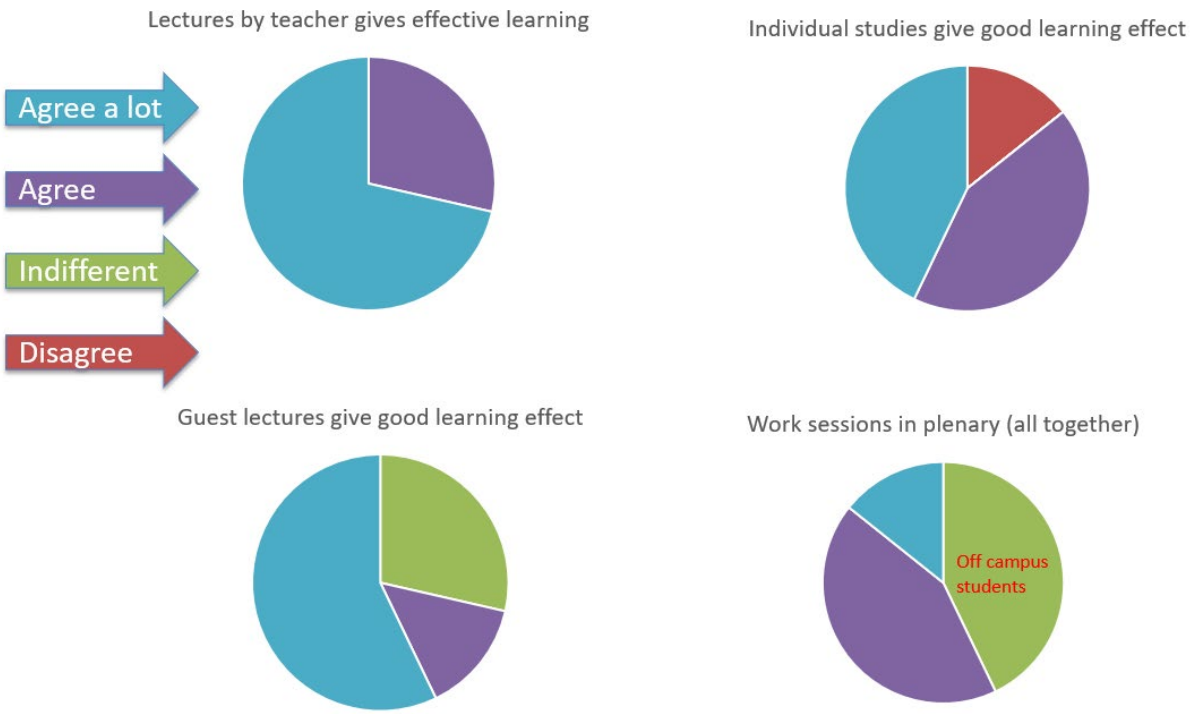

Fig. 4: Example results from student survey, end of course TBA4405 - 2018

Teachers and students are all forced online since everything needs to be digital. There have been times when technical struggles with the platform has been overshadowing other aspects of teaching. To make it feasible, pedagogical and technical assistance is therefore crucial. Our LMS does not come across as intuitive and the lecturers especially feels that the user interface is not user friendly. It seems like everything needs to be done in the right order to function properly. If one fault is made, this has consequences for the rest of what you do. The LMS does not help prevent this from happening.

6 RESULTS

The first group of students were admitted to the new master's program Digital Building Processes at NTNU campus Gjøvik in August 2018. The focus has been on evolving skills and competencies for the future so that our students can be important game changers for the industry and help the industry companies succeed in their digital transformation.

Developing and implementing a master's programme tailored to meet the digital shift in the construction industry has been a discovery journey. A valuable experience for us as an educational institution, for continuous development of our teaching, for improved collaboration with the industry, and finally yet importantly for our students which will be well prepared for future work life.

Developing a brand-new master's programme should mean starting with clean slates and all the possibilities to create something that can stimulate innovation and learning, but this also means testing and trying out, with the risk of failure. As a result, while working together with the students, the content and format has been developed further. It has been quite a journey and a steep learning curve. We have made huge progress. Students, course developers and lecturers have explored new ways of teaching and learning. We gained valuable experiences and acquired knowledge of what works well and what does not.

The mix of online and face-to-face teaching and mentoring have made it easy for the students to work on their own in between seminars, and during the interim periods. They give positive feedback. Even the off-campus students that does not have access to additional face-to-face discussions have shown good results so far.

There are challenges with team work and establishing teams within small group of students. Students have, as other people, different ways of working and also different ambitions and goals, influencing the way the students prefer to work. This has been successfully solved by clear and agreed team contracts, and also cross-team collaboration.

In a multicampus future, it is important to build bridges between departments and teachers on different campuses. The connected courses has been a successful way of working.

With the aim for the students to learn new methods and to develop new skills sought after by the building and construction industry, this has transformed the way we teach and mentor.

Many factors have been decisive and crucial for the accomplishment of creating a new master's programme. The amount of work and dedication invested is one. This is resource demanding. Secondly, the importance of always being at the forefront of the courses and the schedule is important. For example, developing a well-planned programme and an elaborate study guide long before the start of the semester. A third factor is to have good knowledge of the industry, its needs and demands so that the content, contributors and projects can be relevant and up to date. Our close contacts with the industry was a huge asset in this development. This makes it possible to educate students that are well prepared for a construction project manager's duties and responsibilities from start to end of a digital building project.

7 FURTHER WORK

This article presents the development of a new master's programme, developed in 2017 and started up in 2018. We have still to see the continuation and then the results next spring, when the first group of masters' students graduate. Another aspect is the necessity to see if this way of teaching is achievable when we scale up the number of students. NTNU, Norwegian University of Science and Technology, is a university with several campuses. A further step is to explore the possibilities of implementing this programme for the students on all NTNU's campuses, on equal terms and of high quality. Experience so far indicates it is realistic.

REFERENCES

Biggs, J.B. and Tang, C. (2011) Teaching for quality learning at university: what the student does. SRHE and Open University Press Imprint.

Blackboard Learn (2019) https://www.blackboard.com/blackboard-learn/index.html Last approached 24.04.2019.

Bloom, B. S.*; Engelhart, M. D.; Furst, E. J.; Hill, W. H.;* Krathwohl, D. R. *(1956). Taxonomy of educational objectives: The classification of educational goals. Handbook I: Cognitive domain. New York: David McKay Company.*

CDIO (2019a) http://www.cdio.org/about Last approached 24.04.2019.

CDIO (2019b) http://www.cdio.org/participate/project-workshop/extended-cdio-framework Last approached 24.04.2019.

Inspera Assessment (2019) http://www.inspera.com/ Last approached 24.04.2019.

ISO/DIS 19650-1 (2018) Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) -- Information management using building information modelling -- Part 1: Concepts and principles. Available from https://www.iso.org/standard/68078.html

Knotten, V.; Hosseini, A.; Klakegg, O.J. (2016) "Next Step": A New Systematic Approach to Plan and Execute AEC Projects. I: Proceedings of the CIB World Building Congress 2016, Volume III. Building up business operations and their logic. Shaping materials and technologies. Tampere University of Technology 2016 ISBN 978-952-15-3743-1. s. 484-495

O'Flaherty, J.; Phillips, C., Karanicolas, S.; Snelling, C. and Winning, T. (2015) Corrigendum to "The use of flipped classrooms in higher education: A scoping review". The Internet and Higher Education 25 (2015) pp 85–95

Owen, R. (2009) IDDS white-paper, CIB-publication 328.

PeerWise (2019) https://peerwise.cs.auckland.ac.nz/ Last approached 24.04.2019.