Same same, but different – or how construction informatics gets taught at universities in Norway and Sweden

C. Merschbrock & E. Onstein
Norwegian University of Science and Technology, Gjøvik, Norway

P.E. Danielsen
UiT The Arctic University of Norway, Alta, Norway

P. Johansson
Jönköping University, Jönköping, Sweden

ABSTRACT: In response to the increasing demand for construction informatics (CI) expertise, universities in the Nordic countries have developed new educational offers. This study explores how CI related education is being delivered by three different universities, two in Norway and one in Sweden. By comparing curricula and interviewing CI teachers, this paper contributes to the recent debate on the international standardization of CI competence by providing a Scandinavian view. The paper uses a pedagogical framework for hybrid teaching identifying which different "Scandinavian" aspects of CI-based work are focused on education. The results illustrate how all universities provide core competencies for digital work in projects, but their emphasis differs. What all CI education, sampled in this paper, had in common is a strong emphasis on the socio-technical aspects of CI as well the hands-on technical aspects of BIM. It can be reasonably claimed that a more Scandinavian approach to CI education could further inform the standardization of BIM competence. Moreover, this integrated approach appears well suited for creating student engagement and for turning construction into a modern sector of the economy.

KEYWORDS: *Building Information Modeling, education, project-based learning, collaborative learning*

1 INTRODUCTION

A crucial precondition for turning the construction industry into a modern sector of the economy is to provide professionals with an education preparing them for working in a digitized and automated industrial environment. Consequently, construction informatics (CI), a discipline at the crossroads of construction and computer science, has gained increasing importance over the past few decades (Turk 2006).

Although the origins of the field can be traced back to the 1960ies it is not before recently that CI has emerged as a distinct research discipline in its own right with departments and chairs being established at universities around the world (Turk 2000). There are some universities like the Technical University in Munich, the University of Salford, or Stanford that have provided CI education for a long time and who by now have well developed CI programs (Lee et al. 2013).

However, similar education has only recently been established in the Nordic countries. This comes in the wake of industry, government, and universities all recognizing the need for increasing digitalization and automation competency in construction. The latest developments in this area are efforts by ISO to standardize and define required competences and new job roles in digitized construction projects.

There exists an active debate in academia seeking to establish frameworks for how to best deliver tertiary CI education. New participatory pedagogical approaches are viewed as essential for student engagement in CI education (Olatunji 2019). Moreover, graduates need to develop a good spatial understanding and become effective communicators in digital environments (Clevenger et al. 2012).

Since CI education is a recent phenomenon for most universities, educational curricula are still being developed and there is only little consensus as to what such curriculum should contain (Lee et al. 2013). Moreover, there is a wide variety of ideas for how to name study programs which would seem to fall under the umbrella of CI. Additionally, CI education seems to emerge at the trade school level, at the undergraduate, and graduate levels at universities. Moreover, local, regional, and national traditions matter when it comes to the way in which construction education is being delivered. Taking the regional view, this paper explores if there exists what could be viewed as a Scandinavian perspective to CI education. All the aforementioned in conjunction with the recent push for establishing international standards for CI competence and calls for research exploring how the emerging education programs can be made more compatible, this paper sets out to look into how CI education is delivered at three Scandinavian universities. This would then also provide a regional Scandinavian perspective and contribution to the ongoing discussion.

The research question asked in this paper is: *What is the present state of CI education in the Nordic countries and how could a Scandinavian perspective contribute?* We answer this research question based on reviewing present CI education delivered at three universities in Scandinavia. Moreover, data is collected based on a document study of educational material as well as a series of interviews conducted with teachers working at these universities. The educations are categorized, analyzed, and compared based on a framework for hybrid teaching like what has been proposed by Donaldson (2014) and what has been applied to Building Information Modeling education in tertiary education by Olatunji (2019). This framework is useful for understanding how effective the present education is in fostering student engagement and learning in CI. Findings are that each of the educations can be further improved by strengthening project-based learning, student ownership of learning, and collaborative learning.

The remainder of the article is structured as follows: first, the CI education literature and the concept of hybrid teaching is introduced, second an overview of the interviews is provided, third the findings of the study are presented, and last the discussion and conclusions of the paper are presented.

2 SCANDINAVIAN TRADITION

Especially with the emergence of next generation digital systems for building design, namely Building Information Modeling (BIM), the discourse about CI education has been revitalized (Badrinath et al. 2016). Already a decade ago over one hundred US based architecture, engineering, and construction programs had integrated BIM topics in their curricula (Becerik-Gerber et al. 2011). While there is a large and growing body of literature in this area, most of the publications related to CI education have their origin in the US followed by Australia and Brazil indicating that there is a need for more contributions from other parts of the world (Badrinath et al. 2016).

Moreover, questions like what effective resources for would be teaching BIM and finding the right balance between theory and practice have proved challenging (Puolitaival and Forsythe 2016). This is not due to a shortage of articles on BIM/CI curriculum design but rather a consequence of the complexity of the process going far beyond just implementing some subjects in an existing curriculum (Badrinath et al. 2016).

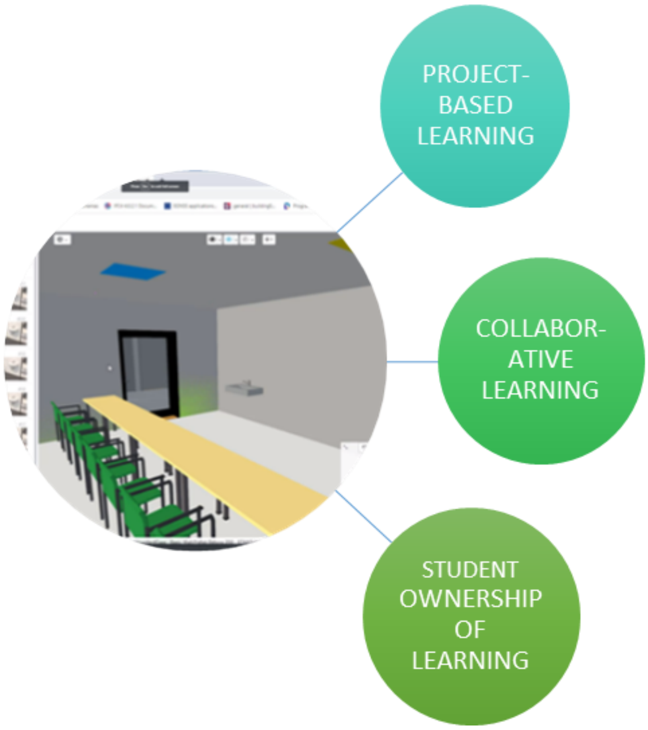

Figure 1. Hybrid pedagogics and CI authorship (adapted Donaldson 2014)

Moreover, a starting point for developing solid CI programs would appear to be an understanding of the skill sets required for filling emerging job roles related to construction information technology (IT) (Badrinath et al. 2016). New job roles requiring strong IT skills include BIM managers and coordinators, BIM analysts, BIM modelers, BIM consultants, and BIM researchers. Beyond BIM, skills related to Geographic Information Systems (GIS) have gained increasing importance over recent years, too. Thus, CI education needs to focus on creating tech-savvy candidates able to serve as effective communicators across organizational boundaries in construction projects (Jacobsson and Merschbrock 2018). Learning to become a BIM/CM professional may benefit from a collaborative and hybrid pedagogical approach (Olatunji 2019). A recent initiative for improving pedagogics in engineering education is the so-called CDIO (Conceive Design Implement Operate). While much of the CDIO initiative is focussed on collaborative design in education and this framework arguably would have been well suited for this study, it does not have its conceptual roots in the Scandinavian design tradition.

The Scandinavian design tradition focuses on the creation of "in-between" space between different participants (Nielsen et al. 2010). In computer science and information systems, disciplines closely related to CI, the concepts of participatory design, sociotechnical design, and computer supported cooperative work all have their roots in the Scandinavian countries (Iivari and Lyytinen 1999). It has been argued that Scandinavian researchers and practitioners emphasize cooperation in IT design and use due to their strong tradition of labor movements (ibid.). Transporting the *Weltanschauung* of the Scandinavian tradition to the context of CI places dialogue, mutual learning, and collaboration between equal partners as central concepts in education (Nielsen et al. 2010). Similarly, pedagogical concepts emerging from the so-called maker movement appear to be informed by the Scandinavian design perspective (Donaldson 2014). For instance, when applying a conceptual model stemming from the maker movement to BIM/CI education, researchers find increased student commitment to be a result of project based, collaborative, and student ownership of learning (Olatunji 2019).

A variant of Donaldson's (2014) pedagogical model for makerspace pedagogics can be found in figure 1. Looking for an educational approach rooted in a classical Scandinavian design tradition, the concept was viewed as a good fit for theoretically informing this study, especially considering that it has been applied for explaining how to engage students in BIM education (Olatunji 2019). The main constructs important in this approach are (1) project-based learning, (2) collaborative learning and (3) student ownership of learning. (1) Project based learning emphasizes learning by doing. This approach allows students to attain deeper knowledge about the hands-on aspects of phenomena like construction informatics (Krajcik and Blumenfeld 2006). (2) Collaborative learning emphasizes learning in groups covering anything from group discussions to collaboration in project work (Bruffee 1999). (3) Student ownership of learning has to do with students' intrinsic or extrinsic motivation and engagement in learning and their drive for setting and achieving learning goals (Conley and French 2014). Frequently named elements of students' ownership include motivation and engagement, goal orientation and self-direction, self-efficacy and self-confidence, metacognition and self-monitoring, and persistence (Conley and French 2014). The analysis part of this article is structured based on the Donaldson (2014) framework as presented above.

3 METHODOLOGY

This study adopts a multiple case study design useful for providing an understanding and comparison of different educational offerings across contexts. The first case selected for this comparison is Sweden's first stand-alone CI program provided at MSc level, namely the "MSc in Sustainable Building Information Management" offered at Jönköping University. This case, hereafter referred to as case A, was purposefully selected as a case of extreme or deviant practice similar to what has been suggested by Patton (2014). Case A is deviant in that it represents a departure from established educational practice. The second case (Case B) is the "Digital Building Processes" MSc program taught at the Norwegian University for Technology and Science (NTNU) at their Gjøvik campus.

Figure 2. Location of the case universities

Further, NTNU Gjøvik offers a one year diploma study in CI which is also included as part of Case B in this paper. Like Case A, Case B is a deviant case in that it constitutes Norway's first stand-alone CI MSc program, making it an interesting case for inquiry. Case C is different from the other two in that it is an example for two single CI classes offered as part of a BSc program in Civil engineering. The location of the CI case studies can be found in figure 2. What the classes entitled "BIM Collaboration Process" and "BIM and Autodesk Revit" offered at the Alta campus of the Arctic University of Norway have in common with the other two cases is that they represent an early example in CI education developed largely in isolation, making it a good example for sampling the Scandinavian tradition in CI education. Taken together, the cases selected for comparison in this article make a solid base for exploring a hybrid pedagogics and Scandinavian perspective in CI education. Data was collected based on 4 interviews with CI teachers working at the different schools. Table 1 provides an overview of the case studies.

Table 1. Case study overview

	Case A	Case B	Case C
Institution	JU	NTNU Gjøvik	UiT
Education	MSc	Dipl., MSc	2x BSc courses
Students (current)	20 (MSc)	15 (Dipl.) + 10 (MSc)	10 (BSc)
Software	Revit, ARCHICAD Trimble connect, BIM Collab, BIMeye, Solibri…..	Revit, Solibri, Trimble connect Vico, Camunda, Bizagi, Enterprise architect UML,	Revit, Focus Construction, Navisworks, DEON, StreamBIM, VirtuaView
Established	2017	2008 (diploma); 2018 (MSc)	H-2016 V-2017

4 RESULTS

This chapter presents the results of our study guided by the three main constructs important for hybrid pedagogics in maker space contexts as introduced in the theory part of the paper. The paper presents vignettes for innovative "Scandinavian" approaches in CI education from Case A, B, and C. First, examples for project-based learning, second examples for collaborative learning, and last examples for student ownership of learning are presented.

4.1 PROJECT BASED LEARNING

Case A: "BIM uses and functions of software such as… model checking, BIM authoring… Revit… [need to be learned hands on]" (case A, teachers #1, #2). The BIM Strategy constitutes the core of the program promoting a holistic view on the use of digitalization in construction projects. The BIM Strategy line of progression in education starts by providing the students with knowledge of requirements and specifications concerning BIM that are necessary to drive BIM strategies and to obtain the information needed in the construction process; CI concepts like BIM uses, BIM Execution Plan and Information Requirement / Information delivery. This knowledge will be used directly in the course BIM – Management, Control and Evaluation, where the students will gain competences and skills in how to manage, control and evaluate BIM-based projects.

Case B: "Software are not the main focus but rather should be used to solve the problems" (case B, teacher #1). This statement illustrates how the lecturers in case B prioritize project-based learning as a method of instruction. The overall ambition of the MSc program is to deliver education based on real-life cases (Klakegg et al. 2019). The typical form of instruction in the CI MSc classes involves first, a theoretical instruction familiarizing students with the concepts important for working based on advanced IT systems in projects. This is then followed by project-based work where students apply information systems informed by their theoretical knowledge to solve practical challenges in real construction project situations. Recent student projects have asked questions like "How can the national, public spatial data infrastructure (SDI) portal and the QGIS application be applied for supporting the design of student apartments in Gjøvik`s Mustad industry park?" or "What is the utility of a digital twin for the Mustad industry park project?". In both of these project-based exercises, students applied construction informatics methods and systems to solve a real-world practical problem. Doing so ensures that students become familiar with the application domains of the information systems as well as construction informatics theory.

Case C: Emphasis on the approach of learning by doing, has been one of the main focuses, when teaching the course in BIM Collaboration Process. Project group work is therefore weighted as 75% of the final grade, rewarding students for in-depth project work. Student insight and knowledge is expected to increase during a semester and the project problems are thus designed to become more demanding and complex to reflect the expected cognitive evolution. As an example of the first project, the students must produce vodcasts on collaboration techniques and software used in the AEC industry. This way the student gets to take their base of theoretical instruction to a deeper understanding and hands-on experience of IT tools and software, but also collaborative methodology used in CI. In their final project, students have evolved their skills and taken on real-world problems (Merrill 2002), where the objective is that the students will be working with a realistic introduction to working with the topic "collaboration across disciplines, roles and organizations" in connection with the response to a public tender (case C, teacher #1).

4.2 COLLABORATIVE LEARNING

Case A: In the BIM Strategy line of progression described above a small construction project is the core. In this project the Master Students work as BIM managers together with the Bachelor students that have the roles of Architects, Structural Engineers, Electricity Consultants and HVAC Engineers. Four different BIMs are designed, collaborated, and checked several times during the project. Several different software concerning collaboration are introduced and used in the project, still it is the organization of the different participants that creates the main issues. In parallel, the project knowledge and theory concerning organizational and management aspects related to BIM strategies' implementation are introduced where the students understand and learn how to implement the current BIM strategies in the construction industry.

Case B: Role play exercises where students enact a range of different professional roles like architects, structural, heating, ventilation, air conditioning, and electro engineers are part of the education for students in the one-year diploma program. The course in which this is focused is the BIM teams' class. Over the past years students have collaboratively created designs for diverse projects such as for student apartments or officer quarters for an army base. The learning outcomes of such collaborative projects is that design would need to be generated based on a range of different IT systems.

Case C: In the final project described above, the students are placed in different roles in the very real project of designing and planning the building of the fire station in Alta. Each group will have to solve a specific task in accordance with stages 2-5 in the framework "RIBA Plan of Works". The tasks will differ but as an example a plan for either collaboration or conflict management, throughout the project, are important and real issues. Also, cost estimates on the implementation of these plans are crucial tasks. The layout of the project work is arranged so that each group will have to give a presentation in plenum, and they will also have to work together in three predefined pairs to comment and reflect on the final product of the corresponding group. The student feedback on this assignment ranges from "nice to see other presentations", "good that presentation was part of the assignment", "very good to be forced to comment on the work of others" and "nice way to learn". These examples of feedback indicate students benefit from interactive group work compared to delivering the same assignment individually, given rise to feedback solely from the teacher.

4.3 STUDENT OWNERSHIP OF LEARNING

Case A: The students have two main opportunities to choose to be active and identify their interest. In the Industrial Placement Course in the Built Environment course, the students can challenge the gained knowledge and skills at relevant companies. The student contacts the education relevant company of their liking and for an internship together with the company. The internship is five weeks. During that period the student also can find a relevant topic to investigate further in the course Final Project Work in Built Environment. During the Final Project Work the student collaborates with the researchers at the University in a topic relevant for both the student and the researchers.

Case B: Several of the Master subjects include exercises-based course designs where students seek to solve real-world industry problems based on using digital methods. While half of the exercises are assigned by the instructors, the other half can be freely chosen within the subject matter of the course. Here, students usually use a range of different IT systems that are made available to them. Cases are typically varied ranging from implementing natural language processing for compliance checking in construction contracts, evaluating existing geographical data sets for future construction projects, or scanning existing buildings. This is done for maximizing students' self-direction and motivation, preparing them for performing engineering tasks somewhat independently in future work situations. A downside is that it can be time consuming for students to have the freedom to identify suitable case examples.

Case C: "Flipped learning" (Bergman & Sams 2014) is an important way of getting students to engage. The concept has been further developed at UiT to a "flipped learning space" (OLR; as Norwegian acronym), meeting the need for combining online students, with students physically present on campus. Student feedback like "…made us challenge ourselves in the way we think and reason" and "excellent to work hands-on with the framework", indicates that they take ownership in achieving learning and that the OLR setup has moved the higher cognitive level into the classroom (Chi 2009). As preparations for OLR sessions, students are encouraged to watch video lectures and do exercises. Preparation, for students and lecturers both, is crucial for the OLR to work as planned. The OLR setup is very time-consuming to get on the rails, but the reward is that it frees time for the lecturer to guide and discuss topics with the students, instead of hectoring.

5 DISCUSSION

Taking the framework of hybrid pedagogics (as presented in chapter 2) to guide our inquiry into three examples of Scandinavian CI education, findings show how all three components namely (1) project-based learning, (2) collaborative learning, and (3) student ownership of learning were embraced in all three educations. As can be seen in table 1, the CI educations were different in nature in that they were offered at both graduate and postgraduate level, class sizes differed, and emphasized different digital authoring tools for construction design.

As to the sameness of the programs, they had in common that all were all established quite recently, namely between 2008-2018, that they were geographically located in Scandinavia, and that teachers appeared to embrace shared ideas about how to best teach construction informatics using concepts in line with the hybrid pedagogics framework (table 2). Moreover, the programs were established independently, without much interaction and coordination across the universities. The relative sameness of the program's pedagogical ideas, regardless of education level, class size, and IT systems indicates that there might exist an underlying shared idea about education which could be viewed as typical for Scandinavian CI education.

One possible explanation for the strong emphasis of cooperation and participation in the pedagogical approach in the three CI programs could lie in the history of Scandinavian computer science. For instance, already in the nineteen seventies, Scandinavian scholars recognized the need for democratic approaches in IT use and development and consequently emphasized the importance of experienced based and hands-on design methods for IT (Bødker et al. 1987). Another possible explanation, raised by one of the teachers, is that the construction industry in Scandinavia increasingly expects CI graduates to have a solid socio-technical skillset. Such skills would enable graduates to work as boundary-spanners enabling inter-organizational digital communication in projects. It has been argued that new emerging job roles of CI professionals require graduates not only to be effective technologists but also to be effective communicators across the different disciplines (Jacobsson and Merschbrock 2018). Moreover, what the studies had in common, was that all were a part of larger building and construction studies. Naturally CI exists at the crossroads of computer science and architecture, engineering, and construction. However, while all the programs required students to have a solid AEC background, none of them admitted students having other backgrounds, including computer science.

Table 2. Examples of hybrid pedagogics

	Case A	Case B	Case C
Project based learning	role-play design logistics center	role-play residential buildings	role-play tender docs
Collaborative learning	BSc and MSc students in multi-discipline teams	group assignments; multi-discipline teams	group tasks (stages 2-5 RIBA plan of works)
Student ownership of learning	Industrial Placement Course; Final Project Work	Task-based work	Flipped learning sessions

Thus, even in the stand-alone study programs (Case A and B), CI teaching appears to be viewed as an “addition” to classical engineering programs with a course design following from that.

Thus, there appears in all contexts a need for a discussion of how to create a balance between new CI focused classes vs traditional AEC subjects. A good question for further inquiry could be how to develop studies further towards a more advanced information sharing and database service-based collaboration in construction projects.

6 CONCLUSION

What is the present state of CI education in the Nordic countries and how could a Scandinavian perspective contribute? was the research question investigated in this paper. The answer is that Scandinavian CI educations, as exemplified by the three cases included in this study, place emphasis on the socio as well as the technical aspects of construction information systems. Especially the collaborative aspects of digital work through project-based learning, collaborative learning, and student ownership of learning appear prominent in the curricula of all cases. It would appear that Scandinavian education, maybe stronger than elsewhere, focuses on preparing their graduates for becoming effective coordinators of digital work.

Considering that all three studies trained their students to work in projects based on participatory role-plays, this might be viewed as typical for Scandinavian CI education. Further, solving projects collaboratively rather than by themselves featured prominently in the three educations. Last, the students in all three educations had a high degree of freedom when it to came defining their own projects and deciding for information systems to be studied and used.

Taken together, while all of the aforementioned educational concepts are doubtless also embraced in

CI educations elsewhere around the world, they appear especially pronounced in Scandinavia. This is in line with local traditions in Scandinavian education that strongly emphasize the social aspects in other subject areas, too. Thus, students become competent technologists while also having a strong set of social skills. Thus, a Scandinavian perspective might be useful for education elsewhere. A further finding of this study is that Scandinavian CI educations should consider more cooperation to map and identify important information systems, exchange teachers, and build a common set of case modules. This could help further developing what could be a new perspective in CI education.

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