INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
7 & 8 SEPTEMBER 2017, OSLO AND AKERSHUS UNIVERSITY COLLEGE OF APPLIED SCIENCES, NORWAY

EXPERIENCES FROM IMPLEMENTATION OF SUSTAINABILITY IN A CIVIL ENGINEERING COURSE AT THE UNIVERSITY OF AGDER

Paul Svennevig[1], **Eilif Hjelseth**[2]
[1]University of Agder, Norway
[2]Oslo and Akershus University College of Applied Sciences, Norway

ABSTRACT
Design and assessment of sustainability is expected to be a mandatory part of the competence of the engineers of the future. Sustainability in design and engineering education has often been solved by choosing environmental friendly materials without use of fact based assessment methods. This case study explores experiences from a new developed mandatory course in the civil engineering education at University of Agder (UiA). This course is based on problem- and project based learning, and the learning of sustainability has therefore focused on how the students has applied assessments of sustainability in their project reports. Analyzing the educational and learning situation consist of multiple elements. The didactic relation model is therefore selected as theoretical framework for analyses of selected elements and their relations. Students reported that the support of software technology motivated them to consider several designs before selecting or recommending solutions, and that these experiences are positive. The students project reports included a more mature and holistic assessment of solutions for the built environment. Problem based learning supported by software technology contributed to enable specialization in different directions when it came to how the students solved the problem. The authors conclude that this type of teaching learning environment can be applied in many different teaching situations, where there is no fixed solution. Examples of subjects are; circular economy, product design, architecture and many more.

Keywords: Sustainability, engineering curricula, pedagogical framework, assessment criteria, learning outcome, building information modelling (BIM)

1 INTRODUCTION
This paper is a case study of the results from the introduction of flipped classroom, problem- and project-based learning and peer-review as tools in the teaching of sustainability in an engineering course at the civil engineering education at the UiA. The background for the introduction of these didactic methods is the master thesis "Main principles for dynamic influences between Sustainability, BIM and Didactics in an engineering course" [1] by Paul Svennevig. The Norwegian Association of Higher Educations Institutions' (UHR) framework for engineering educations [2] say that a student shall gain knowledge in history of technology, the role of the engineer in the society, the development of technology and social, environmental, ethical and economic consequences of technology.

Furthermore, the students shall through a system overview on the engineering profession be aware of the environmental, ethic and economic impact of technological products and solutions, both locally and globally in a lifecycle perspective [3]. This means that sustainability and sustainable thinking must be part of the curriculum of the bachelor studies.

It is almost impossible to meet these criteria's by using conventional teaching methods. The result of this is to use other didactic methods in teaching. The aim of this study is to explore the students experiences of implementation of sustainability in a civil engineering course with the use of the didactic methods that were implemented in the course. There is need for better understanding of challenges and opportunities from implementation of sustainability in engineering education. A critical

element is how sustainability assessments can be integrated in design and planning of solutions for the built environment by support of digital software technology like building information modelling (BIM).

The research question is formulated as "How does the support of software technology, and didactic methods such as flipped classroom, problem based learning and peer-reviews support learning in an open ended project work, compared to lecture based teaching, from the students point of view?"

2 DESCRIPTION FOR THE BIM/ SUSTAINABILITY COURSE

Due to some rearrangement in the structure of how courses are taught in the civil engineering program, there was an opening in the course BYG211 Computer Based Modelling and Surveying to include sustainability in the teaching of the subject [1]. There are different ways to include this topic, but since the scope of the course included use of BIM based software technology, it was natural to implement sustainability by support of technology. The didactic relationship model [4] uses six perspectives to explain how the mentor/teacher can plan the curricula, to create flow between the aspects of mentoring/teaching. These are 1) Learning conditions: is whatever mental, physical, social and academic challenges or opportunities a student have in regards to the teaching of the course. 2) Setting: is factors that (formal and informal) can promote or hinder teaching and learning in many ways. 3) Goals: the goals of the course say something about the intent of the course. 4) Content: is the curriculum. 5) Learning process: is how the learning is intended to be. 6) Assessment: of what the student have learned. This model was use to structure the didactics in the course.

The execution of the course was done in steps. The first 6 weeks of the course consisted of 4 hours where the students learned the use of a BIM-software. This was done with the method of flipped classroom and mentoring by the teacher. The students used video lectures from Lynda.com to learn the use of the software. The students were given a compulsory task, which had to be approved to be able to take the exam in the course. The exam in this part of the course was a group project over the last 6 weeks of the course with the teacher available for mentoring 4 hours per week. There were given criteria's – such as length, with, height, room for technical equipment in each floor etc. for a building. The students were to design a building within the criteria's and utilize tools in the software to gather information on massing of the building elements. From these data, they had to calculate the environmental footprint of the building using Environmental Product Declaration (EPD) and spreadsheets. The environmental footprint was to be given in CO_2-eqivilants. Then the task was to optimize the design in a sustainable way. They had to discuss what a sustainable building is. Some students discussed that a sustainable design is the one with the lowest environmental footprint, whereas others argued that a flexible building when its usage, now and in the future is taken into consideration, and at the same time have a low environmental footprint is the most sustainable design. The findings of the students were to be presented in a report, written in English to furthermore accommodate to UHRs' framework for engineering educations that say that students shall master both Norwegian and English languages after completing their education [2]. Neither one of these solutions were favored when it came to grading the papers. It was the process and the arguments in the discussions that were graded.

3 RESEARCH METHODS AND MATERIALS

This cases study explore the student experiences with the new curriculum and teaching methods in BYG211 Computer Based Modelling and Surveying [1] at UiA in the fall of 2016. This study is based on qualitative feedback from the students. The reason for choosing this methodology was to explore relation between multiple factors in the teaching and learning environment. In their reports, the students were to give feedback on two questions: A) If you were to redo the project, what would you do differently? and B) If you were to give a project on BIM & Sustainability to a group of students, what would you do differently? These findings in included in the experiences from the course.

In January of 2017 the students also received a survey where with five questions related to the teaching of the course. The Findings section include the feedback from the students, and our comments to their feedback.

4 RESULTS / FINDINGS

There are two different sources of feedback from the students that had the course in 2016. The first source is an assessment of how the sustainability as design criteria has influenced the design of the building in their project. The other source is more pedagogic oriented and is based on a survey in January 2017.

4.1 Experiences from the course

The students perspective focuses on solving the project task in a best possible way. In a traditional course, managed by the lecturer, the constraint is clearly presented and the result is an exam with a fixed and predefined result. The project focuses on industrial buildings with high complexity related to structural framework, choice of material – and including sustainability as assessment criteria of designed solution. The BIM based software that has been used was Autodesk Revit Architecture. Example from a student project is illustrated in figure 1.

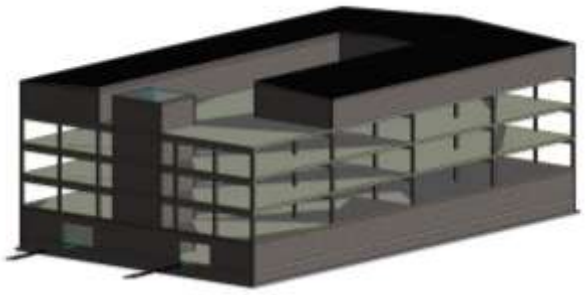

Figure 1. Example of a BIM model from a student project

The challenge with sustainability assessment, is commented in one of the project reports;

> "When designing with sustainability in mind, a common theme is to design support structures as lean as possible within limits. This is reflected well in the model as shown in this chapter. Designing for sustainability does not only consider the materials used for the building, but also the buildings utility and flexibility. Some of the design choices made in previous chapters reflect this. Some solutions in the final design would, when focusing solely on CO_2-equivalents, produce more than other options that were considered. However, the solutions in the optimized model would result in a more flexible building, and in turn ended up being favored over their slightly less CO_2-heavy counterparts. Flexibility in buildings is important, to allow the building to stay up for the entirety of its intended lifespan, without needing to demolish it due to not meeting future needs. This area of sustainable design is particularly challenging, as some design choices does not necessarily provide specific numbers that can be used to compare or measure how environmentally friendly a building is" [5].

This complexity is also illustrated by other students experiences. The assignment were based on materials of steel, LECA and concrete, with specific material qualities. This was done because we did not want the students to get lost in the choices of materials and material qualities. However, if the students asked during the mentoring if they could take other materials and material qualities into consideration, they would get a positive response from the mentor. In the students reports, one could see results of this initiatives. Some groups opted to use wood framing in the dividing walls between apartments, other groups considered the use of Bubledeck in the floors instead of hollow core slabs or cast-in-place floors. Some groups also considered the use of high strength concrete versus ordinary concrete.

4.2 Summary of feedback given in students' final reports:

A. *Question*; If you were to redo the project, what would you do differently? The students say that the project is time consuming, and that they would make a schedule for the project period. They also comment that they would utilize the fact that they work as a team, and divide the project into several tasks. These tasks would be divided amongst the group members, which would result in more efficient use of time. Some groups also say that they would utilize the ability to add properties for different materials in the BIM-software so that calculating CO_2-equvivilants for the design would be more accurate.

B. *Question;* If you were to give a project on BIM & Sustainability to a group of students, what would you do differently? The answers are mostly divided into three categories:
   - Some students wish that there was more information on how a construction like the one in the assignment are put together. In other words, the students feel that they could use a lecture on building technique before they start the project.
   - The students find peer-review very helpful, and they would like to have more than the one that were arranged. The plan was to have two peer-reviews, but since the groups had such different progress in the project it was difficult to see through
   - There are also some students that wish that there were "a goal" to achieve for the project, e.g. "x kg $CO2/m^2$"

In the feedback, there are some comments that tells us that the didactics and assignment has worked when it comes to the wanted learning outcome:
   - The project has been very informative, and we have been enlightened in regards to climate gas emissions from various construction materials, and methods of building
   - We found this project to be very well made, as it gave the students room to explore within well-defined parameters, as well as guiding for those who needed it. This was a project that felt useful for the future, both academically and in more practical purposes. All in all, we wouldn't change anything with the project as it is already thoroughly thought through.
   - The project help us to understand the connection between the process of building and the environmental impact. Through working with the project, we have developed a much better understanding for how these the building industry affects the environment and we now understand a lot better how this connection works. If we were to redo the project, we would beforehand use some extra effort to get a better overview in the BIM-tool Revit.
   - We are very satisfied with the task. It has given us a lot more knowledge about Revit, different material, sustainability, and how to build the support system in a building.
   - We think this was an excellent project, which gave us an insight into the real world of a civil engineering.

4.3 Summary in the survey from January 2017

The survey was directed toward the didactics in the course, in respect to the didactic relation model. It consisted of 5 questions, and the topics regarded; 1. mentoring, 2. peer-reviews, 3. how to work with the assignment, 4. work period and 5. examination. Each question had multiple alternative answers.

1. When it comes to mentoring, the students answered as follow; a) 8 % of the students preferred 4 hours plenary mentoring, b) 50 % of the students wished for weekly mentoring, where the teacher is available for 4 hours and the students get mentoring if they seek it, c) 8 % wanted 15 minutes mandatory mentoring every week, d) 8 % preferred mentoring through discussions in the LMS. 25 % answered that a combination of b) and c) was preferred.
   This shows that the students were happy with the mentoring that was available during the course.

2. The teacher decides what groups will have per-reviews together. The results from the survey were as follow; a) 58 % of the students answered that they preferred that the teacher schedules these reviews and that there should be 2 of them during the work period, b) 8 % answered that the teacher should match the groups, but they should decide themselves when and where they should be held, as long as they had 2 reviews during the project and c) 23 % said that they want the solution given in a), plus one peer-review where the teacher and all the students are present.
   This shows that the intentions for two peer-reviews in 2016 were a good plan, and that except for the fact that there only were one peer-review, that peer-reviews is a way of peer mentoring that the students like.

3. When it comes to how the students would like to work on the assignment, the feedback is that it would be beneficiary with changes from last year's course. Last year, the students were given the assignment and a deadline and were free to plan their work themselves. The feedback shows that 58 % of the students would like to have a startup-meeting with the teacher, where they present a work schedule for the work period. This will help them plan the assignment and avoid the panic of an approaching deadline. 33 % preferred it to be as in 2016, and 8 % wished for the schedule to be presented in the peer-reviews and work progress to be discussed as part of the reviews.
   The feedback from the students illustrate that they are not used to work on open ended problems, and the the importans of structured start-up meeting with the mentor to plan the project work, so that one can avoid the stress created by the dead line.

4. In 2016 the work period started 6 weeks into the semester, and the deadline for the hand-in was in the exam period. The reasoning for this, was that if the report is part of the examination of the course it is natural that the due-date is in the exam period. The feedback from the students is that this is not ideal, because in the exam period they focus too much on ordinary exams and they try to get reports done before this period. In real life, this results in a shorter work period than the course plan states. 67 % of the students recommend that the startup and due-date is moved e.g. 3 weeks earlier in the semester. 17 % would like the start-up to be earlier and the deadline to be as in 2016. 25 % preferred the work period as it was in 2016.
   This state the importance of assessment, and to not let intensive work in finalizing open ended project works be in conflict with priority if time to prepare for ordinary exams.

5. 58 % of the students want the same examination as in 2016. The examination was a report, written in English and it counted as 60 % of the final grade in the course BYG211 Computer Based Modelling and Surveying. 17 % said that the report should be in English and that there should be an oral group presentation, that can adjust the grade up/down one grade. 8 % preferred that the report is in English and that the oral presentation is individual, and that it can adjust the grade up/down one grade. The final 8 % of the students wishes that the report counted 50 % and an individual oral exam counted 50 % - this part of the course would still count 60 % of the final grade of the course.
   This feedback confirm that the evaluation of the projects should reflect the process of the group are through and not just the result itself. The learning process of writing a report in English, that explains the process of the project, and how the discussion is used to explain the results of the work is important to evaluate.

5 DISCUSSION AND SUMMARY

The BYG211 Computer Based Modelling and Surveying course includes multiple profession design criteria, where sustainability is given priority. In the results one could see that the students gained a higher understanding of sustainability and design. This was shown when they in the discussion chapter of their reports discussed sustainability in construction. They argued that a construction that is optimized for the environmental footprint in CO_2-equvivilants, not necessary is the most sustainable building. The reasoning for this is that a building that is designed solely with the CO_2-footprint in mind might not be flexible enough when it comes to the use of the building. If the building is not built flexible enough it might have to be torn down long before it reaches it expected lifespan, because it cannot be rebuilt for different usage than the original use of the building. School buildings is a good example. We know what infrastructure we need for teaching today; classrooms, whiteboards, projectors, desks etc. What are the demands in ten years? This we do not know for certain, the only thing we know is that we cannot demolish buildings and rebuild them to fit the teaching in ten years. Because of this, we must consider flexibility in the design of new school buildings, so that they are sustainable in other ways than just environmental impact.

Combination of sustainability as design criteria, learning usage of BIM-based design tool for design, and working in teams, is very demanding. The Cynefin framework [6] can be used to understand which type of problem one is dealing with. Design is a challenging discipline by nature, and by including sustainability as assessment criteria the BYG211 Computer Based Modelling and Surveying course in position between Complicated and Complex in the figure 2.

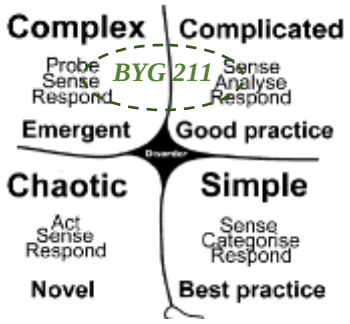

Figure 2. The Cynefin framework [6] with position of the BYG211 Computer Based Modelling and Surveying course

Support of BIM based software enable the students to explore multiple alternatives and criteria of designed solutions. Use of didactic methods such as flipped classroom, problem-and project-based learning and peer-review provide a learning environment that support courses that combine technology, design and sustainability to holistic solutions.

Assessment of content in students repots and feedback from the students confirm that this way of teaching encourage the students to explore solutions and possibilities outside the norm. From student's perspective, the most important outcome from this type of teaching, seen in retrospect, is their experiences as an active learner in a complicated and complex working environment. Being aware that asking the right questions based on multiple factors, instead of solving a problem by a predefined method to a fixed answer, is the is more important outcome from the study.

Problem based learning supported by software technology contributed to enable specialization in different directions when it came to how the students solved the problem. The authors conclude that this type of teaching learning environment can be applied in many different teaching situations, where there is no fixed solution. Examples of these types of subjects are circular economy, product design, architecture and many more.

REFERENCES

[1] Svennevig, P. *Main principles for dynamic influences between Sustainability, BIM and Didactics in an engineering course*. Master thesis at University of Agder, Norway, https://buildingsmart.no/sites/buildingsmart.no/files/2015_uia_paul_svennevig_main_principles_for_dynamic_influences_between_sustainability-bim-didactics_in_an_engineering_course.pdf (accessed 6 March 2017), (2015).

[2] *Guidelines for Engineering Educations*, The Norwegian Association of Higher Education Institutions. http://www.uhr.no/documents/Nasjonale_retningslinjer_for_ingeni_rutdanning_ENGELSK.pdf (accessed 6 March 2017), (2011).

[3] Johnsen, H. *Higher Education in a Sustainable Society*, Springer International Publishing Switzerland, pp. 95-111 (2015).

[4] Hiim, H., and Hippe, E. *Læring gjennom opplevelse, forståelse og handling: en studiebok i didaktikk [Learning through experience, understanding and action]*. Oslo: Universitetsforlaget, (1998).

[5] Student report, BYG211 course, 2016

[6] Snowden, D. *Cynefin: a sense of time and space, the social ecology of knowledge management*. Originally published as a chapter in Knowledge Horizons: The present and the promise of Knowledge Management. https://storyconnect.nl/wp-content/uploads/2015/07/Knowledge-Horizons-The-social-ecology-of-knowledge-management-.pdf (accessed 6 March 2017), (2000).