Main principles for dynamic influences between Sustainability, BIM and Didactics in an engineering course

How to teach sustainability in a BIM-course in the Civil Engineering education at University of Agder so that it meets Norwegian Association of Higher Educations national guidelines for engineering educations.

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This master's thesis is carried out as a part of the education at the University of Agder and is therefore approved as a part of this education. However, this does not imply that the University answers for the methods that are used or the conclusions that are drawn.

University of Agder, 2015

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Foreword

This master thesis is the final work of my Civil Engineering Master education at the University of Agder (UiA). It has been a long road to get to where I can hand in this report. I started my masters’ education in the fall of 2010, while at the same time working full time at UiA. My full time work consists of being study coordinator for the Civil Engineering bachelor program, teaching and working as a senior engineer at the civil engineering laboratory. It has been a puzzle sometimes to make it work, but I feel that it has work well and I do not think that my work has suffered from my studies. There has been times where I have had to prioritize my studies before my work and when that has been the case, everybody – my colleagues, the students, family and friends have been very understanding and supporting. There are several people that I feel the need to thank in writing, but there are too many to list here – so if your name is not on the list, be sure that I feel very thankful non the less.

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Summary

This thesis is a possibility study regarding the topic “Main principles for dynamic influences between Sustainability, BIM and Didactics in an engineering course - How to teach sustainability in a BIM-course in the Civil Engineering education at University of Agder so that it meets Norwegian Association of Higher Educations national guidelines for engineering educations”. It is aimed at educators in the field of engineering in higher education, especially within the field of Building Information Modeling. This thesis is based in an existing engineering course, BYG211 Computer Based Modelling and Surveying.

Dynamic integration of the engineers focus on sustainability, support for BIM tools and processes and use of modern didactic approaches has been a missing link. This multidisciplinary study intent is to improve the students understanding of BIM as a tool to support learning and understanding for the students and how it can be used to create sustainable solutions in the built environment. The problem with teaching BIM in higher education is that most lecturers do not have expertise experience and in many institutions this subject is taught by people from the AEC industry\(^1\) [1].

I have chosen to write this report in a narrative style, to show to the reader that this has been a learning process for me. By writing the report in this way, it also shows that this learning process has taken me from the starting point where I wanted to integrate sustainability in a BIM-course in the engineering education, to become a thesis on how didactics, BIM and sustainability affect each other and the teaching of an engineering course.

To be able to have an opinion on how sustainability, didactics and BIM influences each other in regards to teaching an engineering course, I had to perform a study on pedagogics and didactics. Further, I had to study learning theories and teaching methods that implements modern thoughts on how to teach students in the 21\(^{st}\) century, with all the tools and possibilities it brings with it. This thesis focus on support for the learning process,

\(^1\) AEC industry – Architects, engineers, construction, owner and operator industry
with a teacher/lecturer perspective. Which enables the students to obtain understanding of, and develop, technical solutions. Having the teacher/lecturer perspective will be useful when reading this thesis. The thesis is a reference on how one can integrate sustainability methods and BIM based modeling (software) in higher education.

In the theory chapter, I also had to clarify what BIM actually is, and what the advantages and aids it brings forth. Sustainability also had to be explained in general and of course in regards to a building project and civil engineering.

In the discussion, I relate the changes in the curriculum of the course to include sustainability to the national guidelines for engineering educations by The Norwegian Association of Higher Education Institutions (UHR). I also argue that the change from today’s teaching to a course plan based on flipped classroom and challenge based learning are based in the introduction of sustainability into the course. There are another reason for changing the way of teaching the course, and that is based in the fact that there are many students at UiA, Campus Grimstad and the room capacity is at a max. The classroom fitted for teaching the use of software and BIM has a capacity of 35 students at the time, the course has about 120 students. Earlier this meant that the teacher repeated the lectures three times a week, to reach all the students. Today the lectures on the use of software is done by video lectures, and in the rehearsals the teacher helps the students with their problems. This is what I would call “flipped classroom – light”, because this do not utilize the benefits of flipped classroom. All it does is helping the teacher from repeating lectures, everything else is the same as before.

By changing to didactic methods as flipped classroom and Problem Based Learning, the use of software will still be taught by video lectures. But, when introducing sustainability in the course and the use of Problem Based Learning, the students can work on solving an assignment that utilize BIM to create a sustainable building design. By doing this, the teacher’s role is now the role of a mentor and a facilitator in classroom discussions.

In the end, I conclude that it is possible to teach sustainability and BIM together in an engineering course, based on didactics and 21st century teaching methods, so that it meets the requirements in the national guidelines for engineering educations given by UHR.
The appendix is divided in two parts. The first part of the appendix is information on the case of the thesis – the BYG211-course. The second part of the appendix consists of learning resources that can be useful for teachers and students in engineering education related to understanding, assessment and design.
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Introduction

The background why this thesis and its research question was chosen derives from the fact that I am an employee at the University of Agder, Campus Grimstad. One of my responsibilities is to teach a course called “BYG211 Computer Based Modelling and Surveying”. The course is divided into four different subjects, these subjects are:

1. Surveying
2. Using software for Structural Analysis, software: SAP2000
3. 2D-modeling, software: AutoCAD
4. Building Information Modeling, software: Revit

I have been teaching this course since 2011, from 2008 until 2011 I was a teacher’s assistant in a course in technical drawing. For years these courses were taught in a traditionally way, with lectures and rehearsals. In the lectures the teacher typically showed the students how to use the program, and the students worked with the program solving different problems in the rehearsals with the teacher present to help the when they needed help. This way of teaching was very static and lead to problems for the students, because they only watched and took notes in the lectures and had to remember what functions did what in the rehearsals. When I started teaching “BYG211 Computer Based Modelling and Surveying” in 2011, the first thing I did was to combine the lectures and rehearsals into one “unit”. The teaching then revolved around teaching cases that were similar to what the students had to hand in later. I would show some functions to the students, they worked with it and I went around the classroom and helped. This worked a lot better than the earlier model of teaching, but as the number of students grew – from about 50 in 2008 to about 120 students in 2012, it also resulted in repeating the lectures three times a week to cater to all the students. The reason for this is that at Campus Grimstad we have one classroom fitted with computers suitable for running the programs we use in the course. This classroom has 34 computers available for the students, which results in repeating the lectures three times a week when the numbers of students are above 70. In 2013 I did some changes to how I was teaching the course, these changes was a result of several things. First, I had realized over the two years that I had had the responsibility for the course that most of the students had laptops that they
preferred to work on, instead of the computers in the classroom. I also realized that the way we had been teaching the course were a result of the students did not have the knowledge of the 21st century tools available to them. This was no longer true. The students we have these days have grown up with computers, internet, tablets and smartphones. Another factor, which derives from the fact that the students now have the skills necessary when it comes to the use of computers etc. contrary to earlier is that it is not enough to learn the students how to use the software – one have to learn the students more about the “BIM philosophy” and the theory of BIM. As a result, I had to look at how I was teaching the course. Thirdly, the university had bought a software license that allowed the students to install the programs on their own computers and it had bought license rights to use video lectures from Lynda.com² in courses. Because of this, I was able to use video lectures from Lynda.com instead of me lecturing the students, and my role as a teacher changed from lecturing to guiding the students through the problems at hand. This meant that the students could watch the lectures and work on their hand-ins whenever they wanted, and could go to the rehearsal hours to get help when they were stuck on a problem. As a result, my workload were reduced from twelve hours a week (3 x 4 hours) to 4 hours. The course only allocated a classroom for four hours a week, allowing for easier planning of the teaching schedule and the students could make use of their 21st century tool skills. The student evaluations of this way of teaching has been very positive.

My thesis is to incorporate sustainability into the BIM-course by the use of 21st century teaching methods. This is made possible by the fact that from 2016 AutoCAD will no longer be a part of this course. AutoCAD will not be removed from our Civil Engineering education, it is relocated to another course. The room created in the BIM-course could be used to make a more advanced BIM-course when it comes to the use of software, but instead I will use this thesis to look into the possibility to incorporate sustainability with BIM in the course. This is in accordance with The Norwegian Association of Higher

² Lynda.com, Inc. was founded in 1995 and is headquartered in Carpinteria, California. Lynda.com is a leading online learning company that helps anyone learn business, software, technology and creative skills to achieve personal and professional goals. [49]
Education Institutions’ (UHR) framework for engineering educations. UHR do not use the word sustainability directly in this framework. It says however 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 impacts of technological products and solutions, both locally and globally in a lifecycle perspective [2]. If a student shall learn all this, you cannot deny the fact that they mean sustainability. To be able to incorporate sustainability with BIM in the course, and be able to teach this subject well to the students I have to gain knowledge in Building Information Modeling, Sustainability and Didactics through a literature study. The dynamic interactions between BIM, sustainability and didactics is illustrated below in figure 1.

![Figure 1 - How BIM, Sustainability and Didactics influence an engineering course. [3]](image)

After I have completed the literature study, I can perform an analysis one how to incorporate sustainability in the course and how to teach the course with 21st century teaching methods. The background for the analysis will be the description of the subject, where it is stipulated what learning outcome the students should have in the course. After the analysis, I will draw a conclusion on how to incorporate sustainability in a BIM-course.

3 Didactics – the science, art or practice of teaching [51]
with 21st century teaching methods. The solution I end up with after the analysis should be specific for the course, but also so general that the thoughts on how to teach and build a course could be incorporated to other courses in the Civil Engineering education.
Case and Research Question

One of the three courses that the students of the Civil Engineering education at the University of Agder (UiA) has in their first semester is a course called TFL115 Introductory Course for Engineers. In the fall of 2015, this course changed from previous years teaching in the way that all the engineering studies had 6 weeks of this course to fill with subjects linked to the Bachelor program that the students were studying. This meant that the Civil Engineering students and the Renewable Energy students had subjects as building technology and AutoCAD in the specific part of the course. This leads to possibilities for another course in the Civil Engineering program to change also. This course is BYG211 Computer Based Modelling & Surveying. All students that follow this course through the fall of 2015, will have four elements in this course. These elements are, Building Information Modeling, AutoCAD, SAP2000⁴ and Surveying. The students that started their education in the fall of 2015 already has had AutoCAD when they are to take the subject BYG211. This means that there is an element to replace in this course.

There are two choices when it comes to what to do with this “open slot” in BYG211. One way to go is to increase the hours of Building Information Modeling (BIM) we teach. Today the BIM part of the course consists of a few lectures that is about the theory of BIM and the rest is learning to use a BIM-software. In other words, the BIM-course today is a practical course, which is based on teaching the students how to read and understand drawings and the use of a software. If we were to increase the hours of BIM that we teach, this would mean a more advanced course in the use of a software. Another way to go is to introduce a new topic in the “open slot”.

The Norwegian Association of Higher Education Institution (UHR) have made national guidelines for engineering educations [4] in Norway, were they through a description of what engineering students must learn in their education basically says that sustainability

⁴ SAP2000 is an integrated software for structural analysis and design for civil engineering, made by Computers & Structures, INC (CSI). SAP2000 is compatible with BIM-softwares such as Revit and Tekla, and supports buildingSMART Industry Foundation Classes (IFC) [50].
is very important for engineering students to have knowledge and understanding of. To meet the framework of UHR, sustainability is going to replace AutoCAD in the course.

My master thesis will be the preliminary work on how to make all the elements in the “new” course work together. By preliminary, I mean that I will only focus on two of the four elements in the course, BIM and sustainability – as shown in Figure 2 below.

![Diagram showing course elements](image)

**Figure 2 - Schematic overview of topics in Master thesis.** [3]

Figure 2 can be viewed as a full size image in “Appendix part I”. It is a schematic overview of how the course, that is the topic of my thesis, is being taught today – shown with black arrows. What the black arrows shows is the four for mentioned topics in the course that have hand-ins that the students have to do in order to be able to take the final exam in the course. The red arrows and boxes shows the topics of my master thesis, and the blue arrows and boxes is what I want the course to evolve into.

As this course is taught today it is, as mentioned earlier in this chapter, divided into four topics – Building Information Modeling (how to use the software), AutoCAD (how to use the software), Structural Analysis software – SAP2000 (how to use the software) and Surveying – theoretical and practical lectures and rehearsals. As of the fall semester, 2016
AutoCAD will no longer be part of this course. The “empty slot” left by AutoCAD is being replaced by the topic of sustainability – marked in green in the figure above. This is where the focus of my thesis are, how to incorporate sustainability in a BIM-course and how do these topics influence each other. In the figure, BIM and sustainability are linked together, and they are again influenced by the box “how to teach sustainability and BIM”. The topics that affects that box is the different didactic frameworks and pedagogical theories that together with BIM and sustainability creates the foundation for my thesis and my findings. This is a complex matter, and there are many solutions on how to solve it – the aim of my thesis is to come up with one solution to the incorporation of sustainability in a BIM-course and to highlight the connections between BIM, sustainability and Didactics.

The inclusion of the two other elements, structural analysis software and surveying, will done gradually over the next one to two years. This is because these two subjects are taught be other teachers than myself. There are going to be changes in how is teaching the two other elements in the next one to two years. More than likely, I will teach the structural analysis software. This software is SAP2000 now, but there are many different types of structural analysis programs – so this might change. The same is true when it comes to the BIM software that we teach today, we have to be open to the possibility that different softwares will become class leading and we might have to change. This leads to the fact that the course have to be constructed in such a way that it allows for changes in software. In the next few years, I will also become more involved in the practical parts of the surveying, i.e. the rehearsals. This will make it a lot easier to reach the final goal for the course, which is to base the whole course on problem based learning. The goal is to have all the lectures as video lectures and the teachers in the course will mentor the students on one large challenge that combines all the elements of the course (Figure 2).

Eilif Hjelseth writes in his paper “Use of BIM for learning engineering – Change of paradigm” [1] that the AEC industry have increasingly needs for BIM-related expertise. BIM in higher education in Norway is usually based on learning the use of BIM software, and not what BIM actually is. There are several reasons for this, one of the reasons is that there is a lack of BIM expertise at a scientific level in higher education. Another reasons can be that the courses that have included technical drawing has evolved from teaching
the students’ 2D drawing to become BIM courses. The implementation of BIM have been gradual, so the courses have continued to be technical drawing course with BIM software instead of 2D software. It is important that the students master the skills of drawing, but BIM is much more than drawing and the students need to learn what BIM really is and how it can be used in almost every aspect of engineers’ everyday life.
Research question

Based on the description above I have created the following research question or hypothesis for the research done in this thesis:

“Main principles for dynamic influences between Sustainability, BIM and Didactics in an engineering course”

- How to teach sustainability in a BIM-course in the Civil Engineering education at University of Agder so that it meets Norwegian Association of Higher Educations national guidelines for engineering educations.

To be able to answer this question, I have divided the question into several topics that I have to research:

1. What is BIM?
2. What is sustainability?
3. Pedagogics and didactics – to determine the most beneficial way of teaching a course that consists of sustainability and BIM. In this topic, I also have to look at teaching methods and teaching framework from the teachers’ perspective.
4. Create a plan for teaching the course. What order to teach the elements of the course?
5. Make a new or supplement the existing course description.

Limitation of research

This report will not go into details describing BIM, there will be a short introductory to BIM, but mainly the subject considering BIM that will be written about in this report is subjects that are of interest to the sustainability part of the report. The report will only be about the BIM and sustainability elements of the course. The other two elements of the course – SAP2000 and surveying will not be part of the discussion of this report. They will be mentioned to get the full view of what is the ultimate goal for the course, but they will not be researched when it comes to pedagogics and didactics.
Theory and Method

The following chapters of the thesis will be a description of the methods used in the work with this report and a review of the theoretical foundation of the report.

Method

The main method of this thesis has been literature study. When I started the work with this thesis, the main focus was how one can use BIM and Life Cycle Assessment to get an idea of the environmental impact, sustainability, of a construction in the early design phase. Therefore, the first thing I did was to search the internet for books on the topics Building Information Modeling and sustainability. This is a very wide search, so I narrowed it by combining the two topics in the search. Some of the books I found were “BIM Handbook” by Chuck Eastman et al. [5], “Sustainable Buildings and Infrastructure” by Annie R. Pearce et al. [6] and “Green BIM” by Eddy Krygiel and Bradley Nies [7]. However, my thesis changed focus after a while. The reason for this was that the more I researched sustainability and BIM and how one can combine them in search for the environmental impact of a construction, the more I realized that I also had to figure out how I were to teach this to students. As a reminder of how didactics, BIM and sustainability affects each other when it comes to teaching, I chose to show the figure below again.

Figure 3 - How BIM, Sustainability and Didactics influence an engineering course (repetition of figure 1) [3]
According to chapter 7 “Sustainability and Teaching in Higher Technological Education” in the book “Higher Education in a sustainable Society” [2], the preferred method for teaching sustainability is Problem Based Learning. What is the best way of teaching BIM? How do the BIM part of the course influence the sustainability part of the course? These questions lead me to change the focus of my thesis. The focus changed to how one can teach BIM and sustainability in the 21st century, with all the tools that it brings with it. This meant that I had to extend my knowledge of pedagogics and didactics, so that I can create a framework for teaching the course.

This also meant that my literature study was extended to include literature on pedagogics and didactics. I found literature on these topics through discussions with my mentor, Eilif Hjelseth, and by discussing with colleagues of mine at UiA that has pedagogics and didactics as their field of knowledge. When studying pedagogics and didactics, I realized that I had to look at the curriculums of the other courses in the Civil Engineering programs, both bachelor and master. To get information on what the students learn about sustainability. Since I had a central role in recreating the Civil Engineering bachelor program to follow the national guidelines for engineering education in Norway [4] I had knowledge of what the students learn in each course through their education, but I did not have detailed knowledge of all the curriculums. Studying the curriculums was valuable not only to get an understanding of what the students know when they start BYG211, but also to see what they are supposed to learn later in their education. By studying the curriculums, I could make sure that what I plan for BYG211 do not force big changes to other courses in the bachelor and master program. Another result of studying the curriculums of the other courses was that I found literature that was interesting for my research. In the course “TFL115 Introductory Course for Engineers”, the book “Kjemi og Miljølære” by Nils Chr. Boye [8] is used. Part two of this book, environmental science, contains a chapter on Life Cycle Assessment that became part of the literature study for this thesis. From the course “BYG404 Life Cycle Assessment of Constructions” in the master program, I included “The Hitch Hiker’s Guide to LCA” by Henrikke Baumann and Anne-Marie Tillman [9] in my literature study.
Experience based method is also used in the analysis of this thesis. The experience that some of the analysis is based on is my own experience from working at UiA since January 2008. Since then I have taught several courses and subjects. In “BYG101 Technical Design”, I have taught properties of building materials, both in lectures and in the laboratory. I have taught the use of structural analysis software, G-prog, combined lectures and rehearsals. I have also taught is surveying, and every year I mentor 2 – 3 groups through their bachelor thesis.

The literature study, the studying of curriculums in the Civil Engineering bachelor and master program and my experience as a teacher create the basis for the discussion in the Analysis chapter that leads to the conclusion of this thesis.
Theory, Engineering

This chapter is about the background for sustainable thinking in the building industry and a short introductory to BIM and the theory behind the teaching methods used to implement sustainability in to a BIM-course. It is however, worth mentioning that this report covers three quite substantial topics – BIM, Sustainability and Didactics. Each of these topics could easily have been a master thesis on its own, so as a result of that the theory of this thesis cannot be of the same detail level as a thesis on dealing with only one of the three topics.

Sustainability

To be able to discuss sustainability and how one can incorporate it in a BIM-course, one have to look at how sustainability is defined. It is also important to find out how one can define sustainability in the building sector. Is there a difference, and if there a difference between so called green building (what often is called grønt bygging in Norway) and sustainability – what is it?

Sustainability as we think of it today was defined in what is often called “the Brundtland report”, the correct name of the report is “Our Common Future”. This report was published in 1987 after 4 years of work. In 1983, the UN (the United Nations) had Gro Harlem Brundtland, the Prime Minister of Norway at the time, head the World Commission on Environment and Development. The commission had 22 members all from different countries around the world. The task of this group was to examine the global environment and development to the year 2000, and beyond. One of the outcomes of this report was that the commission meant that it was time to realize that it was important to fuse economy and ecology, in order to ensure the growth of human progress through development without depleting the resources of future generations [10]. The commission define sustainability in this way:

“Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs” [11]
What this means, is that our activities today cannot in any way deplete the earth's resources, so that the future generations of the earth cannot meet their needs. This statement is so strong and vast, that it implicates everything we as human beings are doing. It means that we have to take care of all the resources that is present on earth, and we have to stop thinking solely of “the needs of the now”. We have to start thinking of the repercussions our “needs of the now” have on the ability of future generation’s needs. We have to start thinking and acting in a “sustainable way” in everything that we as inhabitants of the earth do. This means that we have to start developing a sustainable agriculture, building industry, infrastructure, energy consumption – basically everything we produce or use have to have a sustainable politic behind it. This thesis is looking at how one can implement sustainability in a BIM-course at the Civil Engineering education at UiA. This means that in this course, the students have to learn and train in sustainable thinking in regards to civil engineering and design of constructions. They have to be able to explain how sustainability and sustainable thinking affects the design. In other words, they have to be able to different system influences each other, i.e. system thinking.

**Sustainability in building industry**

In the building industry people often talk about “green building” (grønt byggeri in Norwegian) and at the same time they often talk about sustainable building or sustainability in regards to constructions. So is the term “green building” the same as sustainable building? No, it is not. In my opinion, many people mean sustainable building when they talk about green building – in the same way as many people talk about BIM when they say 3D-modeling. I think that people get these terms mixed up, because they do not know the exact meaning of the terms. Therefore, it is important to define what green building and sustainable building.

**Green Building**

Green building is a building that has less impact on the natural environment than the traditionally buildings that is being built [7]. This means that the materials used in a green building have less impact on the environment than the traditional building materials used in the traditional buildings. Very often, it is used recycled materials or natural materials, e.g. sheep’s wool as insulation.
ZEB – Zero Emission Buildings

The Research Centre on Zero Emission Buildings, is a national research center in Norway that is placed in Trondheim – it is organized as a joint SINTEF\textsuperscript{5} and NTNU\textsuperscript{6} unit, and hosted by NTNU. The vision of the center is to eliminate greenhouse gas emissions caused by buildings. The definition of a zero emission building is that the building produces enough renewable energy to compensate for the greenhouse gasses through the lifespan of the building. There are four different levels of zero emission buildings, ZEB-O, ZEB-OM, ZEB-COM and ZEB-COMPLETE. These levels are dependent on how many phases of the lifespan of the building that are taken into consideration. ZEB-O is produces enough renewable energy to cover the greenhouse gas emissions from the operation of the building. If the building produces enough renewable energy to cover the emissions from operation of the building and the production of the building materials – then it has reached the level ZEB-OM. A ZEB-COM building produces so much renewable energy that it compensates for greenhouse gas emissions from construction, operation and production of building materials. The final stage of ZEB levels are COMPLETE which means that the building produce renewable energy to cover emissions from the entire lifespan of the building. [12]

Sustainable building

Sustainable building or more accurately sustainable design is where one in the design process evaluates all the aspects of the materials used in the design. This means that one considers the materials that one use in the design from its cradle to its grave. In other words, from the raw materials are extracted out of the ground, through its production into the building material, through its lifetime in the building – considering the costs and impact of MOM (Maintenance, Operation and Management), reuse and ability to be recycled [7].

From these descriptions, one can say that green building is a small part of a sustainable design, but that there are a big difference in their actual meanings. As mentioned before, 

\textsuperscript{5} SINTEF – is an independent, not-for-profit research institute. The head office is located in Trondheim, but have offices around the world. Employs 2100 people.

\textsuperscript{6} NTNU – Norwegian University of Science and Technology
I think that when people talk of green building they actually mean sustainable design. This because from my experience of talking to people in the building industry, it is clear that they do not just talk about environmentally low impact materials – they are thinking more holistic than that. Most people, whether they talk about green building or sustainable design, are in one way or another thinking of Life Cycle Assessment (LCA) of the materials and/or the building/construction.

![Figure 4 - Example of system thinking of sustainable design in a building project, (3)](image)

Figure 4 is available as a full size image in “Appendix part I”. The illustration is an example of how system thinking of a sustainable design in a building design project can be and how the different elements affect each other. This is by no means complete or a blueprint of the elements that affect the design – there are many more elements that are not shown in the system. This is a small overview to show how quickly this system becomes complicated. The idea behind the different colored arrows is that blue arrows have influence on the interconnecting elements in the middle, and the red arrows raises questions that are posted in the red boxes that surrounds the initial interconnection elements. These questions have to be answered before one can say that there is a solution to the sustainable design.
**Life Cycle Assessment**

Life Cycle Assessment or LCA is a systematic analysis of a product or a material. You can conduct an LCA on a more complex structure than a single product, but then one combine all materials or single products that is incorporated into the complex structure. A complete LCA is an extensive analysis from cradle to grave of all components in the object you analyze, that includes energy used for production, energy used through usage of the object and energy used to recycle or discard of the object. Every process or product has different stages in its life. Each stage consists of many activities. For an industrial product, these stages can be defined as material acquisition, production, use and maintenance, and end of life. For a building or a construction however, the picture is a little different. Here the stages are defined as materials manufacturing, construction, use and maintenance, and end of life [13].

The manufacturing stage includes the extraction of raw materials from the earth, transportation of the materials and manufacturing of the building materials, packaging and distribution of the building materials. In the construction stage, the activities relating to the actual construction is included. This include transportation of materials and products to the work site, energy usage for construction of the building including the use of power tools and heating of the building through the construction, on-site fabrication and permanent impacts to the building site. The stage regarding the operation of the building is called “use and maintenance”. It includes energy consumption, water usage and generation of environmental waste. Repairs and replacement of building elements and systems, and transportation and equipment used to conduct repairs and replacements are included in this stage. The “end of life” stage includes energy consumption and waste produced from the demolition and disposal of the materials to landfills. The transport of the waste is also included in this stage. Recycling and reuse of materials from the building can also be included in this stage, depending on the availability of data [13]. On the next page is an illustration, figure 5, that shows what I have explained schematically.
Different types of LCA

There are three different types of LCA; stand-alone LCA, LCA of the accounting type and LCA of the change-oriented type. Stand-alone LCA is used to describe a single product, often in an exploratory way in order to get acquainted with some important environmental characteristics of that product. It is often used to identify the “hot spots” in the life cycle, i.e. which activities cause the greatest environmental impact. A survey of LCA practice in industry has shown that this type of LCA is probably the most common type of LCA. A stand-alone LCA may also be the first, rough LCA, conducted before any more detailed studies are decided upon [9]. LCA studies of the accounting type are comparative and retrospective. This type of LCA is well suited for different types of eco-labelling and can be used in purchasing or procurement situations since these applications involve comparison of existing products. Environmental product declarations are a special type of environmental product information that builds on a highly specified LCA accounting methodology. Presently, eco-labelling schemes have been developed in many different contexts, by governmental bodies, environmental NGOs as well as by industry. Moreover, this is a type of application where the producers of LCA information are not identical to the users of the information [9]. LCA studies of the change-oriented type are comparative and prospective. This makes this type useful in product development, building design and process choices since decisions involves comparisons of options that may be implemented or produced in the future. This type of LCA can also be used for deciding on waste management options and recycling schemes [9]. This means that for conducting a LCA on a building or a construction, a LCA of the change-oriented type is the one that is best method.
When one have decided upon the system and goal for the LCA, one have to make a
decision what the functional unit is going to be. The functional unit is a unit that describes
how one can compare the results with other results. This unit has to be decided upon
whether you are conducting a LCA on different types of paint or on a building. If the paint
is going to cover a facade, the functional unit can be *the amount of paint it takes to cover
100m²*. However, different types of paint have different life spans, so the more accurate
functional unit would be *the amount of paint it takes to cover 100m² for 50 years*. For
buildings it is not so easy to define a functional unit, but an example of a functional unit
when comparing two building design options could be *provision of a school building that
operates for 50 years* [8] [13]. One more option could be to recalculate all environmental
impacts to CO2-equivalents and have the functional unit as CO2-equivalents/m²/year
lifespan.

**Environmental Product Declaration**

An Environmental Product Declaration, or EPD, is a document that declares the
environmental impact of a product, a component or a service in a standardized, objective
way. To be able to produce an EPD for e.g. a building material, one have to conduct a
 cradle to grave LCA of that material. An objective third party verifies the documentation.
The Confederation of Norwegian Enterprise (NHO) and the Federation of Norwegian
Building Industries (BNL) founded the Norwegian EPD Foundation, EDP-Norge, in 2002.
The reason for its establishment was an expressed desire for standardized and
internationally valid Environmental Product Declarations for products and services [14].

Figure 6 is parts of an EPD for I, H, U, L, T and wide flats hot-rolled sections [15], it shows
the greenhouse gas emissions in kg CO2-equiviliants per kg of steel, energy use in MJ per
kg steel and the degree of recycling.
BIM - Building Information Model – Modeling and Management

As the headline implicates there are three interpretations of the abbreviation BIM – Building information Modeling, Building Information Model and Building Information Management. When we talk about BIM, we talk for the most part about Building Information Modeling. This is apparent when you read literature or talk with people that work with BIM, because when people talk about the actual model they often refers to it as the BIM-model. This is not a correct grammatical term, because when you do not abbreviate it would be the Building Information Model – model. Nonetheless, it has become a common to call it a BIM-model. It referees to the digital model created by a software in a BIM-based process [7], the work done creating the model is what is called Building Information Modeling. BIM is more than just software, and Krygiel and Nies [7] define BIM as: “the creation and use of coordinated, consistent, computable information about a building project in design-parametric information used for design decision making, production of high-quality construction documents, prediction of building performance, cost estimating, and construction planning”.

As Krygiel and Nies say BIM is much more than just an application, it is a process for handling information through the lifespan of a project. Natalia Marszalek refers to BIM in her MSc thesis “Building Information Model (BIM) and Mechanical Joints in Timber Structures” [16] from 2010 at the Norwegian University of Life Sciences (NMBU), as collective term for a complete model put together of several different discipline models.
Each discipline has its own model, created from a BIM-software suitable for the individual discipline, with all the information needed for that discipline.

The parts of the quote above from Kryigel and Nies that refers to construction documents, cost estimating, construction planning is what is called Building Information Management. The management part of BIM can also be used for MOM\textsuperscript{7} work.

In the BIM-world there is often talk about five dimensions (5D), this reflects that a model is more than just 3D modeling. The 3D part of this is the model in 3D, the fourth dimension, 4D, is the time schedule of the production phase and the fifth dimension is the cost of the construction – or calculation of cost. Sometimes, you also hear some people talk of the 0.dimension, which is the material take off from the model. The material take off can be used for calculation of cost. The costing can be done directly in the BIM software, or you can export the take off to costing software or a spreadsheet and do the costing there.

\textbf{Figure 7 - The trinity of BIM as Building information - Model - Modeling - Management\textsuperscript{[17]}}

\textsuperscript{7} MOM is an abbreviation for Maintenance, Operation and Management. FDV in Norwegian (Forvaltning, Drift og Vedlikehold).
Figure 7, on previous page, is a demonstration of how intricate the BIM-world is and how the model, modeling and management influences each other and how they support each other. When modeling, you have to consider how the model is going to be shown and how it is going to be used. If it for example is decided that the costing of the building is going to be done by material take off from the model, you have to consider it while modeling. Because you have to be accurate so that the materials and building elements that you use while modeling is the actual materials and elements that is going to be used, if not you are not able to do an exact costing job. The exactness of your modeling job also have a direct impact on how well suited the model is for MOM through the lifespan of the building.

To make sure that different disciplines’ models can work together with each other, buildingSMART® has created openBIM. OpenBIM lets the different disciplines exchange 3D-models with all the essential information, unambiguous descriptions of the building elements and support processes that assure the quality of projects. OpenBIM can be devided into 3 elements: IFC, IFD and IDM.

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buildingSMART is the worldwide authority driving transformation of the built environment through creation & adoption of open, international standards. [47]
**IFC - Industry Foundation Classes**

IFC is part of an open standard developed by buildingSMART. IFC can be described as a language, and the idea is that if all the different discipline models are converted into IFC-files, then all the different models communicate through the same language and can therefore be put together to one complete model of the project, containing every discipline of the project. In addition to be a language making it possible to communicate between different softwares, it also an international language making it possible to communicate between participants of a project worldwide. The IFC format is based on ISO16739 [18].

*Figure 8 - Illustration of IFC, how to make different software and computers interact [19]*
IFD – International Framework for Data Dictionaries

IFD is the basis for a joint terminology when using openBIM, to make sure that all models are interpreted correctly by the operators and retailers. IFD automates and streamlines processes like product search, product specification, merchandising and MOM documentation. Each country’s data dictionary is defined so that openBIM information is automatically translated from country to country without loss of data or errors [18]. Under is a figure that shows the intricacy of information in one element, and from that one can understand the need for a joint terminology to avoid misunderstandings and in the worst-case scenario getting a building that is not built with the materials and quality that the owner expects.

Figure 9 - Illustration of IFD [20]
**IDM – Information Delivery Manual**

IDM is a standardized process and delivery specification that describes actors, procedures and demands to deliveries in projects [18]. Tobin Rist writes in his MSc Thesis “A path to BIM-based LCA for whole-buildings” [21] that “the central purpose of an IDM is to understand the business requirements for information exchange and/or sharing and developing an object model and software implementations that can be used by practitioners within the industry to satisfy those requirements”. This means that when one is starting a project one have to set up an IDM to clarify when information or data is going to be delivered from one part of the project to the next part, or the project administrator. The IDM also have to specify what has to be included in the information, what kind of data and what kind of file-format is the data or information going to be delivered on. IDMs made by buildingSMART or their partners must fulfill the demands for IDMs in ISO 29481 [21]. The illustration under shows how important it is to have an IDM for the project. There are a lot of information that goes into the model, and to make the work flow better you need guidelines on how to exchanges information.

![Image of IDM](image)

*Figure 10 - Illustration of IDM, making the disciplines work efficient together [20]*
In Figure 11 on the left, you see a triangle with a building project in the middle, each side of the triangle you have properties attached to it. Starting on the left and going clockwise you have Terminology (terminology), Process (prosess) and File-format (digital lagring – filformat). On the right hand side of the figure, you have the same triangle, but IFD, IDM and IFC are now placed in accordance with the left hand side to show how these topics are connected.
Theory, Pedagogics

In order to be able to make a plan for teaching a curriculum, it is important to understand and be able to implement learning methods. To be able to understand the way these methods work, one have to have an understanding of the background for learning theory, didactics and learning framework. The following chapters will go through the theory behind these topics.

The figure below show my train of thought of what parts influence each other when it comes to teaching an engineering course. Before I started work on this thesis I had taken a course called “basiskurs i universitetspedagogikk”, which is a basic course in pedagogics for the employees at UiA. The model below was made from my knowledge of didactics and pedagogy before I started my literature study for this thesis. At the end of this chapter, you will find the same model as below, only it has evolved a lot as a result of my study of pedagogics and especially didactics.

![Diagram](image-url)  
*Figure 12 - Schematic overview of what influences the teaching of an engineering course. [3]*

Figure 12 is available as a full sized image in “Appendix part I”.
Learning theory

The reason for bringing learning theories into this paper is that most of the teaching in engineering education is based on “best practice”. It is necessarily nothing wrong with that, but it is an advantage to have a basic level of understanding of learning theories when teaching. The learning theory is a good basis for both the teacher and the students. For the teacher when planning his or hers way of teaching, and as support for the student to understand the reasoning behind the way a course is being taught.

There are four main theories when it comes to pedagogics:

1. Behaviorism
2. Cognitivism
3. Constructivism
4. Socio-cultural theory

These theories follow a timeline, where Behaviorism were the dominant theory in the early 1900s, Socio-cultural view on learning is the most popular today [23].

Behaviorism

Behaviorism is a worldview that assumes a learner is essentially passive, responding to environmental stimuli. The learner starts off as a clean slate and behavior is shaped through positive or negative reinforcement. Both positive and negative reinforcement increase the probability that the antecedent behavior will happen again. In contrast, punishment decreases the likelihood that the antecedent behavior will happen again. Positive indicates the application of stimulus; Negative indicates the withholding of a stimulus. Learning is therefore defined as a change in behavior in the learner. Lots of behaviorist work was done with animals and generalized to humans [24].

Cognitivism

Cognitivism replaced behaviorism in the 1960s as the dominant paradigm. Cognitivism focuses on the inner mental activities – opening the "black box" of the human mind is valuable and necessary for understanding how people learn. Mental processes such as thinking, memory, knowing, and problem-solving need to be explored. Knowledge can be
seen as schema or symbolic mental constructions. Learning is defined as change in a learner’s schemata [24].

**Constructivism**

A reaction to didactic approaches such as behaviorism and programmed instruction, constructivism states that learning is an active, contextualized process of constructing knowledge rather than acquiring it. Knowledge is constructed based on personal experiences and hypotheses of the environment. Learners continuously test the hypotheses through social negotiation. Each person has a different interpretation and construction of knowledge process. The learner is not a blank slate but brings past experiences and cultural factors to a situation [24].

**Socio-cultural theory**

The main thought in the socio-cultural theory is that an individual ability to learn and gain knowledge must be viewed in context with culture, language and the community that surrounds the every individual. One learns all the time, where ever one are and learning is grounded in the social aspect. By this, one means that everybody knows something and distributing this knowledge is a social act. Learning is something that happens when one is part of a larger group/community, and language is essential in every learning process [23].

As an example one can look at an apprentice training to become a carpenter. The way the apprentice learns is to work alongside the other carpenters (the “community”), being guided through tasks that at start might seem hard, but the apprentice is guided through by explanations (talked through – “language”) and visibly being shown what to do. You cannot learn a trade like carpentry if you are not in the community that works with carpentry and being guided though tasks. The teachers in this scenario are the trained craftsmen that do the guiding.
The didactic relationship model

The reason for bringing the didactic relationship model and later on the further developed model by Mariis, into this thesis is to be able to understand how every choice affects the course and the teaching. Every choice made when planning a course, when developing a curriculum, when teaching the students, when setting goals for what you want to achieve, and how you evaluate the students and the course is interacting on each other.

The didactic relationship model by Hiim and Hippe [25] explains how the mentor/teacher can plan his or hers curricula to create flow between the aspects of mentoring/teaching. The didactic relationship model is derives from the didactic relation model [26] by Bjørndal and Lieberg. Bjørndal and Liebergs’ model is centered more around the teacher than Hiim and Hippes’ model. Their model were developed to show the importance of relations between different elements in didactics using a learning theoretical approach. It is important to be aware of the fact that if you implement a change in one element, it will affect the other elements. Every element is linked together and this is what the lines between the elements represent. The following paragraphs explains each element in the model.
Learning conditions: is whatever mental, physical, social and academic challenges or opportunities a student have in regards to the teaching of the course. By this, one means that you as a teacher should find out what qualities the students have, instead of assuming that they fulfill the requirements expected for taking the course. This is especially important if you are planning to differentiate the teaching [27].

Setting: is factors that can promote or hinder teaching and learning in many ways. Settings can be both formal and informal. Formal settings can be rules and announcements that affects the way the students have to work. Whereas informal settings are the ways each teacher interprets methods, the teachers own boundaries and traditions. The most important is for the teacher to be aware that you yourself is a setting for the course [27].

Goals: the goals of the course says something about the intent of the course. When you define the goals, it is important to make the goals in a way that they can be reached. If possible, you should let the students have influence in how to reach the goals. This makes the students more responsible for how the shall achieve these goals [27].

Content: is the curriculum. This is what course is about and what element that are a part of the course. There is a strong connection between the content and the goal of the teaching. If not, the teaching will not work properly and this can lead to unsatisfied students [27].

Learning process: is how the learning is intended to be. In other words, the learning process is the reasoning behind the choice of teaching methods and who that can influence on the methods. Is it only the teacher that can make decisions? Alternatively, should the learning process reflect reality, in the way that we live in a democratic society and as a result, of this, the students should have influence on the learning process? [27]

Assessment: of the teaching. The most common is to evaluate the course success from the results that the students achieve, in other words evaluate the success of the teaching from what grades the students achieve [27].
However, if one uses the didactic relationship model as assessment model, it will become a little more complicated to assess the teaching. Because one have to assess every aspect of the model. One have to assess according to the didactic decisions that is behind the teaching, and figure out what worked and what did not work. As mention before, every element of the model is linked, so that if you make a change in one of the elements it influences other elements in the model. According to the didactic relationship model, we have to be aware that the relations between the elements can be different from course to course and teacher to teacher. Learning conditions are not always the same from course to course; the same can be the case with settings, goals, contents, learning process and assessment [27].

Mariis didactic relationship model with regards to ICT

A Connective Model for ICT-remediated Didactic Design

Figure 14 - The Connective Model for ICT-remediated Didactic Design [25]
This is Mariis version of Hiim and Hippes’ didactic relationship model. Mariis develops several models, that all build on each other. The main differences from Hiim and Hippe to Mariis’ models is that there are more elements that influences on each other, this because Mariis means that the original didactics relationship model is too generic. And also because Mariis’ further development of Hiim and Hippes’ original model is aimed at Problem Based Learning. In the model above, figure 14, Mariis prefers to call the lines between the elements for connections opposed to Hiim and Hippe that calls it relations. This is because he means that relations indicates that all relations affects each other, while by calling it connections you say that the elements are connected, but do not necessarily have equal impact on each element. This model is more detailed then the generic model of Hiim and Hippe, and is developed through Mariis’ work PhD-project on Blended Learning within Higher and Further Education [25]. As he points out the adding of elements and renaming of some others to have them fit better into teaching with ICT might already be included in Hiim and Hippes’ model, but by including them in the model it makes it clearer what their purpose is. What parts of the teaching each element refers to is explained in the paragraphs under:

**ICT** has the potential of changing the didactic design in a course and has therefore become an element of its own. You can argued that it is part of the setting element of the original model, but as it can influence how to plan and perform the teaching of a course, it has become an element in Mariis’ model.

The two elements **Teacher(s)** and **Learner(s)** are added to the model compared to the model of Hiim and Hippe, this is because Mariis means that teachers have a larger impact on the didactic design of a course than is shown in the original model where teachers is a part of the setting element. In the original model learners i.e. students are included in the whole model as it is describes the learning process. By adding learner(s) and teacher(s) you visualize that they are very influential in the model, because it is important to consider their prerequisites in general to the course that is being taught or planned. Equally important when using ICT-tools in a course is the prerequisites of the teachers and students of these ICT-tools.
Mariis defines **Goals** in Problem Based approach to teaching a way for all participants i.e. teachers and students to share the responsibility of fulfilling the curriculum of the course as long as the theoretical foundation is considered in the planning of the course.

**Content** is based on each course curriculum and goals, but through a Problem Based approach to teaching and planning this can be based more on collective decisions between the participants of the course.

Teaching and learning is always set in a **Context**, in Didactic Design this is typically physical buildings and formal settings. However, it is not restricted to these settings, in a Problem Based approach to teaching with ICT-tools the teaching and learning can be more fluid than this. Students can work and communicate through the internet and the teacher can be available to mentor the students in the same way, by using discussion forum in the learning platform available at the teaching institution. By using discussion forums, the teacher can mentor one or all the students at once. Students should use the forum actively to search for possible solutions to a question or problem in existing discussions. They should also participate actively to help the other students. This approach can lift the learning outcome of all the participants of the course. It is important to have a moderator of the forum, this role is the teachers’ responsibility.

**Activities** is an element that is important because it shapes the teaching and learning processes and possibly the outcome. This element can be tightly knitted to the context element, an example of this is the discussion forum mentioned above.

In Hiim and Hippes’ model, the **Evaluation** element is called assessment. Mariis thinks that assessment relates too much to the assessment of the students only, whereas in this model evaluation should involve a critical review of the teacher and the teaching of the course. Therefore has this element change name from assessment to evaluation in his model. This to ensure an evaluation of the quality of the whole course and the students achievements.

**Time**, this is a very important element. Learning takes time, and often students has to “mature” in the subjects in which they are participating. The more time they have to work with the subject, the better the chance is for the student to develop a deep understanding
of the subject. However, time is a very important factor for the teacher also. The teacher must have time to learn and master the ICT-tools used in the course, and have enough time set aside to be able to mentor the students and moderate the discussion forums [25].
Technological Pedagogical Content Knowledge, TPACK

There are several different frameworks with different perspectives for teaching, some have the perspective of the teacher and some have the perspective of the learner. The reason for choosing TPCAK as the framework for teaching in this thesis is that it has the perspective of the teacher. TPAC is designed to support how one is organizing the teaching. On the web page www.tpack.org there is a description of the framework, the description is as follows: “Technological Pedagogical Content Knowledge (TPACK) attempts to identify the nature of knowledge required by teachers for technology integration in their teaching, while addressing the complex, multifaceted and situated nature of teacher knowledge. The TPACK framework extends Shulman’s idea of Pedagogical Content Knowledge” [28].

![Figure 15 - The TPACK framework](image)

TPACK is a pedagogical framework for the teacher to understand how he or she can utilize the skills and knowledge he or she has when it comes to pedagogy, the content of the course and the technology incorporated in the course. What this framework does is that it looks at the intersections between pedagogy, content and technology and define these intersections as new kinds of knowledge. The Pedagogical Content Knowledge (PCK) is the...
intersection between pedagogical knowledge and content knowledge, and what it describes is the knowledge of pedagogy that uses when teaching a specific content. When combining technology and content, we end up with Technology Content Knowledge (TCK). Which is the reflection of how technology and content affects each other. Technological Pedagogical Knowledge (TPK) is the intersection of pedagogical and technological knowledge. What it represents is the influence the components and capabilities of technology, and the existence of technology, have on how we teach and learn a subject. The combination of PCK, TCK and TPK, i.e. the intersection of these in figure 15 is defined as Technological Pedagogical Content Knowledge or TPACK [29] [28]. The reason for using this framework for the teachers perspective on how to implement his or hers technological, pedagogical and content knowledge, this is very interesting for teaching in the field of engineering, because when you are teaching engineering you usually have to combine several knowledges and skills in most of the courses. An example of this is the concrete design course. The teacher of that course have to teach the students how to approach the problem, how to do the calculations, how to interpret the national standards, how to write a report, how to present drawings of the solution and how to present it orally to a potential customer.
21st century skills and tools

Learning and education in a day-to-day living has changes radically over the last few decades, and it is a reflection of how the world and everyday living has changed so fundamentally in the same time-period. However, the skills needed decades ago is still very much needed in today’s society. The skills of critical thinking and problem solving might even be more needed today, but how we teach and learn the students these skills has changed a lot with time and it is changing continuously. In addition to how we learn and practice these skills today, there are many new skills that the students today have to master – such as the knowledge or skill to master digital media. The skills often referred to as 21st century skills are; basic Information and Communication (ICT) skills (use of computers, internet – search for information, media etc), Learning and innovation skills (oral and written communication, critical thinking and problem solving, collaboration and teamwork, and creativity) and Life and Career skills (professionalism and work ethics, applying technology, leadership and project management).

Most of what we think of today as necessary tools for everyday life were unthinkable a few decades ago [30]. The idea of personal computers, smartphones, tablets etc. were like science fiction back then. To illustrate this, here is a couple of quotes about computers and the future:

“I think there is a world market for maybe five computers”

Thomas Watson, the president of IBM said this in 1943 [31]. Even better at illustrating this is what Ken Olsen, the founder of Digital Equipment Corporation said back in 1977 [31]:

“There is no reason anybody would want a computer in their home”

These quotes might seem ridiculous today, but it show how hard it is to predict how the future is going to be and how our everyday life is going to change because of that. To show how we can use the computers to our advantage in teaching, I would like to present two more quotes from two of the brilliant minds of the last few years:

“Computers themselves, and software yet to be developed, will revolutionize the way we learn.”
Steve Jobs said this [32], Bill Gates has said the following [32]:

* I think it’s fair to say that personal computers have become the most empowering tool we’ve ever created. They’re tools of creativity, and they can be shaped by their users.*

According to Trilling and Fadel [30] a study conducted in the US a few years back, showed that hiring executives of major corporations meant that students graduating from technical colleges was lacking both basic skills and applied skills such as:

- Oral and written communications
- Critical thinking and problem solving
- Professionalism and work ethic
- Teamwork and collaboration
- Working in diverse teams
- Applying technology
- Leadership and project management

Even though this study was conducted in the US, there are good indications the shows that this is the case for students in Norway also. All the topics that are listed above are what we can call 21st Century skills.

The Civil Engineering education at UiA have put together what we call a reference group. This group has members from different municipalities, contractors, engineering offices and education. The aim of the group is to make sure that we as a university are training students so that they have the basic skills needed in “real life”. Most of the findings in the study from the US, is what this reference group says is the important skills that we can learn the students.

To be able to train the students in the skills needed for their future professional careers, we have to implement and integrate 21st century skills and tools in our teaching, at a greater extent then what we do today. It is important for students to learn and master these skills and tools before they are to enter into the workforce. In other words, the
schools system (from elementary school through university), have to prepare the students by training them in using the skills and tools in their education.

Figure 16 - P21 Framework for 21st Century Learning [33]

Figure 16 shows a schematic overview of the P21 Framework for 21st Century Learning, which introduce the 4 C’s of education – Critical thinking, Communication, Collaboration and Creativity. Comparing the 4 C’s, Life and Career Skills and Information, Media and Technology Skills with the outcome of the study that Trilling and Fadel [30] refers to, one can see that they coincide very well with each other. Therefore, it is important to include these skills in education, so that the students learn skills that are needed in their professional life after school. One person that advocates this point is Sir Ken Robinson. Sir Robinson has an extensive carrier in the field of education. He was the professor of education at the University of Warwick for twelve years. He has lead a national commission with focus on creativity, education and the economy for the UK Government. The report from the commission “All Our Futures: Creativity, Culture and Education” also known as “The Robinson Report” was publish in 1999, and received wide acclaim [34]. Sir
Robinson is the most viewed speaker in TED\(^9\) history, it is estimated that more than 250 million people has seen his videos from February 2006 – “Do schools kill creativity?” [35] and February 2010 – “Bring on the learning revolution!” [36], another video of his that is worth have a look at is the animated video “Changing Education Paradigms” [37]. What Sir Robinson advocates is that the education system that we are used to are focused on treating the students as a homogenous mass, instead individuals. Which again leads to less creativity in the schools and you get students that “follows what they are told”, instead of students that challenges “the truth” by being creative thinkers. He claims that we have to change this way of teaching and start teaching the individual student. By considering the individual student one can inspire them, promote problem solving and critical thinking in the student, and as a teacher one can adapt the mentoring and teaching to each students skill and knowledge level [35] [36] [37]. If you are to change the way of learning students, I think that you have to change the way you are teaching the individual course. I do not think it is possible to consider the individual student by being a teacher in the traditionally way, i.e. standing in front of the class and lecture them in a topic. I mean that if you are to learn the students in 21\(^{\text{st}}\) century skill and tool you have to include Problem Based Learning and Flipped Classroom in your teaching.

\(^9\) TED is a nonprofit organization devoted to spreading ideas, usually in the form of short, powerful talks. TED began in 1984 as a conference where Technology, Entertainment and Design converged, and today covers almost all topics – from science to business to global issues – in more than 100 languages. [48]
**Problem Based Learning**

Problem Based Learning (PBL) is a method where the goal is to get students to study and learn the topics of the course through solving problems, i.e. the method is problem oriented. The method challenges the students at their “home turf”. In the beginning of the course, the students will be introduced to one or more problems based in the curriculum. They then choose a problem to focus on, that they have to answer based on what the learning outcomes are described as in the course description. After they are presented the problem, they have to identify what kind of theory and skills they need to master to be able to solve it. The curriculum of the course is one source of theory, but they have to actively search for more material through libraries, internet etc. to be able to solve the problem. The role of the teacher is different from “ordinary” teaching. Instead of being the center of attention as the lecturer in front of the class giving a presentation of the subject at matter, the teacher is now a mentor for the students. Helping the students solve the given problem by guiding them through the curriculum and their findings from other sources. An essential part of PBL is that the students work in groups or teams to solve the problem at hand. The problem that they are to solve has to be true to real-life, in other words it should reflect a problem that they could meet as a professional engineer. Another important part of PBL is that problem solving demands students to be creative, and that there is no single answer to the problem or problems. The creative process and the learning that comes from this process is just as important as the answer to the problem. PBL is about the whole problem solving process and getting the students to learn through creative thinking and teamwork. When the students work in teams, it is easier for the teacher to adjust the problem at hand to the level of each student group and student. For “weaker” students this can give them a sense of empowerment in the subject, and “stronger” students still feels challenged in the subject. When evaluating the students in the course, it is important to evaluate the whole team and the individuals. You have to evaluate the knowledge and competence that the group has achieved through the work and you have to evaluate the understanding of problem solving. Through the course, the groups have to get feedback on their work and the problem from you as a mentor, but you should also allow for class discussions. This could be done by having the groups present what they have at a given time. After every
presentation, there could be a class discussion on the problem at hand and you can have the other students perform a written peer-review on the presentation and the work of the presenting group. By doing so the student groups get other feedback than just from the teacher and they might consider other aspects of the problem, then what they think the teacher wants [23] [38] [39] [40].

Underneath is a basic sketch (in Norwegian) on how PBL works. You start with getting a problem presented, then you identify what you need to gain of knowledge and skills to be able to solve the problem, then you gain the knowledge and skills and you use it to solve the problem at hand. When you are at the point of trying to solve the problem, you might realize that you to extend the knowledge and skills that you have gained to be able to fully solve the problem. Alternatively, you might need additional skills or gain more knowledge to solve the problem. Because of this realization, you might have to repeat the circle several times before solving the problem.

Figure 17 - Basic PBL sketch [23]
Flipped classroom

In order to make PBL work, it is important that the time you have available with the students in the classroom is used for mentoring and discussions with the student groups. To be able to allocate time for that, one has to change how the students receive lectures and information from the teacher. Flipped classroom is one tool one can use to allocate time in the classroom. To make flipped classroom an efficient tool, the students and the teacher have to change their approach to how they normally would work with a course. The students have to spend some of the time they normally would have used outside of the classroom to work on assignments in the course, to gain knowledge of the curriculum. The teacher can make the curriculum available in different ways. Short video lectures is one tool to help them gain the knowledge, another tool is a specified reading plan of the curriculum where it is made clear what it is expected of the students to have read at any moment through the course. The teacher also have to be aware of his or her role in the classroom. You are no longer supposed to be the focal point in the classroom. Your role as a teacher is now the one of mentor guiding the students through the curriculum and leading discussions on topics that the students are working on. It is getting more and more common to use flipped classroom as a teaching method in courses where the students have to work in laboratories. In these scenarios, the students have prepared for the laboratory practice through the “flipped material” and they use the time allocated for being in the laboratory to actually working on the problem at hand [41].

After studying both PBL and flipped classroom, it is quite obvious to me that these two methods of teaching can supplement each other to become a strong tool for teaching. They have many similarities, such as the need to make time for group work and discussion in the classroom and changing the teacher’s role from the lecturer in front of the class to the mentor that guides the students through the problems at hand. Other similarities are the need for the students to develop skills such as critical thinking (looking at a problem in a new way), collaboration (working in teams), communication (group discussions etc) and creativity (for problem solving). These four keywords are called the 4 C’s of education, and they are key elements in 21st century learning as shown in figure 16.
The model above is a development of figure 12 from page 39, which shown my initial thoughts of how curriculum, didactics and evaluation were connected and how they interconnected and how that would lead to the evolution of a course. In “Appendix part I” figure 18 is available in full size. In the model above one can see how I trough my literature study have gained better understanding of the intricacy of teaching. This model will be further discussed in the discussion chapter in the Result and Analysis part of this thesis. But if one look closer at the model above one can understand that if one choose to use Mariis didactic relationship model for ICT as a didactic background for teaching the course, that will influence how one mentor, interact and evaluate the students in the course. And it also influences the way one evaluate the course itself. The framework, TPACK that considers the knowledge and skills the teacher have affects how one teach the sustainability part and how one use the skills and tools of the 21st century in the course. The students background when it comes to their knowledge of 21st century skills and tools again affects the use of video lectures for the development of software skills. By using video lectures one have taken a long step towards a course based on flipped classroom, which again makes it easier to implement Problem Based Learning as a basis.
for the course. Problem Based Learning and the didactic relationship model have influences on how one evaluate the students, and this again have an effect on the evaluation of the course. The course and student evaluation will then influence changes for the next time the course is being taught.
Result and Analysis

This report is a possibility study, which means that it is that this part of the report is based on the theory study from theory chapter. Which means that the chapter result and Analysis will be a deductive discussion on the findings in the literature study. There are no empiric data to analyze, because these data will not be available until the course have been taught in the fall of 2016. The earliest one can do an inductive analysis of this report is the spring of 2017.

Discussion

I have chosen to divide this part of the report into one chapter called discussion, and then I have divided that chapter into smaller chapters or segments and the discussion will take place in these chapters.

How technical drawing has been taught until 2013.

As a lead in to the discussion on the problem of this thesis – “Main principles for dynamic influences between Sustainability, BIM and Didactics in an engineering course”, I will start by explaining how the teaching of technical drawing in our education has evolved over the last ten years. I will not go into detail about the course configurations - technical drawing has been combined with different subject in the civil engineering education over the years. This part of the report is to show how the teaching and evaluation of the part of the curriculum linked to technical drawing.

In 2005, I was studying civil engineering at HiA\(^{10}\) and had technical drawing as part of a course in my education. Back then, there were only focus on 2D-drawing. The lectures were given by the lecturer in an auditorium, what he was doing was projected on a screen and we had to take notes on what to do. After the 2-hour lecture, we were expected to duplicate the lecture on the computers in the computer laboratory. The teacher was present in the computer laboratory so that we could ask for help. This way of teaching was very passive and only the students that found drawing interesting were the ones that

\(^{10}\) HiA – Høgskolen i Agder, or Agder University College in English, established in 1994. In 2007 HiA became University of Agder, UiA [53].
learned anything. The evaluation of the drawing part of the course was that our hand-ins were evaluated as a pass or a fail. If we failed, we could do the hand-in again and correct the mistakes according to the feedback from the teacher. In January 2008, I was hired as a senior engineer at the civil engineering laboratory at UiA, and one of my first tasks was to be the teacher’s assistant in the drawing course. By this time, the drawing course had become a course on its own, and BIM was included in the course. The BIM-part of the course were focused on the use of the software. The teaching of the course moved from the auditorium to the computer laboratory. This was made possible by the fact that the computer laboratory was doubled in size and at the same time, there was made room for the teacher to do teaching in the room. The teaching however did not change, it was still done in the same way. The teacher held a 2-hour lecture on how to do the different things, and the students were expected to pay attention and then repeat what the teacher had done in the rehearsals that followed the lectures. This did not work that well, because as the teaching took place in a computer laboratory and the students tried to work while the teacher were teaching. As the students tried to work while they were being taught, they lost track of what the teacher did and this meant that the rehearsals were spent trying to learn the students what they had just been taught. The teaching was done in this way because this was how the teacher always had taught the class and he were determined to continue teaching this way. The evaluation of the students was based on their hand-ins and the grading was done as a pass or fail of the course.

There were no change in how the course was taught until I took over the responsibility of the teaching in the fall of 2011. By now, the school had moved to our current location at Campus Grimstad. At the new campus, we have a computer laboratory that is very well suited for teaching and rehearsals. As a result of this I could change the way of teaching, so that I were showing the students a feature in the software, then made a pause in the teaching were the students could learn the feature. Then I showed something else, and the students work again. This resulted in a more dynamic learning experience for the students and for me as a teacher it was much easier to make sure that all the students were at the same level in the course. The course was still graded as a pass or fail of the course.
In 2011 engineering schools nationwide could chose if they wanted to start teaching according to UHR’s new national guidelines for engineering education [4], or if they wanted to wait until they had to in 2012. The engineering program at UiA started following the national guidelines from 2011, this meant that from the fall of 2012 the drawing course no longer was a course on its own. The course, which is the same course as this thesis is based upon, included surveying as the other subject of the course. The drawing part of this course had to be repeated three times of week because of many students and the fact that the computer laboratory only have 34 computers available to the students. In addition to teaching 2D-drawing with AutoCAD and the use of BIM software, the students also received a few lectures based on the theory behind BIM. The course was now graded based on an individual written exam. The exam was a digital multiple-choice exam, where the students had to answer questions regarding surveying and the theory behind BIM. The students was now graded on a scale from F – A, the grading was done according to UHRs guidelines.

**BYG211 Computer Based Modelling and Surveying in 2015**

The course that forms the background for this thesis is “BYG211 Computer Based Modelling and Surveying”. This is course is taught in the 4th semester (the second year) of the Civil Engineering Program. In 2014 there were made some changes to the curriculum and the name of the course was changed to what it is today. One of the changes were the inclusion of use of a structural analysis software, as a result the course is divided into four different elements. The elements are surveying (theoretical lectures and practical rehearsals), Structural analysis software – SAP2000 (use of software), AutoCAD (use of software) and BIM (use of software and a few theoretical lectures). Other changes were made to how I was teaching AutoCAD and BIM. The changes was possible because UiA had gotten rights to use lectures from Lynda.com, and there are many excellent video-courses on the use of AutoCAD and Revit. Revit is our BIM software. Almost every student today has his or her own laptop, and I realized that there were no point in me repeating lectures three or more times a week, when the students could watch video lectures online on how to use the software on their own computers. This also made it possible for me to use classrooms that did not have computers in my teaching. A result of this was that I reserved enough rooms to cover the amount of students in the course for four
consecutive hours once a week. The two first hours was earmarked for the students to watch the video lectures, and the two hours after that I was available as a rehearsal teacher. The theory lectures that I previous years had held for the students, was now made available through our learning platform\textsuperscript{11} and the students had to read this information on their own. The teaching and grading of the course is done in the same way today.

This subject is also available as an elective course for students that follows the renewable energy education, but they do not have the knowledge of statics. This has resulted in a separate element taught only for them, which is building technology.

\begin{figure}[h!]
\centering
\includegraphics[width=\textwidth]{week_plan.png}
\caption{Week plan BYG211 fall 2015. [3]}
\end{figure}

As one can see from the week plan above, there are 96 hours in the course. These 96 hours are given as a combination of lectures and rehearsals. The teachers teach more than 96 hours in the course, it is the students that have 96 hours of lectures and rehearsals. If you calculate the hours above, you will find that the schedule for the students are more than 96 hours, but every semester we have to have one week without teaching. In the schedule, there is room for two such weeks and I never put those weeks into the schedule, because I want the flexibility to be able to place those weeks according to conferences I

\begin{footnotesize}
\textsuperscript{11} UiA uses Fronter as learning platform. Fronter is where we as teachers presents the curriculum, week plans, tasks, etc. to the students. The students have to be up to date with what is presented on Fronter.
\end{footnotesize}
want to attend. This flexibility in the plan also allows a teacher to be home sick and still be able to maintain the schedule.

**Didactics**

![Diagram](image)

*Figure 20 - Repetition of figure 18 for discussion [3]*

This part of the discussion is based on the box on the upper right side, encircled in green, of figure 20. The original figure is available as a full sized image in “Appendix part I”.

When you are planning a course, you have to consider what methods you are basing your teaching on. There are many different methods and theories one can based the teaching on, but you have to be aware that the choices you make shapes the way you teach. This thesis is about how sustainability, BIM and didactics influences each other when teaching an engineering course as the figure 21 on the next page shows.
All of these three topics are substantial enough to be a master thesis on its own, because of that this thesis cannot dive too deep into each subject. This part of the discussion is important to build a foundation for how I want to teach and build the curriculum.

There are four main theories when it comes to pedagogy, from the early 1900s to about 1960 behaviorism was the leading learning theory. In this theory the learner are look at as a clean slate and behavior is shaped through positive and negative reinforcement. Learning is defined as a change in behavior in the learner. In the 1960s behaviorism was replaced with cognitivism as the main learning theory. Cognitivism focuses on inner mental activities. Mental processes such as thinking, memory, knowing and problem solving need to be explored. Knowledge can be seen as schema or symbolic mental constructions. Learning is defined as change in a learner’s schemata. Constructivism is a reaction to didactic approaches such as behaviorism and programmed instructions. Constructivism claims that learning is an active, contextualized process of constructing knowledge rather than acquiring it. Knowledge is constructed based on personal experiences and hypotheses of the environment. The most popular learning theory today is the Socio-cultural theory, which is based on the thought that an individual ability to learn and gain knowledge must be viewed in context with culture, language and the community that surrounds every individual. Learning is based in the social aspect and one learns all the time. Everybody knows something and distributing this knowledge is a social...
act. Learning is something that happens when one is part of a community, and language is essential in every learning process.

In this course the students are to work in groups and every member of that group brings their own experiences and knowledge into the group. Some of the student have worked as tradesmen before they start to study, some students have work in completely different fields that construction, but brings with them work experience from their field. Both of these groups of students bring with them knowledge of what is expected of a person that works for a company. Then there is the group of students that come to university straight from high school, they have a different type of experience that is equally important in the group process, they know how to study. As a teacher I bring with me experience on how to mentor group projects. Each year I mentor two or three groups through their bachelor projects. I also bring with me experience on being a teacher, after teaching this course and other courses since I started at the university in 2008. Before I started my civil engineering education, I work as a carpenter for ten years. As soon as I was done with my apprenticeship and were fully trained as a tradesman, I had apprentices with my up to the day I quit carpentry. The way I trained the apprentices, the way I mentor bachelor groups and the way I conduct my teaching of my courses is very similar to Socio-cultural learning theory, so it is natural to me to use this theory as a basis for this course.

After deciding on a learning theory to build your teaching on, you should have a didactic framework for how you want to plan, execute and evaluate the course that you are designing. Hiim and Hippe have introduced the didactic relationship model [25], shown below in figure 22.
This is a very popular framework for how to plan, execute and evaluate a course, is show how everything that goes into teaching a course is interconnected and affects each other. What is lacking from this model is that it is not specified when it comes to the integration of 21st century skills and tools in the education. This is where Mariis’ updated version of the didactic relationship model comes into play. Mariis’ model is shown in figure 23.
In this model one can see that ICT, in this case that is the 21st century skills and tools is part of the model. One can also see that Mariis has renamed some of the element in the model and has increased the number of elements from six to nine. This redesigned relationship model is aimed at Problem Based Learning, which is going to be part of this course, so it is natural to choose this model as a framework to build the course round. The learners is the students in the course, and as I described earlier in this chapter, I hope to utilize the fact that the students are an inhomogeneous group. Their background vary a lot. Some students have years of experience as tradesmen before they start at the University, they have a very practical background and are not as trained at being a student as students directly from high school. If I the teacher can utilizes the fact that the students have different background into my teaching by the way I have the students work for example through teamwork, one can achieve that the students learn from each other. The students directly from high school can teach the students with more practical background.
how to study and how to work theoretically. The students with work experience can teach the other students how e.g. the design of a structure works in real life and what the obstacles are for carrying out the design at a work site is. Since this course is based on the use of ICT-tools, one also have to consider the knowledge the students have of working with these tools. Students of today is more used to working on their computers and searching for information through the internet etc., then students were just a few years ago. This is 21st century knowledge they have but not necessarily think of it as skills, as it is just natural for them to use these skills and tools.

Mariis defines goals in Problem Based approach to teaching a way for all participants i.e. teachers and students to share the responsibility of fulfilling the curriculum of the course as long as the theoretical foundation is considered in the planning of the course. The goals for the teaching can be divided into long-term and short-term goals. A curriculum for a course has long-term goals – learning outcome and skills the students are to obtain through the course. The short-term goals are what you as a teacher would like the students to learn in a week, in a lecture etc.

Content is linked to what subject is being taught, ergo linked to the description of the subject and to the goals for engineering education given by The Norwegian Association of Higher Education Institutions (UHR). The curriculum should also take into consideration what future employers wants the students to have knowledge of when they enter the work force, e.g. skills in BIM. Another important subject to incorporate into the curriculum is environmental awareness in the students, e.g. the choices they make as engineers affects the environment and they have to be taught this through their education so that they can go out and be responsible engineers for the future. This is the sustainability part of the course. Content is based on each course curriculum and goals, but through a Problem Based approach to teaching and planning this can be based more on collective decisions between the participants of the course.

Context and activities is tightly knitted together. This course is going to be using flipped classroom and Problem Based Learning as methods for the teaching, where I will have the role of mentor. When one talks of context one mean the physical building and the formal settings for the teaching. In this course the classroom will be used for mentoring and
discussions, which will be the activities of the course. But since it is expected that the students use their computers at other times to watch the video lectures and read the curriculum, and they have to use the internet etc. to find information on the problem that they try to solve, this will also be part of the context of the course. I will try to get the students to use the discussion forum on the learning platform that we use at UiA, and then I will function as mentor and moderator of the discussion.

Time is a very important element in teaching, and in this model. Learning takes time, and as a result of that one can see in chapter “Course plan and content for fall 2016” that I have planned that the BIM and sustainability part of this course will run the entire semester.

The teacher in this model shows that the teacher have a large impact on the didactic design of the course. The teacher have to be aware of when planning, executing and evaluating the course and the students. The teachers’ knowledge of the content, pedagogy and technology affects the didactic design of the course. This is where the TPACK framework come in, the teacher can combine his or her skills in technology, pedagogy and content and form Pedagogical Content Knowledge (PCK), Technology Content Knowledge (TCK) and Technological Pedagogical Knowledge (TPK). By utilizing you knowledge you can reflect on how technology and content affect each other (TCK), you can teach a specific content based in your knowledge of pedagogy (PCK) and you can reflect on how capabilities of technology affect how we teach and learn a subject (TPK). I chose to repeat a section from the chapter on TPACK:

The reason for using this framework for the teachers perspective on how to implement his or hers technological, pedagogical and content knowledge, this is very interesting for teaching in the field of engineering, because when you are teaching engineering you usually have to combine several knowledges and skills in most of the courses. An example of this is the concrete design course. The teacher of that course have to teach the students how to approach the problem, how to do the calculations, how to interpret the national standards, how to write a report, how to present drawings of the solution and how to present it orally to a potential customer.
Evaluation should involve a critical review of the teacher and the teaching of the course. This to ensure an evaluation of the quality of the whole course and the students’ achievements. This course is going to be based on Problem Based Learning where the students have to work in groups. The evaluation of the students will be done on the work that the groups hand in at the end of the semester. The evaluation of the course will be based on the students’ evaluation of the course, the students’ results and the teachers’ experience from teaching the course. Later in this report there will be a chapter that discuss the evaluation of the students and the course.
**Curriculum**

This chapter will revolve around the curriculum of the course. Figure 24 shows how curriculum (upper left side of the figure, encircle in green) is connected with didactics and evaluation of the students and the course. The original figure is available as a full size image in “Appendix part I”.

![Figure 24 - Repetition of figure 18 for discussion [3]](image)

**Sustainability**

The designs that engineers today and in the future design and build affect the environment on many levels. Therefore, they have to consider how they can design constructions that are friendly to both the global and local environment. When e.g. a building is design and built, it affects the local environment by occupying an area that, if not built on, could absorb CO2-emissions and rainwater through the plants and soil in that area. When the building is built, the plants are removed and the soil is covered. Because of this, the local environment has less area to absorb CO2-emissions and rainwater. In a global aspect one pollute when putting in a new construction. This pollution comes from producing building materials, transport, use of energy, and spills of hazardous materials from worksite and more.
To address this while designing the building, one can design the building with “green areas” e.g. walls or rooftops with grass and plants that will absorb CO2-emissions and also will absorb rainwater and delay its run of into the municipality’s drainage system. The usage of the building also has to be taken into consideration when designing it, it might be built as an office building – but is it going to be used as an office building throughout its lifespan? Usually a new building has a long lifespan, and many buildings are torn down long before this lifespan is reached because the originally design is too rigid for what the building owner want to use the building for now. There are several ways to go about this problem, one is to design the building in such a way that building elements can be reused as is, another way is to design the building in such a way that the “innards” can easily be rebuilt without having to redesign the load bearing structure. To achieve this type of design, the engineers working on designing buildings has to have a “sustainability” mindset.

In the spring of 2010 Grønvold, Gulbrandsen and Reiersølmoen [42] wrote their bachelor report on how one could create a more sustainable design of concrete constructions through three steps. The report was named “Tre steg mot økt bærekraft i betongkonstruksjoner” which would translate into “Three steps towards sustainability in concrete structures”. Their research was to design a load bearing structure of an office building, and compare traditional design with a design that is approved through the design codes, but not traditionally used in Norway. The traditional design was B35 concrete and traditional concrete floor, beam and column design. This design was compare with several solutions, but the best result was with 100MPa concrete and bubbledeck. These solutions are well within what is approved in the design codes. The building had a footprint of 1500m² and 4 floors, the total area of the building was 6000m². This is a small building, but still their findings were impressive. The results showed that the load bearing structure in the conventional design would cost NOK 5 787 558, it would have a CO2-emission of 532.2 tons and a lifespan of 52.9 years. By using the untraditional building design and 100MPa concrete the load bearing structure would cost NOK 4 993 661, the CO2-
emissions would be 242.3 tons and the lifespan would be 206+ years\textsuperscript{12}. What this report shows is that by challenging the traditional design one can create a sustainable design of a building. In this case the students ended up with results that showed a reducing of CO2-emissions by more than 50 % and at the same time, had positive results for lifespan and cost.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure25}
\caption{Repetition of figure 4 for discussion [3]}
\end{figure}

There are different approaches to creating a curriculum that teaches the students sustainability. Figure 25 (repeat of figure 4) shows how what I have presented so fare in this chapter affects a new construction and the sustainability of the building. The original figure is available as a full size image in “Appendix part I”. The figure also shows the complexity of sustainable thinking in the design of a new building or construction. There are many more influences, the figure above shows some of them. It is however a great starting point for discussing how to include sustainability in a BIM-course.

One can focus only on the LCA process, or a type of building design that is sustainable. Zero Emission Buildings is one type of design one could focus on, and say that we teach sustainability trough the teaching of ZEB design and thinking. You could focus on green building and say that it is the focus area of the sustainability in this course. I chose to

\textsuperscript{12} The calculation of lifespan was done with Life-365 – 206+ years is the maximum that the software manages to calculate. Life-365 is a software designed to estimate the service life and life-cycle cost of concrete mixtures [54]
incorporate it differently, I want to present all of the above-mentioned factors and use all of them as a way to teach the students that sustainability is a very wide and difficult subject. Sustainability also bring ethics to the table, in the form of the decisions that the engineer have to make on materials, building methods etc. I want the students to be able to be critical about the design they chose, and I want them to be able to argue their choices based in sustainability and ethics.

Zero Emission Building is one of the elements that the students have to learn about, but they also have to learn that there are different ways to think of sustainability. ZEB is divided in several steps as mentioned in the theory chapter of the thesis. ZEB is that a building have to produce enough renewable energy through its lifespan to compensate for the emissions emitted from the building.

Green building is a small step towards sustainable design, it is that you use environmentally friendly materials in the building. It do not consider the cradle to grave thinking of a total sustainable design.

Life Cycle assessment is a method that you have to know about when it comes to sustainable design. There are three different types of LCA:

1. Stand-alone LCA, which is an life cycle assessment of a single product
2. LCA studies of the change-oriented type, which is an life cycle assessment that is comparative and prospective. This makes this type useful in product development, building design and process choices since decisions involves comparisons of options that may be implemented or produced in the future.
3. LCA studies of the accounting type, which us an life cycle assessment that is comparative and retrospective. This type of LCA is well suited for different types of eco-labelling and can be used in purchasing or procurement situations since these applications involve comparison of existing products.

The students have to learn about life cycle assessment, but I will not expect the students to conduct a life cycle assessment of the building that will be part of their problem in the problem-based learning. The reason for teaching about LCA is so that the students will
understand how the Environmental Product Declaration, EPD, is developed and how the results that is in the EPD has been found.

**Teaching methods and 21st Century tools and skills**

As I have describe in the chapter “BYG211 Computer Based Modelling and Surveying in 2015”, I do not teach the use of BIM software or theory of BIM in the traditional way, i.e. standing in front of the class giving a lecture. I have taken advantage of the fact the UiA have bought rights to use video lectures from Lynda.com. Lynda.com have very good video lectures on how to use the Revit software, which is the BIM software that we use in our education. The theory lectures is presented on Fronter. There is no point in me spending time lecturing on the use of Revit when the video lectures on Lynda.com is of very high quality and it gives the students the opportunity to watch the lectures whenever they want, and as often as they want. Since I no longer give lectures, but help the students, master the use of the software in the rehearsals I would say that my role has changed from teaching to mentoring. I would describe this as a “flipped classroom light”. The reason for me calling it a light version of the teaching method flipped classroom is that there are no discussions or mentoring linked to the curriculum of the course. The mentoring that I do perform is only related to the use of the software. After teaching the BIM part of the course this way for two years now, I have noticed that this works well for most students. They really like the fact that they can decide themselves when they want to work with the subject, as long as they do the hand-ins. This is giving them a freedom that they do not have in other courses. As I said, it works for most students, but the students that have trouble planning their workweek, often procrastinate and have a hard time getting the hand-ins done in time. Another thing I have realized after doing this for two years is that the teacher only sees the students that needs help, and that the students in the course loses the interaction between the “strong” and the “weak” students. I think that the interaction is very important in a learning situation, if you have a problem you can discuss this with your fellow students and through that discussion more than likely find the solution to the problem, rather than wait for the teacher to come and help you.
These observations is why I want to fully incorporate flipped classroom in the teaching of the course. I want to achieve student-student interaction, because I think that it will lead to a higher level of understanding of the curriculum for the students, this is illustrated in figure 26 below.

![Figure 26 - Repetition of figure 1. [3]](image)

There will always be different levels of student skill in a class. If I can encourage discussions between the students, and the students help each other with problems that occur then this way of teaching can lift all the students to a higher level of understanding the curriculum then if I had taught it in a traditional way, i.e. standing in front of the class lecturing.

Sustainability will also be part of the curriculum of this course, and the question then is how do you teach sustainability? There are many ways of doing this, but as the book “Higher Education in a Sustainable Society” [2] says, Problem Based Learning is a teaching method that is very suited for teaching sustainability in higher education. This is very true in the case of teaching sustainability in an engineering course, and especially so when it is combined with BIM. There are no blueprint to what sustainability in a building design is, there are many things one can teach as sustainable design. As I have mentioned earlier in this chapter, you have Green Building, Zero Emission Buildings, Life Cycle Assessment that all could be the curriculum for teaching sustainability. What I want the students to learn from this course is that they have to realize that they have to consider sustainability in
their professional life as engineers, and that every decision that they make when it comes to building design has an effect on the environment. What they as engineers have to try to do is to minimize this effect through the design and material choices.

I want to use Problem Based Learning to teach the students of this. I will present a case to them, presented in chapter “Case for Problem Based Learning”. Through group work, discussions in groups and in the classroom, with me as the teacher and mentor, with my knowledge of the different softwares, my knowledge on the curriculum and my knowledge of didactics, the students will work to solve the problem at hand.

The combination of Problem Based Learning and flipped classroom is as far as I can see a very good combination. Because the time we have in school can be used on the problem solving, not the teaching of the curriculum, freeing up time for discussions and mentoring of the different student groups.

The groups will have to present their solution in a written report, the report has to be written in English. This is to strengthen the students’ skills in writing reports, which is a big part of the professional life of an engineer and to strengthen their language skills. The template for the report will be the same as they have to use when they are writing their bachelor thesis, so it will also prepare them for that. Two times during the semester the groups have to give an oral presentation to the class of what they have done up till that point. These presentations will be peer reviewed as well as the teacher will give feedback on the presentation. The feedback will help them evaluate their project. These presentations can also bring ideas to the groups, when they see what the other groups are doing, and they can also become grounds for discussions in the class. To be able to make the group work and to solve the problem the students have use their communication skills, they have to collaborate and be creative and the have to use critical thinking. The groups will more than likely use all of these skills without thinking about it, but it is my responsibility as the teacher of the course to make sure that the groups that have problems use these skills to work on the problem at hand.

The case that the students are to use as a starting point for their problem is presented in chapter “Case for Problem Based Learning”. The idea is that each student in each group
use Revit to model the load bearing structure of the building. Then the group decides which one of the models they are to continue working with. The reasoning for the decision that every student is to model the load bearing structure in Revit, is that it is important that students have the basic skills of using a BIM software. We use Revit at UiA, but there are many other BIM tools available. We do not teach any other BIM software and the reasoning for this is that if the students have learned to use one BIM tool, they have shown that they have the skills to learn such a software and will be capable to learn whatever BIM software a future employer uses in their operation.

After they have selected the model, the groups use this model as a starting point for designing another load bearing structure for the building. As a result of this, the group will have two load bearing structures in different materials, for example one concrete structure and one structure made of steel. These load bearing structures have to be analyzed to make sure that they are structurally sound. To be able to this they have to use the knowledge they gain in the structural analysis software part of the course\textsuperscript{13}. When the groups are doing the structural analysis of the structures, they probably have to change the designs, but by doing this process, they gain knowledge of the design process and in the end, they will have two different designs of the load bearing structure. These designs will be used to conduct an environmental analysis to find the most sustainable load bearing structure.

There are many resources available to conduct an environmental analysis of the structures the students have modeled with the BIM software and validated through the structural analysis software. I will give a brief presentation of some of them here.

**Klimagassregnskap.no** is a free web-based tool for calculating greenhouse gasses for buildings and building projects. The tool calculates the buildings carbon footprint, and includes use of materials, energy usage and transport in the operation phase of the building and the use of energy and transport in the construction phase.

\textsuperscript{13} The teaching of structural analysis software in the course is not a part of this thesis. The fact that it is not part of this thesis, do not mean that the students cannot use the knowledge gained in that part of the course in the problem they have to solve through the Problem Based Learning method.
Klimagassregnskap.no can be used for planning and documentation. It is also featured as one of the documentation demands to score points in BREEAM-NOR. The tool have to be used in all of Statsbygg\textsuperscript{14} new projects. [43]

**BREEAM-NOR** is the Norwegian adaptation of BREEAM. BREEAM is the oldest environmental rating tool in the world, established in 1990, and it is the leading environmental rating tool in Europe. BREEAM-NOR was introduced in 2011, the idea of BREEAM-NOR is to promote sustainable design from the early design phase, through the building phase to the building is handed over to its owner. It is a tool for integrate sustainable thinking in all levels of the project and coordinating all the different participants in the project. An important part of the BREEAM certification is to document that the measures adopted are actually implemented. UiA is a member of BREEAM-NOR. \textsuperscript{[44]}

**SimaPro** is a Life Cycle Assessment software. The software allows you to model and analyze complex life cycles, so that you can measure the environmental impact of the product in all life cycle stages. This software is use in academia and industry in more than 80 countries. With SimaPro, you can do sustainability reporting, carbon and water footprinting, product declarations etc. [45]. UiA uses SimaPro in a course in the civil engineering master education called “Life-cycle assessment of constructions”.

**openLAC** is a free, professional LCA and footprint software [46]. It is open source, i.e. its source code is freely available and can be modified by anyone. It started out as an environmental LCA software, but has been extended to enable economic life cycle assessments models also. Especially in a combination with LCA, in the form of Life Cycle Costing.

Through this brief presentation I have shown that there are many tools one can use for documenting the sustainability of a design, and all of them could be used in this course. However, I want the students to learn basics of sustainable design, so that they understand what effect different designs have on the environmental footprint of the

\textsuperscript{14} Statsbygg is the Norwegian government’s key advisor in construction and property affairs, building commissioner, property manager and property developer. [55]
building. As in any other engineering subject, students learn the theory and basic skill of calculations before they use software to analyze the problem at hand. I want to apply the same method in this course, the students have to search for the environmental impact of different materials through Environmental Product Declarations, EPDs, and combine the findings with the amount of the material in their design. I believe that this will lead to a better understanding of how the design affects the environment, rather than using a Life Cycle Assessment software that “hands” you the results. If you do not have basic skills in the field, you cannot form an opinion on whether the results from the software is correct or false. If you have done the basic work a few times, you will gain a “feel” for what is right and what is wrong. The students will learn to use SimaPro if they proceed to the civil engineering master education. There are also students who chose to incorporate Life Cycle Assessment in their bachelor thesis, and with the knowledge they have for this course, it is easier for them to use software on that problem.

Because I want the students to learn the basics in this course, they have to use the material take off from the model created in Revit to be able to do an environmental analysis of the structures. Material take off can easily be gathered from the models. By combining the material take off with the EPDs for the materials, you can calculate the environmental impact of the design in a spreadsheet. To get accurate numbers for the environmental impact of the different designs, one have to give the building a physical location. This have to be done so that one can include transport of material in the environmental impact analysis. From the environmental analysis, the students can conclude on which design they would recommend.

From their work in this course I want the students to learn and realize that there is no absolute truth when it comes to sustainability, but that they have to embrace sustainable thinking as engineers. I want them to challenge the traditional way of designing a building, and their results should be based upon ethical choices, critical thinking, discussions in the group, discussions in the classroom and mentoring. At the end of the course there will be an oral presentation of the report that the groups have written. There are several reasons for this, one is to make sure that all the students in the group have participated in their work and have understood what they have done. Another reason for this presentation is
to prepare the students for what will meet the in their professional life, an engineer have to be able to sell his product to the building owner. If you can sell a product with numbers as what Grønvold, Gulbransen and Reiersølmoen found, then it should be an easy job to sell the design. Maybe there is not such a big difference in your design compared to other designs, and then you have to sell your solution with reasoning in sustainability, ethics and management, operation and maintenance cost.
This part of the thesis will be about how the evaluation of the students work will be conducted. As a basis for this will be the lower left box in figure 27, encircled in green, the original figure is available as a full size image in “Appendix part I”. As one can see from the figure, the student evaluation is being influenced by the curriculum, but the didactics will influence how one will evaluate the students. The influence of didactics is from the didactic relationship model for ICT by Mariis, and what it implies is that the students have to be evaluated in context with the content of the course. Since the result of the didactic discussion in this thesis is that I chose to use flipped classroom and Problem Based Learning as methods for teaching this course, it is natural that the students will be evaluated on their final report on the problem that they work on in the Problem Based Learning. The case and discussion on what problem the students are to work with will be presented in chapter “Case for Problem Based Learning”. The plan is that the students work with a problem as a team, and the will receive mentoring from me on the topics they
have to work with on the assignment. The semester is 12 weeks, and twice during the semester, the students groups will present orally for the class what they have done so far. Where in the semester these presentations will be, will be decided in corporation with the students. The idea with these oral presentations is that the students get training in presenting their work and that they will receive feedback in the form of peer-review, i.e. the students are to give each other constructive criticism on the work that has been done. This will hopefully also lead to discussions in the class and within the groups on what to include in their final product and where they have to gain more knowledge on the subject at hand. These peer-reviews and the mentoring by the teacher will give the groups a substantial feedback on their work. Earlier in my work with this thesis I had planned for the peer-reviews to be part of the grading of the course, but as I continued working with this I realized that it would not be a good idea. There would be a legal problem with that solution. If a student complained on his or her grade, the grade could not be re-evaluated because the peer-reviews was given by fellow students. I did not want to lose the peer-reviews as a tool in the course, because it is easier to receive criticism from your peers that from an authority figure, the teacher. That is why the peer-reviews now have become a tool in the mentoring of the groups, by using it as a tool for feedback after the presentations. The mentoring by me as the teacher and the feedback from the peer-reviews will be helpful for the groups when they write the final report in the course. They will have to write the report in English. This will strengthen their language skills and combined with the oral presentations, they are measures to help with what Trilling and Fadel [30] refers to as lacking skills in students from technical colleges, according to a study in the US some years ago. The reference group for the civil engineering program at UiA, have through our meeting told us that these are important skills for students to learn. The reports will be evaluated according to UHRS’ guidelines for grading engineering students. The reports will be graded on a scale from F – A. In the course the students will get an individual grade, this is based on the grade of the report on BIM and sustainability and an individual written exam on the other topics of the course – surveying and structural analysis software. The grade from the group report and the grade from the individual exam will be weighted and together they are the basis for the individual final grade of the course.
Figure 28 - Comparing of weighting of grades [3]

Figure 28 is available as a full size image in “Appendix part I”. It shows how different weighting of the grades affects the final grade. The PBL assignment is weighted either 60 % or 70 %, and the individual exam 30 % or 40 % accordingly. From this comparison, I have decided to use the weighting 60 % PBL assignment and 40 % individual exam. The reasoning for this choice is that I want the students to work hard on the other parts of the course also, and if I had used the 70/30 weighting then the individual exam would not influence the final grade in the same way as it does with the 60/40 weighting. With 60/40 weighting it is still possible to get an C overall, if the student works hard on the other parts of the course and get an A at the exam. The same is a fact if you get an A on the group work, and an E on the exam, then you will get an C overall, with the 70/30 weighting the student would then get a B. By having a 60/40 weighting the students will understand that they have to deliver good results in both parts of the course to get a good overall grade in the course.
Evaluation of course

The evaluation of the course will be done after each semester the course has been taught. The evaluation of the course is shown in figure 29 in the lower right box, encircled in green, and by the black arrows from each of the “evaluation boxes” that runs back to the course itself on top of the figure. The original figure is available as a full size image in “Appendix part I”. In the box on the right side of the figure one can see that the BIM and sustainability part of the course will be under continuously evaluation, this is a result of the discussions in the classroom and the mentoring of the groups through the work with flipped classroom and Problem Based Learning. The discussions and mentoring will provide me as the teacher with constant feedback from the students on the course. This combined with the mandatory course evaluation that UiA have mid-semester gives me grounds for changes while the course is running. This feedback, the results of the students and my evaluation of the teaching and the course, will be the basis for any changes to the course before the next time it will be taught.
Course plan and content for fall 2016

As I have described earlier in the report will this course undergo changes from the fall semester of 2016. This is because the element that consists of AutoCAD has been moved to another course for the students that started their civil engineering education in the fall of 2015. In this chapter, I will present and discuss the course content and plan for 2016.

Figure 30 - Week plan BYG211 fall 2016. [3]

Figure 30 is a schematic overview of the week plan for the course, as it will be taught in the fall of 2016. The course is 10 ECTS. At the engineering department of UiA we teach 96 hours in a 10 ECTS course, as the week plan shows. There is an inconsistency in the text in the week plan compared to week numbers if you calculate the hours in the plan. As I have explained in chapter “BYG211 Computer Based Modelling and Surveying in 2015” this is to create flexibility for the teacher. The difference in week numbers between figure 19 and 28 is because the semester start in different weeks in 2015 and 2016. In the course handbook for engineering courses at UiA it is described that an average student is expected to work 27 hours per 1 ECTS, which means that an average student in this course is expected to spend 270 hours in this course. When you deduct the 96 hours from the average students expected workload, there is 174 hours left for the students to work on their own. In this plan, I expect the students to spend a portion of these hours on material

ECTS – European Credit Transfer and accumulation System is a credit system design to make it easier for students to move between different countries [52]. ECTS is equivalent to the Norwegian studiepoeng.
that is “flipped”, and instead they will get mentoring and guidance in the hours available in the week plan.

I chose to present the week plan this early in the discussion because the teaching of the other elements of the course and the total amount of hours that we teach in a 10 ECTS course creates boundaries for the implementation of sustainability to the BIM part of the course. It also creates boundaries for how many hours I can use learning the students about these subjects. From figure 19 and 30 one can see that I have chosen to leave the surveying element the same as before. The reason for this is that fall in Norway, even in the as far south as we are located, get more unstable weather the later in the year we get. When doing practical surveying outdoors you are dependent on the weather, and by stopping the surveying part of this course in the beginning of October, we reduce the risk of weather interrupting the outdoor part of this course. Furthermore, one can see that I have chosen to change how we teach the structural analysis program in 2016. I have changed it from four hours a week for six weeks to 2 hours a week over a period of 12 weeks. This does not change the amount of teachable hours for the students, but it does create room for BIM and sustainability to be a part of the course from the start to the end of the semester.

There are several arguments for doing this change. As the plan is to use flipped classroom and problem-based learning as methods to learn the students about BIM and sustainability, it is best to utilize every week in the course to make sure that the students have time to learn and mature in their way of thinking on these subjects. Sustainability alone is a broad and difficult subject that needs time to mature in the heads of the students before they can start having critical thoughts on sustainability and how this affects the design process, building process and management, operation and maintenance of a construction. The students also need time to master how to use the BIM software and to understand how the BIM philosophy affects the design process, building process and management, operation and maintenance of a construction. With flipped classroom and problem-based learning the goal is for the students to be mature enough so that they through critical thinking, discussions, mentoring, their knowledge of
sustainability and BIM can create a sustainable design for the entire lifespan of a construction.

The problem based learning method will be used on a group project. This project will start with the case presented in chapter “Case for Problem Based Learning”. The students will from the start of the semester join in groups of four, all of them shall with the use of a BIM software model a building. The group shall through discussions in the group and with the teacher decide on one of the four models to continue working with through the project. After they have decided on which model they want to continue with, they will use this model to decide on material choices and find the environmental impact of this building. The way that they find the environmental impact of the building is to use material take off from the model, and combining this with environmental data gathered for EPD’s and environmental impact of transport of the materials to the building site. (All this is discussed in detail in chapter “Assignment for the students”)

The grading of the course will be based on two grades that is combined into one final grade for the course. The two grades that combined into one is the grade on the group project, counting for 60 % of the final grade. And the grade from the individual, written exam, counting for 40 % of the final grade. (Discussed in detail in chapter “Evaluation of students”)

**New description of the course**

Based on the discussion of this thesis I have made a new description of the course. The description of the course in 2015 is in the appendix of this report. The new description is intentionally made very general, this makes it easier to make changes to the curriculum if necessary, and there are no mention of a specific software because I want to be able to change what software I use without having to rewrite the course description. The text below do not show details as which study program the course belong to or other elements that is of no importance to what the students are to learn from the course. A complete course description will be found in the appendix.
Description of the course

Learning outcome

After completing the course, the student is expected to:

- Understand the subject's correlation to the other courses in the civil engineering program.
- Be able to describe the principles and the use of instruments in surveying.
- Be able to understand and describe the content of scaled drawings and 3D models.
- Be able understand and describe importance and use of 5D-building information models (BIM).
- Be able to perform calculations of geometric data between terrain and model.
- Be able to create 3D model of a given construction, and produce 2D detail drawings from the model.
- Be able to perform structural analysis of constructions with digital models
- Be able to describe the influence of sustainable thinking on building design

Course content

- General use of surveying instruments.
- Surveying in three axes.
- Reading of drawings.
- Digital production of detail drawings.
- Digital production of building information model (BIM).
- The 4th and 5th dimensions of the building information model.
- Software for structural analysis (civil engineering students)
- General introduction to constructional details (renewable energy students)
- Sustainability in building design
Teaching methods

Lectures and laboratory exercises.

Examination requirement

Portfolio must be passed. Details of the portfolio will be presented in Fronter at semester start.

Assessment methods and criteria

1. Individual written exam, 2 hours, 40% of final grade
2. Project group work written in English, 60% of final grade
Case for Problem Based Learning

The following case will be presented to the students in the beginning of the course. The Problem Based Learning will be based on this case.

Case study

Grimstad municipality is planning to build a new middle school, Grimstad Middle School (GMS). The politicians has decided that the design of the building have to take into consideration that the cost of Management, Operation and Maintenance (MOM), and the environmental (carbon) footprint of the building has to be low. The vague terms set by the politicians for this project have no detail level, the terms are just general terms. The municipality has its own company, Grimstad Property Management (GPM) that is in charge of MOM for the existing buildings in the county. GPM is also in charge of planning and building new buildings for Grimstad. The vague terms given by the politicians are a problem for GPM. They assign one of their employees, Civil Engineer Knut Knutsen an experienced project manager, to run the project and to figure out how to meet the terms given by the municipality’s politicians.

Knut contacts several consulting offices within civil engineering to discuss how the terms should be interpreted and the best way to come up with solutions to the terms. The answers that he gets shows that there are no easy way to decipher the vague terms. One of the consulting offices – Building Consult AS (BC) – has a lot of experience in Building Information Modeling (BIM) and Life Cycle Assessment (LAC). Building Consult, with Siri Jensen (BIM-specialist) and Gunnar Hansen (LCA-specialist) suggest that it would be interesting to conduct a general study together with GPM where the outcome is to figure out whether it is possible to conduct an LCA in the early design phase of a building, based on a BIM-model. Such an “early LCA” will not be as accurate as an LCA done on the finished design, but BC thinks that it will be accurate enough to make the decision whether to continue with a chosen design or to take a step back and redesign the building to meet the given environmental and MOM terms. In the suggestion for the study BC says that builders in general have little knowledge on how to specify what they mean when they give terms for a project based on environmental footprint and MOM, these terms is usually given in very vague terms and Grimstad municipality is in no way special when it
comes to this problem. BC suggest that environmental footprint and MOM should be recalculated to give a total number for CO2-equivalents for the given building during its lifespan. This is based on the more than likely scenario that buildings in Norway in the future will be taxed according to their environmental impact, based on CO2-equivalents.

To conduct such a study costs money and time. Building Consult is interested in participating in such a study and suggest that Grimstad pays 50 % of the cost, and BC pays 50 % of the cost. To get Grimstad council to agree with this, Knut has to come up with reasons why it would be a good idea to partake in this study. He tells the council that it is much cheaper to do changes in the design in the early stages of design, rather than changing the design of a building when the design is complete. This because if you change the design after its completion you have wasted a lot of work hours, so the earlier you can test a design, the earlier you can do changes without losing too many work hours. Furthermore, he presents the intention of recalculating the environmental footprint and MOM to CO2-equivalents and says that this way of thinking will meet the terms given by the council regarding cost of MOM, because of the expected taxes on CO2-equivalents. The leader of Grimstad council, Gunnar Gundersen, asks Knut whether this study could result in costlier buildings for the municipality. Knut answers that maybe the initial cost can be higher than what it is for some of the buildings they build today, but more than likely, this is because of higher quality on materials. The higher quality of materials will reduce the cost of maintenance, and more than likely, these materials are easier to clean and maintain, so the cost of operation will be lower. Materials that are “nicer” and of a higher quality, will more than likely reduce vandalism on the building, which again will reduce cost of maintenance. Knut says that this is, in his opinion, arguments for a higher initial price of a building, because the cost of MOM will be lower and because it is expected that buildings will be taxed on CO2-equivalents. This, he says, should make any builder – and especially a governmental builder – start thinking of projects in the terms of “cradle to grave”. At the end of his presentation to the council he also argue the fact that GPM has to modernize the way they work, and that they have to take full advantage of the possibilities in BIM and BIM-software. Until now, GPM has only used BIM as a 3D visualization tool, and has not used the “information part” or the management part of the software in their work. Here he says GPM has a lot to learn, so that they can use the
information in the model for detailed descriptions of constructions put up for bids, and the management part in the building process and for MOM of the buildings and structures for which GPM has responsibility.

Grimstad council grants the money for the study.

BC and GPM puts together a workgroup to conduct the study. The members of the workgroup (in addition to Knut, Siri and Gunnar) are: architect Cecilie Hansen from GPM, civil engineer Johan Johansen who are a specialist in building physics and Trond Olsen who is an civil engineer, with his field of expertise being building technique and building materials. The group of six starts out discussing what obstacles one can expect when wanting to conduct an LCA in the early design phase of a project, they come up with this list:

- Should STOP/GO be based on CO2-equivalents distributed over the expected lifespan of the building?
  - What emission level is acceptable for continuing with the design and at what level is it recommendable to redesign the building?
  - What is the industry norm?
  - Is there an industry norm?
  - Should there be different levels of acceptance for STOP/GO depending on what usage the construction is being built for?

- Building materials
  - Should all the transportation of materials be charged to the building? By which they are thinking of transportation of raw materials to where they are refined. And should transport from refinery to storage (building supply store, contractors storage etc.) be charged to the building?
  - Should the refinement of raw materials be charged to the building? Or can you think that the materials would be produced regardless of the building is being put up or not.
  - Should the extraction of raw materials be charged to the building?
At what detail level must the early phase BIM-model be so that you can get decent results from an LCA?
  o How detailed must the load bearing structure be?
    ▪ Is it enough with rough modelled load bearing structures in different building materials (steel, reinforced concrete)?
  o Can curtain walls and inner walls just be modelled as reinforced concrete or wood structures?
    ▪ Or do they have to be described into detail when it comes to how they are put together?

How to set a correct life span of a building? There are different aspects to factor in here:
  o What are the primary uses of the building? Some buildings are more prone to rebuilding than others (schools, office buildings etc. vs. warehouses, garages etc.). For example a school is built for how we teach today, but we do not really know how teaching will be practiced in a few years (this may also vary regarding at what level the teaching is – primary-, middle-, high school or university).
    ▪ How many students will there be in each classroom?
    ▪ Will classrooms be used as much as today, or will there be areas for self-studying in addition to the classrooms?
    ▪ Will “flipped classrooms” be used more, so that the self-studying areas is in more demand than the classrooms?
  o Uncertainties like these make it hard to set the life span for the whole building. Maybe the correct way for “living buildings” like these are to set a lifespan for the load bearing structure and the exterior of the building and another life span for the interior (inner walls, flooring etc.) – e.g. 100 year life span on the exterior and load bearing structure and 10 years for the interior.
Main principles for dynamic influences between Sustainability, BIM and Didactics in an engineering course

- **Energy**
  - An “early phase LCA” should be able to consider different types of heating-/renewable energy sources for a building (e.g. district heating, ground source heat pump, solar panels, solar collectors, windmills).
  - District heating is very popular, but it should be considered in each case. It is not environmentally friendly if the building is designed for district heating and there are no infrastructure (or will be no infrastructure for it in the near future), so that the building will be heated by burning fossil fuel.

- **Recycling**
  - When it comes to recycling of the building, one has to calculate the environmental impact of the recycling. If the building is expected to have 100 years life span, then it is not certain that today’s “green materials” are considered “green” at the time of recycling. How is this going to be considered in a “cradle to grave”-analysis? This raises the dilemma: *should one consider the whole building as waste or should one consider the degree of recycling of the materials according to today’s knowledge.*

- **“Early phase LCA”**
  - Should it be considered to develop an “early phase LCA”-software, e.g. spreadsheet based? Alternatively, are there suitable freeware already available?
    - Must the data (databases) used in such an early analysis be Norway specific – or can one have a global view on the analysis?
      - Environmental impact is both local and global. Most of the environmental impact from the building industry is CO2-emissions and that is a global problem. The local impact from building industry is mostly from production of building materials and transportation of the materials (diesel exhaust – NOx and particulate matter).
      - Will international data give accurate enough data to use in Norway for an “early phase LCA”?
Assignment for the students

The group assignment that the students are to work with in the course will use the case study as a starting point. All the students will have to use the BIM software to create a model of a part of the school building described in the case study. They will not create a model of the full building, but they have to model the load bearing structure of a given part of the school. The dimensions and what the selection of the building shall contain of rooms, windows etc. will be presented to the students at the start of the semester. After every student in the group has modeled the basic model, the group will decide which model is to be the basis for their continued work.

From the case study each group will be assigned one of the main problems (main bullet points) from the case study, that they have to come up with an answer to. They will also have to come up with one additional problem on their own that they want to answer through their work.

To be able to come up with answers on the problems and conduct an environmental impact study on the building they are working with, they have to further develop the model they have decided to base their work on. They have to model two different load bearing structures, they will decide on materials for the structure themselves. These two load bearing structures shall be structurally sound, so they have to use the knowledge they have learned in the structure analysis part of the course to analyze the structures. They will be given the loads that they have to use in the analysis, I will not require that they calculate the forces that affects the structure. This analysis will give them two different load bearing structures, there will be different span widths and amounts of column etc. It will be a realistic design challenge for the students, because they have to consider placements of column etc. according to how the rooms, windows etc. are placed in the building. From the two load bearing structure models, the groups can get material take offs, and calculate the environmental impact from the building by the use of EDPs. To be able to take transport into consideration when it comes to the environmental impact of the building, the school has to be given a physical location. This location will be given by the teacher.
Conclusion

Through my work with this thesis, I have realized that there are many different approaches to how one can create dynamic influences between didactics, sustainability and BIM in an engineering course. It became clear to me early in my work that I had to have a framework for how I wanted to teach the course, so that I could create a curriculum and a plan for evaluation both the students and the course. I started out with learning theories and found that for the way I like to teach, the Socio-cultural learning theory is a good base for the approach to learning. When I had this base, I had to find a model to build the curriculum. The didactic relationship model by Hiim and Hippe [25] was a good starting point for that, and as my work continued I found that the didactic relationship model for ICT by Mariis [25] was an even better model for the course I was working on redesigning.

In UHRs’ national guidelines for engineering education, sustainability is not mentioned by word, but through their description of what an engineering education should contain, it is obvious that sustainability is important to incorporate in the education. There is no specific directions in the guidelines on how to incorporate sustainability, it is up to the different institutions how they want to include this in their education. In this course there is an empty slot after parts of the course is moved to another course, so it became natural to include sustainability in this course. However, how do you teach sustainability? In the book “Higher Education in a Sustainable Society” [2], it is said that there are many ways of teaching sustainability, but that Problem Based Learning is a very suitable method. This method uses discussions, group work and mentoring as methods for teaching. This occupies much of the hours available for teaching in the course, so how do I teach the students the use of BIM software and theory? Well, I have already used video lectures from Lynda.com to teach the use of software. This has been used because there is many students in the course, and by using video lectures I can spend my time on helping the students in the rehearsals instead of repeating lectures. I have found this to be a good solution, but I have seen that the only students that show up for the rehearsals is the students that are the “weakest” and as a result of this the students lose out on the bonding between the students in the course. There are no “stronger” students to help the “weaker” students and there are no discussions in the class. Therefore, even though the
way I have conducted the teaching resembles the flipped classroom method, it lacks the discussions in the classroom and the bonding of the students. By combining flipped classroom and Problem Based Learning, I believe that this will result in a much more active class that discuss solutions with each other and gives each other feedback on their work.

Another thing that I had to consider when I was working on this thesis, was the fact that the students need to learn 21st century skills and tools. Such skills is presentation or communication, both in writing and orally, critical thinking, collaboration and creativity.

By using BIM and case study as the grounds for the group work on sustainability that the students have to do in the Problem Based Learning part of the course, it is easy to encourage discussions in the class and in the groups and my part will become that of a mentor for the groups. Through their work on the assignment, the groups have to present their work to the other students. I will use peer-review as a tool for both feedback on the presentations and the work, but also as grounds for discussions in the class. The students have to use 21st century skills and tools when they work on their assignment, they have to collaborate and communicate in the group, and they have to communicate their findings through the presentations, they have to use critical thinking and creativity as tools to find answers or solutions to the problems. The group work will count for 60% of the final evaluation of the course, the other 40% will be an individual written exam. In the background for the choices for teaching and for evaluation the students, and finally the entire course is the didactic relationship model for ICT.

The outcome of this way of teaching will be evaluated in the spring of 2017, since the course will be taught in this way for the first time in the fall of 2016. I hope that this is a success and this thesis can be used as a guide for introducing the didactic relationship model for ICT, flipped classroom and Problem Based Learning in other courses in the Civil Engineering education at the University of Agder.
Recommendations

In the spring of 2016, I will continue to develop the curriculum for the course and planning the BIM and sustainability part of the course in detail.

For the rest of the recommendation chapter I chosen to write the about what I would like draw from this thesis in the future. I would like to continue evolving the use of problem based learning with 21st century skills in education, especially with in my “world of education” which is civil engineering. In my thesis, I have looked at how to incorporate sustainability and 21st century skills in a BIM-course. In the beginning of the thesis, I have explained that this course consists of several elements, surveying and structural analysis with software are elements that is not included in the thesis. My next goal is to continue working with this course, so that surveying and the structural analysis will be part of the challenge that the students will work with in this challenge based learning course. This means that the teachers of these elements have to be encouraged to be part of this change. After a while of teaching the course with a challenge based learning philosophy and gaining experience on how to get a “best practice” for challenge based learning, I will research the results of the evaluations of both the students and the course. If this research is positive, I would like to try to incorporate this way of teaching to other courses in the civil engineering education at UiA. My ultimate goal, if the results are positive, is to incorporate this philosophy of teaching in the entire civil engineering education at UiA. This will in my opinion, make it easier to train the students through their education in the skills needed in as a professional civil engineer.
References


Appendix

Appendix part I – Information about the case, BYG211 course

Course plan 2015

<table>
<thead>
<tr>
<th>Week 34</th>
<th>Week 35</th>
<th>Week 36</th>
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<td><strong>Surveying</strong>&lt;br&gt;2x2 hours a week</td>
<td><strong>Structural Analysis software (SAP2000)</strong>&lt;br&gt;(for civil engineering students)&lt;br&gt;2x2 hours a week</td>
<td><strong>Building Technology</strong>&lt;br&gt;(for renewable energy students)&lt;br&gt;2x2 hours a week</td>
<td><strong>AUTOCAD</strong>&lt;br&gt;2x2 hours a week</td>
<td><strong>BIM (Revit)</strong>&lt;br&gt;2x2 hours a week</td>
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Course description fall 2015

BYG 211 Computerbased Modelling and Surveying

10 ECTS credits Starts Autumn 2 semester Grimstad

Study program

Civil Engineering – Bachelor's program

Teaching starts

Autumn

Language of instruction

Norwegian

Learning outcome

After completing the course, the student is expected to:

- Understand the subject’s correlation to the other courses in the civil engineering program.
- Be able to describe the principles and the use of instruments in surveying.
- Be able to understand and describe the content of scaled drawings and 3D models.
- Be able understand and describe importance and use of 5D-building information models (BIM).
- Be able to perform calculations of geometric data between terrain and model.
- Be able to create 3D model of a given construction, and produce 2D detail drawings from the model.
- Be able to perform structural analysis of constructions with digital models.
Course content

- General use of surveying instruments.
- Surveying in three axes.
- Reading of drawings.
- Digital production of detail drawings.
- Digital production of building information model (BIM).
- The 4th and 5th dimensions of the building information model.
- Software for structural analysis (civil engineering students)
- General introduction to constructional details (renewable energy students)

Teaching methods

Lectures and laboratory exercises.

Examination requirement

Portfolio must be passed. Details of the portfolio will be presented in Fronter at semester start.

Assessment methods and criteria

Individual written examination, 2 hours

Pass/fail grading.

Level of course

Bachelor's level

Name of contact person

Program Coordinator Paul Svennevig

Recommended or required reading

The curriculum will be publish in Fronter at semester start
Credit reduction

BYG112 - G – 5 ECTS credits

Offered as a free-standing course

No

Faculty

Faculty of Engineering and Science
## Course plan 2016

### BYG211 Computer Based Modelling and Surveying

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<tr>
<td>34</td>
<td>BIM + Sustainability</td>
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<tr>
<td>35</td>
<td>Methods: (students prepare on own time) flipped classroom and Problem Based Learning</td>
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<tr>
<td>36</td>
<td>Mentoring: (teacher available for students) first 6 weeks, 2 hours pr week last 6 weeks, 6 hours pr week</td>
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### Surveying
- 2x2 hours pr week

### Structural Analysis software (SAP2000)
- 2 hours pr week
Course description fall 2016

BYG 211    Computer Based Modeling and Surveying

10 ECTS credits    Starts Autumn    2 semester    Grimstad

Study program

Civil Engineering – Bachelor’s program

Teaching starts

Autumn

Language of instruction

Norwegian

Learning outcome

After completing the course, the student is expected to:

- Understand the subject’s correlation to the other courses in the civil engineering program.
- Be able to describe the principles and the use of instruments in surveying.
- Be able to understand and describe the content of scaled drawings and 3D models.
- Be able understand and describe importance and use of 5D-building information models (BIM).
- Be able to perform calculations of geometric data between terrain and model.
- Be able to create 3D model of a given construction, and produce 2D detail drawings from the model.
- Be able to perform structural analysis of constructions with digital models
- Be able to describe the influence of sustainable thinking on building design
Course content

- General use of surveying instruments.
- Surveying in three axes.
- Reading of drawings.
- Digital production of detail drawings.
- Digital production of building information model (BIM).
- The 4th and 5th dimensions of the building information model.
- Software for structural analysis (civil engineering students)
- General introduction to constructional details (renewable energy students)
- Sustainability in building design

Teaching methods

Lectures and laboratory exercises.

Examination requirement

Portfolio must be passed. Details of the portfolio will be presented in Fronter at semester start.

Assessment methods and criteria

1. Individual written exam, 2 hours, 40 % of final grade
2. Project group work written in English, 60 % of final grade

Level of course

Bachelor’s level

Name of contact person

Program Coordinator Paul Svennevig

Recommended or required reading

The curriculum will be publish in Fronter at semester start

Credit reduction

BYG112 - G – 5 ECTS credits
Offered as a free-standing course

No

Faculty

Faculty of Engineering and Science
Main principles for dynamic influences between Sustainability, BIM and Didactics in an engineering course
Main principles for dynamic influences between Sustainability, BIM and Didactics in an engineering course

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Mind maps through the work with the thesis
Main principles for dynamic influences between Sustainability, BIM and Didactics in an engineering course
# Title & Subtitle

**Case study on...**

A *prophetic story* and *sustainability* in the *context* of civil engineering education.

# Summary, Write Now → Rewrite

How to implement 21st-century teaching skills into civil engineering education. Focus on embedded sustainability course.

Justere "introduction" (se Eilif kommentare)

# Case and Research Question

1. Rename e.g. "Case and Research Focus"
2. Dette er en mulighetsstudie
3. Based på "best practices & theory"
4. Chapter "Case" → Rename
5. Use example for practical use
6. 12. Gjeven → 1-(2) pr prosjektrapport i grupper
7. Chapter "Research Question" → Rename
8. E.g. Research Focus: "For development of learning module" & "Theory" - For å presentere ferdighetene inn i inngangs-
9. Større univers. Hvordan ta feil i prioriseringer
10. Not i learning resources
11. Location:meye nyttig innførsel - trekk frem innføring
12. Komunikasjon
13. Med utvikling - "Out-of-the-
14. Market" - Trykk

Rewrite

Glamorous personal - living on pot

CDL - Neben

Forhåndse

3. Generalizing experience & street

Intuition
Main principles for dynamic influences between Sustainability, BIM and Didactics in an engineering course
Appendix part II – Learning resources

The material that is presented in «Appendix part II – Learning resources» were written before there were a final decision whether to write the thesis in English or Norwegian. The material in this section is not used directly in the thesis, and as a result of this I have not spent time translating the early material that was written in Norwegian. Appendix part II – Learning resources have its own reference list at the end, this so that the material here and its resources not is to be confused with the references of the main report.

The topics in “Appendix part II – Learning resources” is included in order to show that there are many relevant learning resources that can be integrated into a curriculum, whether dissemination based, or in support of the first phase of students’ own learning process.

There is an increasing requirement for documentations and EPDs is a good example of a specific solution that is particularly relevant within BIM supported sustainability.

EPD til diskusjon og informasjon i undervisningen


BREEAM-NOR bidrar til kraftig økning i antallet EPD-er. Antallet EPD-er av produkter har skutt i været de siste årene og i 2015 er nytårsforsøket å runde 300. En økning i antallet BREEAM-bygg kan bidra til at målet nås. «Antallet EPD-er har økt med 50 % - fra 147 ved utgangen av 2014 til 220 nå. I det vesentlige er det byggevarer som står for veksten, og som er tildelt de fleste EPD-ene samlet sett. Men andre bransjer kommer tydelig etter, sier daglig leder Dagfinn Malnes i EPD-Norge i en pressemelding». Antallet bedrifter som har
EPD-er for sine produkter er også økt betydelig fra 54 ved forrige årsskifte til 80 nå. I tillegg kommer EPD-er fra andre land – Finland, Latvia, Danmark og Nederland. Både i Norge og i flere andre europeiske land ser man at etterspørselen etter EPD-er er stadig økende. Malnes mener dette kommer av flere årsaker, men at BREEAM-NOR er en spesielt sterk driver for etterspørselen etter EPD-er her til lands. «Ønske om å oppnå en BREEAM-NOR klassifisering bidrar til den positive utviklingen i Norge. Internt i bedriftene er det også interesse for å bruke resultatene fra EPD i forbedrings- og produktutviklingsprosesser. EPD-ene kan oppdateres etter hvert som produktutviklingen når nye nivåer. Norske bedrifter har god kultur for utvikling og omstilling, sier Malnes».

Utvikling av EPD-er har blitt mer standardisert og harmonisert gjennom europeisk samarbeid, og har ført til at det å lage den første EPD-en tar ca. 2 måneder mot tidligere rundt et halvt år. Har man først laget en EPD, så kan mye av opplysningene (bedriftsinterne opplysninger) gjenbrukes i andre EPD-er fra samme bedrift. [1]


I foredraget kommer han med flere interessante påpekninger, som at spesifiseringer av CO2/tonn produkt kan slå feil – altså vi må se på helheten, ikke bare på enkeltprodukter. Videre tar han for seg problematikken rundt hva som er enheten for miljødata bør være (m2, m3, tonn, bæreevne, bestandighet, levetid). Han poengterer at miljøeffekt fra transport av produkter til byggeplass må med i miljøberegningene. Han sier også i foredraget at det er god tilgang av spesifikk miljødata, men typiske data for produkter på det norske markedet kan benyttes i tidligfasen av prosjekter. [2]
Information from literature study on LCA, not included in report

System boundaries and allocation

Impact assessment method

“There are several different types of LCA applications, each with its particular methodological requirements. Our thesis is that methodological choices are governed by the application, although this is not always clearly acknowledged in many LCA manuals and guidelines. Moreover, it is also useful to distinguish between the LCA model and the LCA study: definition of functional unit, system boundaries issues in general and allocation problems in particular, type of data used in the study, how the impact assessment is made. Any reader of an LCA report should be aware of the implications of these four issues” [3]:

Why do a Life Cycle Assessment (LCA)?

- What do you want of answers from the LCA?
  o Definition of the question you want the answer to is very important (just like the research question in a master thesis)
  o You can only get an answer to what you want to figure out – the Hitch Hikers guide to the galaxy – the great question of life, the universe and everything – answer is 42.... Same thing goes for a LCA.

- You have to define the customer
  o What does the customer want of answers?
  o Who is the audience/receiver of the LCA? Who is the LCA going to be presented to?

- LCA relative to other environmental tools
  o The ecological footprint is foremost a method for assessing and illustrating environmental impact. It can be used in combination with LCA to calculate the ecological footprint of a product but also together with material flow accounting to show the ecological footprint of a region. Ecological risk assessment is a more specialized environmental tool than LCA since it is mainly used for assessing the real and potential impacts of toxic substances.
- Check out: “analytical tool for environmental design and management in a systems perspective” (Wrisberg et al 2002) and “Tools to aid environmental decision making” (Dale & English 1999)

- For this thesis it seems that Change oriented LCA is the way to go, maybe in combination with “Ecological footprint – method”

- Initial flowchart is a smart way to start the LCA – to get an overview

- What should be “green-light” for process – when is the design OK, by that I mean when can you say that the LCA gives satisfactory results so that the design phase can continue into the detail phase of the project.

- Boundaries: should transport be taken into account? Packaging of product? Where is the “start-line” for the LCA and where is the “finish-line”? 
**Learning resources, different LCA-tools**

Here I will list some of the different LCA tools available and that are not mentioned in the main report. It is important to explain that this is a selection of what is available.

**U.S. Life Cycle Inventory database**

National Renewable Energy Laboratory (NREL) and its partners created U.S. Life Cycle Inventory (LCI) Database to help life cycle assessment (LCA) practitioners answer questions about environmental impact. The database provides individual gate-to-gate, cradle-to-cradle and cradle-to-grave accounting of the energy and material flow into and out of the environment that are associated with producing a material, component, or assembly in the U.S. This is of limited use for this thesis, since its only for the U.S. – but it might be a good starting point as a database. It refers to several “Life Cycle Assessment Tools” – both “General LCA Tools” and specified tools for different areas. [4]

**BEES - Building for Environmental and Economic Sustainability software.**

The BEES (Building for Environmental and Economic Sustainability) software brings to your fingertips a powerful technique for selecting cost-effective, environmentally-preferable building products. BEES measures the environmental performance of building products by using the life-cycle assessment approach specified in the ISO 14040 series of standards. [5]

**Building Ecology – website**

Building Ecology is a website for indoor air quality for sustainable buildings, according to its editor Hal Levin. This website has a feature for sustainability and in this feature there is an overview over different types of Life cycle Assessment (LCA) software, tools and databases. [6]
References for Appendix part II – Learning resources


