

# Ventilation Technology Educational

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## Abstract

With today's rapidly changing environment of exponentially increasing knowledge and constantly development of new technologies, it is critical that the educational system keep up with the newest and most recent material when teaching tomorrow's generation engineers. It is important that students in higher education gain the necessary knowledge and develop skills which can be directly or indirectly applied into their real-life engineering careers, what was relevant a decade ago may not be applicable today, and it is a university's responsibility to make sure that the content is of satisfactory quality. In the light of this rapid change of knowledge and new technologies, the course *Energy- and Heating, Ventilation- and Air Conditioning (HVAC) -Technology* at the University of Tromsø needs a major makeover. In order to, design an enhanced syllabus and make suggestions to a new educational program for this specific course, this thesis will; analyze research of different methods of how to successfully teach and learn higher level of engineering by using methods like; problem based- and technology enhanced learning methodology, it will explore how similar courses are taught through a collection of a numerous syllabi from universities and colleges across Norway and USA to find what topics are emphasized and what textbooks are favored, then the course's strengths, weaknesses and improvement potential are determined, and evaluated through a detailed questionnaire of previous students who have completed the course. This work represents an overall suggestion how to design a new educational program for this specific course, higher level engineering in ventilation technology.

*Keywords:* Teaching Engineering, Problem-Based Learning, Laboratory Based Learning, Technology Enhanced Learning, Ventilation & air-Conditioning, HVAC Technology

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## 1. Introduction

Over the past decades, the construction industry has been exposed to a highly-increased focus on environmental design triggered by the rapid change in new and improved materials and better technology, along with firmer building codes and restrictions. This has impacted the way we plan, design- and construct new buildings and rehabilitate existing structures, from a highly efficient building envelope to greener and more environmental focus on technical installations, such as low-energy heating, ventilation- and air conditioning systems (HVAC). Future engineers will face the challenges of this green shift, considering the use of new products and materials, a rapid change in technology and a more frequent austerity measures of building regulations- and codes. It is key that universities and professors keep up with the high pace in order to provide students with the newest and recent material when teaching engineering. As the industry itself rapidly changes, the classroom environment has been and are constantly evolving, especially considering the use of new technologies and E-learning recourses. Education and knowledge are no longer limited to four classroom walls, knowledge is everywhere, and easily accessible through personal laptops and smartphones. The biggest challenge of today, is not the technology itself, but the speed of how fast things changes, and we must keep up with the pace, also in the classroom.

## **2. Methods**

### **2.1. Survey**

To analyze the existing course' strengths and weaknesses and potential improvements in term of content and quality, a quantitative research was conducted in the form of an online questionnaire, using *Questback Essentials*. The 10-question survey was constructed to specifically explore detailed; views, opinions and perspectives from former students, which completed the course the spring semester of 2016. Students were also encouraged to contribute with tips, comments or ideas to increase quality and learning outcomes and to come with suggestions how to make the course more interesting and exciting.

### **2.2. Collection of Syllabi**

In order to find appropriate literature to the course and what topics to emphasize, universities and colleges teaching either whole HVAC-degrees, bachelor or master programs, or institutions offering single-subject courses in HVAC, ventilation or air conditioning – technology in Norway and the U.S. were requested to share their syllabi. The universities were clearly informed about the purpose of the request, and the universities and colleges that were invited to be a part of this study were approached either by e-mail to the responsible department, by phone, or through online questionnaires on their web-sites. 25 universities and college institutions were invited to share their syllabi / course information. In total, 11 syllabi and 10 descriptions from 18 universities and colleges were collected and used in further work, mainly to identify what textbooks are being used in similar courses, what topics are being emphasized, but practical information as grading system, laboratory work etc. were also used as in this study.

### **2.3. Literature Review**

Based on the collected syllabi and course descriptions, relevant HVAC- and ventilation technology literature in the form of text books (printed / E-version) were hand selected and reviewed in detail up against the course' description and learning outcomes. The existing course does not have any form of required literature such as a textbook, and the main purpose of the review was therefore to find appropriate literature to supplement the course. The various textbooks were also used as a foundation for designing a new course compendium.

## **3. Teaching Engineering**

Just 40 years ago a student graduating with the required education like an engineering degree would have gained a career for a lifetime, back then information technology was slow and the life of knowledge was measured in decades. Today knowledge is growing exponentially and changing rapidly and in many disciplines, knowledge is now measured in months and years (Siemens, 2005), especially thinking about the constant development of new and better technologies. Peter Goodhew argues: "It matters not whether we call them 'Generation X, Y' or Millennials'...the background attitudes and expectations of students are changing increasing rapidly. Each generation grows up in a different technological environment, in a different economic climate and according to different social mores. Engineering education cannot stand aside from these factors, even if we believe that many of the fundamental concepts and practices of our chosen profession are reasonably timeless. It has to be the business of engineering educators to motivate students to engage with modern engineering and to relate to their offered programs to the contemporary environment, both in content and style" (Goodhew, 2010:11).

### **3.1. Subject Based Learning**

Subject based learning or also known as classic lectures is defined as where the instructor teaches through blackboard or PowerPoint slides, and it is the most common way of teaching engineering. However, it has known for many decades that this type of teaching, the classic lecture style, or teacher-centered instruction might not be the most efficient as a way of developing either knowledge or understanding. Science courses

cannot solely rely on lectures, reaching out to students, it is necessary to consider other teaching methods than classic lecture or supplement these lectures with other activities to motivate and encourage students to deep learning (e.g. understanding of principles which can be applied elsewhere) and critical thinking (Kalman, 2008, Goodhew, 2010). Research indicates that a listener can only give their full attention to a speaker for approximately 15-20 minutes, and it can therefore be practical to break up a 45-minute lecture into two mini sessions with an active element in between to keep students' attention (Goodhew, 2010:45). Rodriguez et al. (2015) argues that one of the main issues found in our schools is low participation among students in lecture, and a low interaction with their instructor. An opponent to classical lectures are active learning methods which for a fact has proven to increase and strengthen the student-instructor interaction.

### **3.2. Active Learning and Problem Based Learning**

Active learning can take place in the classroom, in the laboratory, during a project, in student debate or discussion groups or when working in teams, "active learning involves students in doing things and thinking about the things they are doing" (Bonwell & Eison, 1991:3). The active learning model, particularly benefits engineering education, because training in engineering has an essential practical component, graduate-level courses, which have a very technological and systematic nature are well-suited to implement active learning, such as problem based learning (Rodriguez et al. 2015). By introducing active learning into the educational environment, students will remember more content, develop enhanced critical thinking and problem-solving skills and learn how to cooperate in teams. Faculty adopting these active learning methods is also more likely to positively influence student attitudes, study habits and perhaps also increase their performance (Thomas, 2000). Problem based learning (PBL) is an educational strategy where learning is driven by problem solving, the characteristics of PBL is particularly the lack of lectures and the reliance on the student's own effort to discover and understand. PBL is a model that organizes learning around real-life application in the form of a project (Goodhew, 2010). In a PBL environment, students build skills and knowledge by actively participating, interacting with the environment, working independently as well as collaborating in teams, while the instructor directs and guides (Thomas, 2000). "The instructor acts to facilitate the learning process rather than to provide knowledge" (Bridges et al. 2012:3). It is also considered as a tool to 'learn how to learn', through problem-solving and projects, students make use of higher-order skills instead of memorizing information in isolated and unconnected contexts (Majo & Baquero, 2014 as cited in Basilotta Gomez Pablo et al. 2016:2). The core idea of PBL methodology and learning how to solve problems is that "learning should be intrinsically motivating and not be 'forced upon' students through examinations and other means that were considered to increase extrinsic motivation and competition among students rather than collaboration; and that students should take responsibility for their own learning" (O'Grady et al. 2012:27).

### **3.3. Laboratory Based Learning**

Experiential learning is a process of learning through experience or 'learning by doing', but trying to incorporate practical work such as laboratory work successfully into the engineering curriculum can represent a number of challenges. Lab-exercises are expensive to run, sometimes requiring specialist equipment to be purchased that can rapidly become outdated, practical sessions can also be time-consuming to organize, manage and assess and space and equipment can be limited. "Despite the challenges, the application of theory in a practical setting remains an expected and fundamental part of the engineering curriculum" (Davies, 2008:2-3). Students achieve a satisfactory understanding of engineering when they have significant exposure to hands-on laboratory work and substantial individual project work, the curriculum should include both design and research-led projects which are expected to develop independence of thought and the ability to work effectively in teams (QAA, 2006 & UK-SPEC, 2004 as featured in Davies, 2008). There are various approaches to designing practical work; demonstration, exercise, student-enquiry, open-ended enquiry or project. The use of technology with computers and simulation software can also be used to assist in both the delivery and assessment of laboratory work. Even virtual laboratory work can have great benefits in learning engineering as well as it is easily accessible and most likely cost effective compared to traditional laboratory work (Davies, 2008).

### **3.4. Technology Enhanced Learning**

“Students entering today’s classrooms are profoundly different than those of twenty years ago. The rapid advancement of mobile, connected, personal computing is transforming the lives of students outside of school” (Chan, et al., 2006:6). Preville (2016) argues that successful teaching will eventually depend on how technology is applied, both in and outside the classroom to keep students engaged and raise their knowledge. With technology constantly changing and evolving, “it is no longer practical to train students to use specific tools. Instead, applying technology in the classroom will sharpen the high-level competencies that make the students more employable, good communication skills, resourcefulness and the ability to collaborate, assess, provide feedback and develop a marketable digital persona” (Preville, 2016:11). Technology enhanced learning (TEL) includes bringing digital technology into the classroom environment, TEL often distinguishes between the two terms; e-learning and e-delivery. E-learning include students using computers or mobile devices to access electronic learning materials and e-delivery relates to the professor/ lecture using technology as an aid to the purpose of teaching (Goodhew, 2010). Technologies which are used in TEL can be; podcasts, wikis, educational blogs, social media, Twitter, Youtube, Slideshare, Flickr, digital surveys, online quizzes, Google Docs, visual digital presentation tools, Trello TopHat, etc. (Goodhew, 2010, Preville 2016, Kharbach, 2014, McGuire, 2016).

## **4. Syllabus**

The syllabus main function is to help the instructor prepare and organize the course as well as a basis for a common understanding between instructor and student. The syllabus provides the framework for the course’s goals and expectations and shall define course’s outline, structure and content with the basis in the educational goals and learning outcomes. The syllabus should stimulate interest in the course by defining what major topics will be emphasized, as well as how time will be spent on certain topics, the syllabus shall clearly communicate prerequisites and expectations and contain information about assignments, labs, projects and exams and how these are weighed in relation to the final evaluation. Logistic information such as the course name and number, instructor’s contact information, texts and literature-list, required or/and recommended readings, due dates, exam times, course requirements and policies, academic integrity, attendance policies, homework and relevant information which students implicitly agree to abide by when taking the course. Information about student recourses and supplementary material can also be beneficial. However, the syllabus is not a document carved in stone, changes and adjustments might occur during the semester and information about subject to change should also be mentioned (WUSTL, 2017).

### **4.1. Learning Outcomes**

Constructing a syllabus is an important part of the process of planning a university level course, and as a part of designing and formulating an improved educational program for this course, an enhanced syllabus is built based on the pre-defined course’s goals and learning outcomes. Learning outcomes (LOs) are the statement of what students will learn in a class or course session. LOs are the knowledge, understanding and competencies which engineering programs are designed to develop in their students (Goodhew, 2010:20). The LOs and the goals of this course is already given in the university’s course description and is therefore reproduced in the syllabus. The overall goal is to be able to plan, design, dimensioning and control energy-efficient HVAC systems.

Students who successfully complete this course will gain knowledge about:

- Regulatory requirements such as the appropriate building codes, regulations, rules and industry standards for designing energy efficient ventilation systems.
- Energy and indoor environment calculations
- Different ventilation principles and how to ventilate living spaces

Students will gain the following skills gained in this course:

- Manage to construct and design descriptions for ventilation systems

- Be able to design and size an energy efficient ventilation system, including ventilation unit and duct network
- Be able to design / dimensioning ventilation solutions at room level that provides acceptable indoor air quality with respect to temperature, features, air quality and sound

## 5. Student Survey

The class of 2017 that completed the course *Energy- and HVAC Technology* the spring semester of 2016 was asked 10 questions through an online survey. The key goal of the survey was to investigate how satisfied students were with the course they had completed, ranking different aspects of the existing class revealing its strengths and weaknesses and evaluating structural elements of what should be emphasized in the future that might increase the quality and strengthen the learning outcomes. The intention was also to reveal what areas students feel the most confident, and what topics need to be highlighted more, what they are the most and the least satisfied with. Students were also encouraged to contribute with tips, comments or ideas, making suggestions to how making the class better from a student's perspective. The findings in the survey are a foundation for designing an enhanced syllabus and constructing a new educational program for this course.

### 5.1. Findings

The main conclusions that can be drawn from the findings of the survey are that:

- The course must be 'upgraded' from only-blackboard lectures, even introducing the lecture material in the form of Power Point slides will likely make the course more time efficient and help students follow lecture better. Relevant video-content might also be an element considered being incorporated to lecture.
- Some fundamental topics must be emphasized more so all the course goals can be achieved, that includes more focus on dimensioning- and scaling ventilation-systems and a stronger focus to incorporate governmental requirements, codes and standards which involves students becoming familiar with specific requirements, key figures, amounts, etc.
- Elements like a physical inspection of an actual system, student-project or/and laboratory-work or lab-demonstration should strongly to be integrated into the course.
- Students should be familiarized with real HVAC-blueprints/ technical drawings or ventilation systems visualized in a BIM-model, can enhance the course and break up classic lectures and make lectures more interesting.
- Introducing more non-mandatory assignments with readings or/and calculations need to be addressed so students have enough work after class.
- A well-designed compendium updated to today's standards is a necessity.
- The amount of lecture is evaluated as sufficient, but only if the students have enough individual work outside the classroom (assignments, project, readings, etc.) Extending lecture by +1-hour (after lunch) will positively be embraced.
- The final grade may consist of a combination of 5-hour written examination and a student project/ assignment/laboratory-work or report, emphasized for example 60/40% or 80/20%.

## 6. Literature

The course did not include any required textbooks when it was taught in the spring semester of 2016 and one of the central tasks in this study has been to find appropriate literature which covers the course goals and learning outcomes. The material for the ventilation- and air conditioning part that was provided for this course was the instructor's own handwritten notes and oral material presented in classic blackboard lectures. However, the survey showed that textbooks, printed or e-books are highly desirable and ranked as the number one preferred form of literature. Wankat & Oreovicz (2015) argues the quality of the textbook will have a major effect on the quality of the course and how can conveniently be covered. Textbooks (including electronic texts) are used in about 90% of college courses in the United States, and in the past many

engineers kept their textbooks and used them as a primary reference for many years in their professional lives, but in the modern classroom, there is a discussion about the use of textbooks. A good textbook can be a tremendous aid, but in some specific engineering courses, it can be difficult to find appropriate literature to cover the course.

### 6.1. Literature Review

The basis for the literature review of this thesis work has been the required textbooks/literature found in the syllabi collected among universities and colleges around the U.S. and Norway. Reviewing textbooks and literature and its relevance in this study have been a difficult task, but the main goal has been to find ideal literature that covers the learning outcomes and goals in the course description / syllabus. In total 7 textbooks was reviewed, 5 books were selected on basis of the collected syllabi and 2 books especially recommended by the industry.

1. Refrigeration and Air Conditioning Technology, 8<sup>th</sup> ed., Tomczyk, J., Silberstein, E., Whitman, B., & Johnson, B.
2. AHRI Fundamentals of HVAC/R, 3<sup>rd</sup> ed., Stanfield C., & Skaves, D.P.E.
3. Heating, Ventilation and Air Conditioning Analysis and Design 6<sup>th</sup> ed., McQuiston F. C., Parker J. D., & Spitler, J. D.
4. ASHRAE Air Conditioning System Design Manual, 2<sup>nd</sup> ed., Grondzik, W.
5. 2013 ASHRAE Handbook Fundamentals, ASHRAE – American Society of Heating, Refrigerating and Air-Conditioning Engineers
6. Ventilasjonsteknikk I, 3<sup>rd</sup> ed., (English title: Ventilation Technology I), Ingebrigtsen, S.
7. Ventilasjonsteknikk II, 1<sup>st</sup> ed., (English title: Ventilation Technology II), Ingebrigtsen S.

With the respect of the course's goals, four of the seven reviewed books were considered as appropriate texts; 'Heating, Ventilation and Air Conditioning Analysis and Design, 6<sup>th</sup> ed., '2013 ASHRAE Fundamentals' and 'Ventilasjonsteknikk I & II'. Ventilasjonsteknikk I, also, used at the other Norwegian educational institutions like; the Norwegian University of Science and Technology (NTNU) in Trondheim and the University College of Applied Sciences (HiOA) in Oslo, seem to cover the course's goals and learning objectives the best. The book emphasizes main topics which should be covered in order to reflect the goals and learning outcomes in the syllabi, like; good environmental indoor quality, ventilation system components and moist air ventilation-problems using the Mollier's chart and not the psychrometric chart, which is applicable to the industry norm in Norway with more. The newly published Vol.2, Ventilasjonsteknikk II supplements Vol.1, and covers important topics such as; energy consumption, duct system and dimensioning and scaling of ventilation- and AC- systems applying recognized approaches such as Bahcos 1/3-method. These books are also the only two, out of the seven in this study who consequently refers to current governmental requirements and relevant Norwegian- and European codes and standards, which is an essential part of the course goals. The fact that both textbooks are available both as printed texts and online e-books is an advantage, according to research conducted by the Chronicle of Higher Education Almanac (2013, as featured in Wankat & Oreovicz, 2015) over 89% of all students were satisfied or very satisfied with the use of electronic books. Based on the American books reviewed, one book excelled from the others; 2013 ASHRAE Fundamentals. The text is well designed and easily read, and it is available both in Inch-Pound (IP) and System-International (SI)-units. With the respect of this specific master program Integrated Building Technology, this text can be used in several other courses prior to *Energy- and HVAC-technology*. Based on the review and the book's advantages, 2013 ASHRAE Fundamentals is therefore a greatly recommended textbook used in this master program in general, or optionally as a substitute text.

## 7. Compendium

The printed course compendium that once was a part of the course available for purchase at the student book store is extremely outdated, both in terms of theory and references to requirements in codes which is not relevant to the current standard, and therefore impracticable and useless in today's teaching. However, a handwritten compendium with a collection of ventilation theory, calculation examples and problems by the

lecturer has been available for copying, but the survey shows that this compendium was ranked the lowest regarding access to literature and course resources and comments from former students of the course also addresses the necessity of a new updated compendium. Based on the survey, an updated and improved *Ventilation- and Air Conditioning Technology Compendium* was designed to represent the technology and standards of today's ventilation systems. The new compendium is meant as a supplement the suggested textbooks. It is constructed to reflect upon the syllabus and course's goals, learning outcomes, it is structured and based on lecturer Erling Bøe's original handwritten texts, and is supplied with theory, essentially literature from the textbooks collected in the literature review. The data collected from the student survey has also been used as an important source to identify what elements should be emphasized in the new compendium.

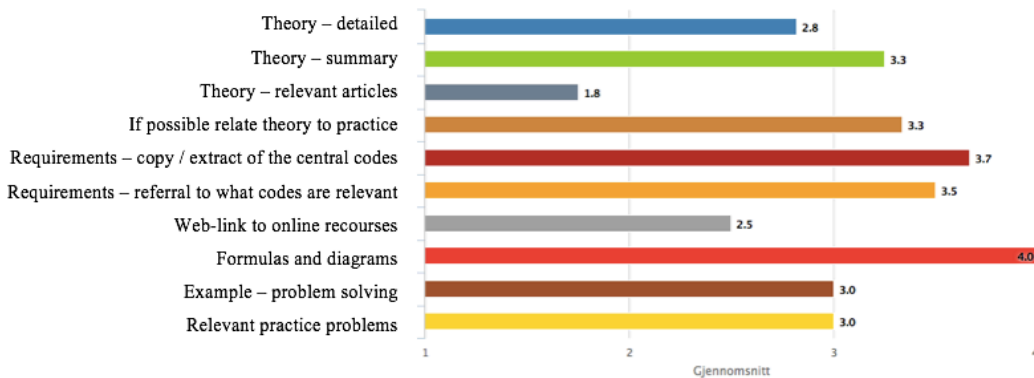


Figure 1. Findings student survey, question #7 "if the university makes a compendium for the class, what should it contain?"

## 8. New Educational Program

### 8.1. Lecture

This course has solely been taught ineffectively through teacher centered blackboard lectures only supplemented with overhead slides, in a 4-hour long session. Like, studies show (Preville, 2016, Goodhew, 2010) it is unrealistic to think that a lecturer can keep students' attention and motivation over several hours of lecture straight, and in this case, getting through all the theoretical material only using the blackboard. The findings from the student survey support the need to refresh and make lectures more time effective, it is necessary to stress that the use well-known visual digital presentation tools, like Microsoft PowerPoint will speed up lectures, as well as provide students with lecture material capturing key topics.

### 8.2. Video

Showing shorter videos can be introduced as active elements to breaking up classic lectures. Video- or animation clips can illustrate a complex process or engineering problem much easier than it is explained in words, and it can easily be accessed online, often free of purchase, like for example YouTube. Free content can understandably vary in quality, but it is certainly possible to find decent videos that can enlighten and reinforce the topic lectured. If one is willing to pay for 'professional' made content, there exists options like for example, *Kompetansebiblioteket's* lecture- and information videos (VVS-TV) or video-courses available in *ASHRAE's* eLearning Center.

### 8.3. Laboratory work

Like a various of studies have shown, PBL in the form of a project or laboratory work significantly improves students' learning and understanding of fundamental engineering principles, it increases motivation and fosters higher level aims like critical thinking skills. For the ventilation- and air conditioning part of the course, a project or/and laboratory work is highly suitable, especially since the class stretches over a full-

semester, but on the other hand also has its constraints of it being limited to two weekly sessions. Findings from the survey show that students are positive to PBL methods such as project or/and laboratory work, individually or in teams, and data from the collected syllabi show that most universities and colleges teaching similar HVAC- and ventilation courses contain laboratory work. What specific type of laboratory experiment was not defined in the syllabi, neither available information on the universities websites, but laboratory work; exercises or demonstrations, will conceivably vary greatly depending upon several different elements like: the university's laboratory facilities, access to lab-equipment, lecturer/lab-staff, class-size, funding etc. If the necessary facilities, resources and sufficient time allow it, laboratory work, either in the form of a facilitated demonstration or student lab-exercise appropriate to air ventilation technology, and to reinforce theory learned in class is greatly recommended to be integrated as a part of this course. The use of technology with computers and simulation software can also be used to assist in both the delivery and assessment of laboratory work, even virtual laboratory work can have great benefits in learning engineering (Davies, 2008). Facilitating a computer lab and familiarizing students with computer programs such as: Revit MagiCAD, Flow3D, BIM, etc. can reinforce the learning outcomes from the lab-work itself.

#### **8.4. Project**

A PBL method approach in the form of a student project is also greatly recommended to be incorporated into the course program. There are several approaches to facilitating a project, it can be individual or in teams and the size, structure and complexity can vary greatly. However, group projects seem to be more beneficial in this case considering time constrains, but also the fact that PBL methodology greatly favors team work where students gain valuable collaborative skills, self-management, leadership, time management and skills on communication and problem solving (Thomas, 2000). For this specific course, a project centered around scaling and dimensioning ventilation systems with the respect of acceptable indoor air quality, can be a very suitable activity to recap and reinforce the theory lectured in class, as well as students gain practical calculation skills which they later will profit from in the following fall-course STE 6270 *Building Engineering Design*. The project can be centered around a 'real-life' engineering challenge, where students get hands on experience by choosing the appropriate air distribution solution, calculating air volumes, defining ventilation unit and its components, size ducts, sketch the distribution and exhaustion network etc., gaining familiarity to technical drawings, governmental requirements, relevant building codes and standards. The final results of the project would preferable be presented in the form of a written and/or oral report summarizing the procedure used to produce the product and present the outcome. Presenting the results to peers will make a basis for a class discussion.

#### **8.5. Assessment**

“One of the most important drivers of student learning is how that learning is assessed and it has been shown that student's attitudes towards their studies are strongly affected by the nature and timing of assessment” (Rust, 2002 as cited in Murphy, 2009:2). Murphy (2009:2) argues that a “well-timed and well-designed assessment can have a powerful impact on how students approach their learning”, the outcome of the survey also show that students would be preferred a more dynamic form of assessment and do not only being graded based on one final exam. The collected syllabi construct a picture of how grading is done in various universities with similar courses in Norway and USA, the student survey also points out opinions and suggestions how to assess and grade this specific course. There is a clear difference between how engineering students are graded in the U.S. compared to Norwegian universities, in this case considering HVAC- graduate courses. The final grade in Norwegian courses is solely based on one single written exam at the end of the semester, in comparison to American universities and colleges which the final grade consisting of several elements throughout the semester such as: class participation, assignments, quizzes, projects and exams. The survey shows that students would prefer a combination between written exam and laboratory-report or/and student project or mandatory assignment(s), ranking either 60/40% or 80/20% exam/assignment higher in comparison to 100% written exam. The preferred form of assessment was on the other hand a little more irrelevant from the students' perspectives ranking the alternatives, like open/closed book, quite equally. If incorporating a lab work or/and project it will be logic and recommended having it count as a percentage of the final grade to keep students motivated and encourage them to get down some serious work and strive for the best possible result.



## 9. Conclusion

**#1 Breaking up lecture:** This course has solely been taught ineffectively through teacher centered blackboard lectures, it is necessary to stress that the use well-known visual digital presentation tools, like MS PowerPoint will speed up lectures, as well as provide students with lecture material capturing key topics. Breaking up lecture with elements of short video clips, discussion groups, etc. can also strengthen the classic lecture structure, keeping students' focused (Goodhew, 2010). Like, Davies (2008:3) points out; "application of theory in a practical setting is an expected and fundamental part of the engineering curriculum", and aiming to link theory to practice should be a goal in designing a new educational program for this course. The survey implies that a physical inspection of an actual system, like the university's own ventilation system is highly desirable. Familiarizing students with 'real life' systems will likely give a broader understanding of the ventilation unit and its components after being lectured the theory in class. A physical inspection has its advantages being easy executable, accessible on-site, not very time consuming and does not require extra resources or a lot of planning. Students are also motivated to either have longer sessions of lectures or more course related work like assignments to efficiently fill the time after class.

**#2 Take advantage of PBL methodology:** Several research supports that it is necessary to consider other teaching methods than classic lecture or supplement these lectures with other activities to motivate and encourage students to deep learning. Active learning methods such as problem-based learning (PBL) which is centered around problem solving has proved to be a well-suited approach to reach that deeper understanding in fields of engineering. A student-centered approach like PBL is an effective way to both motivate students and foster critical thinking skills, and can easily be incorporated as an active element to lectures in this course, which spans over one whole semester. For this course, it is suggested to introduce PBL in the form of laboratory work or/and a student project, as a suitable active element to encourage higher level aims and strengthen the learning outcomes, as a supplement to classic lectures, the survey also shows that students are positive to incorporate methods of PBL.

**Laboratory work:** Laboratory work can either be exercised by the students themselves, by the lecturer in the form of a laboratory demonstration or/and as a computer-lab, depending upon the university's laboratory facilities and resources. It is certainly an active element that can reinforce theory in a practical way, and can be designed as complex or simplified whichever suits the rest of the content of the course. Report writing is a skill highly relevant to the engineering profession (Gibbs et al., 1997 featured in Davies, 2008) and could logically be given as an assignment to recap the topic and highlight the theory and learning outcomes, if necessary due to time constrains, the report can be completed in groups, as a short presentation etc. Facilitating a computer lab, for example letting students play around in a pre-made BIM-model guided by an instructor, or optionally introduced to students by a demonstration in class can be interesting and inspiring.

**Project:** A student project can also easily be a good fit for the ventilation-part of the course, for example, a project built upon scaling and dimensioning ventilation systems with the respect of acceptable indoor air quality, which is a central part of the course goals as well as it being valuable skills needed in the following fall-course *Building Engineering Design*. The project can be centered around a 'real-life' engineering challenge, where students get hands on experience with calculating air volumes, defining unit components, size duct, etc., gaining familiarity to technical drawings, governmental requirements, relevant building codes and standards and so on. Presenting the results for peers will increase students' presentation skills and make a good basis for group discussion.

**#3 Appropriate textbook and literature recourses:** The existing course did not have any required texts in the form of textbooks, etc., and it was only supplemented with a handwritten course compendium. The survey showed a strong necessity of having access to appropriate literature preferable in the form of a textbook (printed or e-book) as well as upgrading the compendium to today's standard. An extensive literature review of HVAC- and ventilation textbooks were evaluated in contradiction of the course goals and learning outcomes. In this context, Ventilasjonsteknikk I & II (Ingebrigtsen, S., 2016) seemed to undoubtedly be the best suited texts, it also has its advantages being available as e-books, and are easy accessible and reasonably priced in comparison to many of the other textbooks. Based on findings in the survey and the strong necessity for an updated course compendium, a new compendium was designed to complement the textbooks, highlight and fulfill the course's goals in the syllabus and key data collected from the survey made the foundation for the design, content and topics emphasized.

**#4 Examination and grading:** With the respect of contributing the course with a new compendium, the examination in this case will logically be a written exam restricted to permitted aids being calculator and course compendium. Since the suggested literature is available as e-books, which many students likely will prefer, it will create a conflict having an open-book exam indirectly imposing students to purchase the printed texts. The course compendium should be sufficient both in terms of formulas, diagrams, and theory, and it will also motivate students to become familiarized with the text throughout the semester. In comparison to the American grading model and based on the survey, it is recommended that laboratory work or/and project should be considered in the assessment, and it is suggested to count as a percentage of the final grade in addition to the regular 5-hours written exam.

In brief, facilitate lectures with visual tools and breaking them up with active elements, incorporate PBL methods, such as laboratory work or/and course project, take advantage of appropriate literature and breaking up assessment into several elements will strengthen the course, encourage and motivate students and foster higher level learning.

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