Department of Building, Energy- and Material Technology

Ventilation & Air Conditioning 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, Designing a Syllabus, Ventilation & air-Conditioning, HVAC Technology,
Table of Contents

Abstract ................................................................................................................................. 1

1. Introduction ...................................................................................................................... 4

2. Background ...................................................................................................................... 4

3. Methods .......................................................................................................................... 5
   3.1. Survey ....................................................................................................................... 5
   3.2. Collecting Syllabi .................................................................................................... 5
   3.3. Literature Review ..................................................................................................... 6

4. Teaching Engineering ...................................................................................................... 6
   4.1. Develop Critical Thinking Skills .............................................................................. 7
   4.2. Higher-Level Aims .................................................................................................. 8
   4.3. Methods and ‘Teaching Styles that Works’ .............................................................. 8
   4.4. Problem Solving ....................................................................................................... 9
   4.5. Subject Based Learning - Classic Lecture ............................................................... 9
   4.6. Active Learning ....................................................................................................... 10
   4.7. Problem Based Learning ......................................................................................... 11
   4.8. Experimental Learning / Laboratory Based Learning ........................................... 16
   4.9. Technology Enhanced Learning ............................................................................. 18
   4.10. The Power of Feedback ......................................................................................... 20

5. Syllabus .......................................................................................................................... 20
   5.1. Constructing a Syllabus ........................................................................................... 20
   5.2. The Purpose of a Syllabus ....................................................................................... 21
   5.3. Learning Outcomes and Course Goals ................................................................. 22

6. Student Survey ............................................................................................................... 23
   6.1. Student Survey Findings: ....................................................................................... 23
   6.2. Survey Summary and Conclusion .......................................................................... 26

7. Literature ......................................................................................................................... 27
   7.1. The use of Textbooks ............................................................................................. 27
   7.2. Reader ...................................................................................................................... 27
   7.3. Literature Review .................................................................................................... 28
   7.4. Literature Summary and Conclusion ..................................................................... 30
8. Compendium ........................................................................................................... 34
  8.1. Content of Compendium.................................................................................. 34
9. Presentation material ............................................................................................... 36
  9.1. Power Point.................................................................................................... 36
  9.2. Video Content ................................................................................................ 37
10. Lab / Project .......................................................................................................... 37
    10.1. Laboratory Work ......................................................................................... 37
    10.2. Student Project ............................................................................................ 39
11. Assessment ............................................................................................................ 39
12. Conclusion .............................................................................................................. 42
13. Future Work .......................................................................................................... 45

Bibliography .............................................................................................................. 46
Appendix A. Syllabus .................................................................................................. 48
Appendix B. Student Survey ....................................................................................... 52
Appendix C. Overview - Collected Syllabi ................................................................. 72
Appendix D. Book Information - Literature Review ................................................... 73
Appendix E. Suggested Video-Clips .......................................................................... 82

Figures and Tables

Figure 1. PBL in contrast to subject based learning ....................................................... 12
Figure 2. Response to questionnaire (Toulouse et al. 2008). ....................................... 15
Figure 3. Findings #1 Student Survey ....................................................................... 23
Figure 4. Findings #9 Student Survey ....................................................................... 23

Table 1. Levels of autonomy for types of laboratory activity ..................................... 16
Table 2. Literature compared to learning outcomes and course goals ....................... 29
Table 3. Literature compared to course skills ............................................................... 29
Table 4. Laboratory exercise at different universities and colleges ............................ 38
Table 5. The form of examination at different universities and colleges ..................... 40
Table 6. Advantages and disadvantages with different assessment forms .................. 41
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 paste 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.

“Student’s today know that they are training themselves for jobs and technologies that don’t yet exist. They need to be highly adaptable” (Preville, 2016:11).

2. Background

The master program Integrated Building Technology taught at the University of Tromsø (UiT) Campus Narvik, focuses on the relation between the building and its technical installations and the courses consists of a combination of fundamental- and specialized engineering subjects. To be able to understand a building, analyze and solve problems and to lead and manage construction projects, it is necessary with knowledge about the different elements involved, and how they interact with each other, both in the designing phase and in operation after the building is completed. The master program; Integrated Building Technology gives the students a perspective of the larger picture, an understanding of the complexity of a building and its technical installations, and how these different elements relate to each other with a special focus on energy performance and indoor environment quality. The program gives knowledge about sustainable building- and construction technology, building physics, energy- and HVAC-technology, fire engineering, building materials as well as operation and maintenance of existing structures.
The course STE 6230 Energy- and Heating, Ventilation- and Air Conditioning (HVAC) -Technology is a central part of the program and has been a part of the syllabus since the program started in 1991, and is considered as more important than ever for engineers, both for those who are aiming to in the consulting businesses as those who are headed towards working in the field for a contractor firm. Since 1991, several professors and lecturers have been responsible for teaching the course, equivalent with the rapid change in the industry, new technology and firmer building codes. Today, in 2017, it is therefore time for a major makeover to increase the course’s quality and relevance as well as keeping it up to date.

This master thesis’ focus will be to design an enhanced syllabus and make suggestions to a new educational program for the ventilation and air conditioning part of the course Energy-and HVAC- Technology. The course description and learning outcomes will remain the same, but the thesis will study research conducted on how to teach in the modern classroom, specifically how to teach and learn higher level engineering, collect and examine syllabi from other universities and colleges with similar courses, do a comprehensive book and literature-review based on the collected syllabi, conduct a thorough analysis of previous students’ evaluation of the existing course and evaluate its strengths and weaknesses as well as improvement potential and make suggestions how to construct an upgraded course.

3. Methods

3.1. Survey

To analyze the existing course’s 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.

3.2. Collecting 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 websites. 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.

3.3. 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’s 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.

4. 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 slower 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. In the view of what time we are living in, Goodhew (2010:101-102) raises some speculative, but interesting statements about where engineering education is unlikely to remain static and where:

• In the future, graduate working lifetimes are likely to be less than 50 years
• There will be regular national and international crises and ‘grand’ challenges thinking of global warming, energy, water etc.
• There will be rapid change in ways we cannot today imagine and the rate of change will be higher
• Information will be readily accessible, by almost everyone, everywhere
• There will be new engineering disciplines
• Biology will become more important, and more controlled
• Engineering and understanding will be even more crucial to the operation society

And this rapid change can consequently cause:

• Fewer individuals will be prepared to spend more than 4-5 years on their initial formation as engineers
• The apparently most important applications of engineering in terms of addressing society’s issues will change every 10 year or so
• Bio-inspired processes will become important to engineers
• That we cannot, and will not be able to, demand depth of study in all areas deemed ‘important’ by any group of engineers

Further, can expertise, knowledge, appreciation, communication skills and societal understanding be more important attributes of the future engineering graduates (Goodhew, 2010). However, one cannot predict what the students of today will need to learn in the future, but it is of even greater importance than ever to keep track of time, current technology and the engineering course’s relevance.

“The pipe is more important than the content within the pipe. Our ability to learn what we need for tomorrow is more important than what we know today. A real challenge for any learning theory is to actuate known knowledge at the point of application. When knowledge, however, is needed, but not known, the ability to plug into sources to meet the requirements becomes a vital skill. As knowledge continues to grow and evolve, access to what is needed is more important than what the learner currently possesses” (Siemens. 2005)

Referring to Siemens (2005), this thesis is as much about ‘the pipe’, the actual structure and frame of the course as it is the actual ‘content of the pipe’, in this case HVAC- and ventilation & air-conditioning theory and principles, I will therefore explore and try to highlight the recent research and main conclusions among studies about how to best teach- and learn engineering.

4.1. Develop Critical Thinking Skills

An instructor’s goal of any university level introductory course is to give students an understanding of the basic principles of the subject, as well as the importance of guiding them to develop higher order skills, like critical thinking; an intentionally application of higher order thinking, making reasoned judgements or where one actively and skillfully conceptualize, applies, analyzes, and evaluates information gathered from observation, experience, reflection, reasoning or communication, as a guide to belief and action (Angelo, 1995, Beyer, 1995, Scriven, 1996, as cited in UTC, 2017). A part of the reason why students do not develop their critical thinking skills may be found in the idea that students establish a comfort zone, which is hard to break out of. Students have over their years of schooling picked up success strategies, like the memorization of content and delivery of that memorized material in examinations, which do not gain higher order thinking skills. Kalman (2008) therefore stresses the importance of enhancing student’s critical thinking skills and encourages to activities like conceptual conflict exercises and critical discussions in the classroom.
4.2. Higher-Level Aims

Higher-level aims are defined as those who go beyond learning the specific use of equipment. Gibbs et al. (1997, as cited in Davies, 2008:4-5) recommend “the design of practical work should take a pragmatic approach targeting only aims that can be realistically achieved given the resources available” such as:

- Developing experimental, design, problem-solving and analysis skills
- Developing data-recording and analysis skills
- Familiarising students with equipment techniques and materials
- Developing practical skills
- Developing communication and interpersonal skills
- Developing technical judgement and professional practice
- Integrating theory and practice
- Motivating students

A key goal of the study of engineering education is to facilitate the students’ development as lifelong learners and to equip them as graduates to start a professional engineering career. Stressing these higher-level aims is necessary to successfully achieve this goal (Davies, 2008:5).

“…engineering education will never be satisfactory until theory and practice are taught simultaneously…” (Carnegie Foundation Mann, 1918, as cited in Goodhew, 2010:13).

4.3. Methods and ‘Teaching Styles that Works’

What types of teaching methods and what really works are and will always be a theme for discussion. Wankat & Oreovicz (2015:9-11) have listed 19 ‘known-to-work’ methods that based on numerous papers and various books of different authors:

1. Guide the learner. Be sure that the students know the objectives
2. Develop a structured hierarchy of content
3. Use images and visual learning
4. Ensure that students are active by writing or speaking
5. Require practice by task, problem solving
6. Check for understanding frequently
7. Provide feedback and give directions
8. Communicate expectations
9. Have positive expectations of students
10. Provide means for students to be challenged yet successful and provide enough time
11. Individualize teaching style by using a variety of styles and learning exercises
12. Make the class cooperative by using group exercises
13. Ask thought-provoking questions
14. Be enthusiastic and demonstrate the joy of learning. Enthusiasm is motivating
15. Encourage students to teach each other. Students who teach others learn more
16. Care. Professors who puts teaching on “automatic” cannot do an outstanding job
17. Track student performance and share the result with the students
18. Determine effective routines for transitions, disseminating, materials, collecting assignments
19. Separate teaching from evaluation. If a different person does the evaluation the teacher becomes a
couch and ally whose goal is to help students learn

4.4. Problem Solving

The most common way of designing a course and curriculum in engineering education is to put all the
fundamentals first, once these have been covered the course can proceed to practical and real-life
problems. Most learn best when they know why they need to learn something, introducing a real-life
problem early can help motivate students. Watching someone else solve problems does not make one
a good problem solver, and students must solve volumes of problems several times in order to become
good problem solvers. Solving problems collaboratively in groups both in and out of class is also
effective to increase these skills since the interactions help many students (Wankat & Oreovicz, 2015:62), the use of collaborative learning strategies, like group learning is also the best way to foster
critical thinking (Cooper, 1995 as featured in UTC, 2017).

“The practices of engineering are meaningless outside of the context of the entire problem-solving
process” (Cunningham & Carlsen, 2014: 201).

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).

4.5. Subject Based Learning - Classic Lecture

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. Goodhew (2010) claims that this way of teaching only seems to be efficient in
transmitting information, defining the syllabus to the students and then to be examined on the content.
The lecture is a popular way for professors and lecturers to mass transfer knowledge and seem like a painless way for students of delineating what they need to memorize to pass the exam, but almost every 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).

Activities that can be introduced as active elements to classic lectures can for example be:

- Asking a question
- Do demonstrations, play a video
- Calculations – either demonstrate or make the student alone or in a group calculate
- Discussion group
- Mini-quiz

One study that backs up this theory is a study conducted at The Catholic University in Washington, D.C., which showed that students’ attention spans during traditional lectures, and do not even last for 10 to 20 minutes. Students constantly fluctuate between engagement and disengagement in ever-shortening cycles (Bunce, Flens & Neiles, 2010 as featured in Preville, 2016), Philip Preville even states: “after 200 years, we have clearly reached the point where the traditional pedagogical model is irretrievably broken” (Preville, 2016:3). 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).

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.

4.6. Active 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). One of the drivers of active learning has been the creation of the ‘new’ European Higher Education Area (EHEA), a model which involves a transition from an educational system based on teaching, to a system based on learning, making students the center of the learning process. In teacher-centered instruction, students are not given the opportunities to construct their own understandings of science, information is poured into them without participation on their part. Various kinds of student-centered instruction, like the use of active learning forces students to examine their views and can help them develop intellectually (Kalman, 2008:11). 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 project 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 students’ attitudes, study habits and perhaps also increase their performance (Thomas, 2000).

4.7. Problem Based Learning

Problem based learning (PBL) also identified as project based learning, is an educational strategy where learning is driven by problem solving. The method was first introduced to medical students at McMaster University, Hamilton, Ontario, Canada in 1969, were students were supposed to learn primarily by self-directed studies in groups and a number of lectures were limited to one or two. Almost 50 years later, PBL stands very strong in medical education but has later also been embraced in other fields like economics- and business, psychology, law, biology and engineering (O’Grady et al. 2012:22).

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 and begins with an assignment to carry out one or more tasks/problems usually with no preliminary preparation, but their prior knowledge, that conclusively will lead to the production of a final product, a design, a model, a device or a computer simulation. The finale of the project is normally a written and/or oral report summarizing the procedure used to produce the product and present the outcome (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). PBL methodology promotes responsibility and independent learning as students must collaborate and learn to work together to find solutions to problems (Krajcik et al. 1999 as featured Rodriguez et al. 2015). A study on classroom based pedagogy found that active and collaborative learning and students being involved in the educational process are better ways to learn in
comparison to subject-based learning. The authors identified the following attributes (Smith et al. 2005 as cited in Ciocanel & Elahinia, 2008:3):

- Learning is student-centered
- Learning occurs in small student groups
- Teachers are facilitators or guides
- Problems are the organizing focus and stimulus for learning
- Problems are the vehicle for the development of problem solving skills
- New information is acquired through self-directed learning

![Figure 1. PBL in contrast to subject based learning (Smith et al. 2005 as cited in Ciocanel & Elahinia)](image)

Goals of PBL include develop student’s (Bridges et al. 2012:3):

1. **Flexible knowledge** beyond learning simple facts; flexible knowledge integrates information across multiple domains in long-term memory
2. **Effective problem-solving skills** ability to apply appropriate metacognitive and reasoning strategies. Different strategies may be appropriate for different domains and for different problems
3. **Effective self-directed learning skills** they must be able to plan how to achieve their goals, developing lifelong learning skills: being a self-regulated learner
4. **Effective collaboration skills** effectively participating in a small group
5. **Intrinsic motivation** which occurs when learners work on a task for their own satisfaction, interest, or challenge

Thomas (2000:3-4) lists five aspects that should be considered in PBL projects:
- Projects are central, not peripheral to the curriculum
- Projects are focused on questions or problems that drive students to encounter the central concepts and principles of a discipline
- Projects involve students in a constructive investigation
- Projects are student driven to some significant degree
- Projects are realistic, not ‘school like’
and PBL methodology emphasizes activities which:

- Are long-term
- Are student-centered
- Are based on collaborative team learning
- Are integrated with real world practices
- Have productive outcomes
- Have an impact on skills like self-management, teamwork, leadership, time management, communication and problem-solving
- Use of technology-based tools

“In order to promote flexible thinking, problems should be complex, ill structured, and open ended; to support intrinsic motivation, they must also be realistic and connect with the learners’ experiences” (Bridges et al. 2014:7). Sockalingam & Schmidt (2012 as featured in O’Grady et al. 2012:150) defines 11 key characteristics of PBL problems:

1. Lead to learning issues / goals
2. Trigger interest
3. Relate to, or fits student’s prior knowledge
4. Be of suitable format
5. Stimulate critical reasoning
6. Promote self-directed learning
7. Be suitable clarity
8. Be of appropriate difficulty
9. Enable application or use
10. Stimulate elaboration
11. Promote teamwork

A study among students in a PBL environment in Space Engineering education at the Technical University of Madrid conducted by Rodriguez et al. (2015), showed that PBL methods encourage students’ motivation and improve results. The results of a two-year survey of the students in this study showed that:

- PBL students felt more confident about their technical knowledge than students who only attended class and not participated in the PBL process
- PBL increased student’s motivation, satisfaction and interest in the subject topics
- A PBL approach enhanced learning outcomes and improved student’s confidence in technical skills as well as transversal skills that classical learning methods not necessary develop
- PBL required more effort and dedication from students than classical lectures
This dynamic of working in teams ensures that no individual alone can achieve the goal if their peers do not. This type of interaction involves attitudes that facilitate support, and the students are stimulated by both their own classmates and their teachers, which has an impact on motivation and ultimately on academic performance (Johnson & Johnson, 2009 as featured in Basilotta Gómez-Pablo et al. 2016).

The lecturers in this specific study had a deep professional relation to the project and the space industry, an important factor in PBL and project work is that instructors with the lack of real engineering experience can be a problematic (Rodriguez et al. 2015). The instructor’s role in the process of integrating and making PBL successful in the classroom is fundamental, and in order to achieve this the instructor needs to (Railsback, 2002:24):

- Define the problem and what skills which are required to carry out the project
- Determine the contribution of the project to learning objectives and establish an action plan
- Be supportive during the execution and evaluation of the project
- Facilitate and guide student’s decision making, thinking and problem solving
- Facilitate an assumption of student’s responsibilities
- Promote the development of interpersonal skills such as socializing and teamwork among students.

The result of a teacher’s evaluation of PBL in different schools in Spain conducted by Basilotta Gómez-Pablo et al. (2016) showed that in general PBL was experienced as positive in terms of the development of the learning process and the results achieved from the projects. Factors that stood out in the teacher’s evaluation was; students’ active participation and motivation, students’ capacity to take on responsibilities, and complementary roles that allow them to develop the tasks autonomously and through interacting and collaborating with peers. Also in terms of results there was a positive evaluation of the achievement of various types of skills such as digital, metacognitive, emotional and social, as well as the development of their creative capacities. Another aspect of the same study discovered that teachers found integrating PBL difficult; due to the lack of support from the upper management, shortage of material and technological resources, but also the lack of necessary time, not only in terms of their coordination with other teachers, but also regarding the students’ collective reflection on the work process. PBL work requires time for students to discuss, reflect on and achieve expected learning outcomes which are highly valuable in PBL (Basilotta Gómez-Pablo et al. 2016).

“If ‘understanding engineering’ is to be an educational goal, students will need experience doing complete engineering projects” (Cunningham & Carlsen, 2014:202)

Bridges et al. (2014:30-31) features a study by Toulouse et al. (2012) which gathered data from nine different batches of pharmaceutical students from 1996-2005 to evaluate PBL. The findings from this study are shown in Figure 2, along with the data, comments supplied go the surveys were interesting findings as well.
Most survey respondents indicated a frustration with the workload of PBL. One survey respondent wrote:

> Emphasis should be put on the fact that lecture-based courses are necessary/essential as it would take a super human to complete a solely PBL program.

Despite the workload, most indicated a high degree of satisfaction with the program, as one respondent indicated:

> I have been challenged beyond any expectation that I could have had and I feel satisfied and fulfilled to have completed the program successfully.

Responders felt confident with their skill-set upon graduation. One respondent wrote:

> Some of the most valuable skills to me include oral and written communication and ability to work as a team.

However, there were quite a few who commented on the disparity in work ethics of their classmates:

> I am a hardworking, honest, self-motivated person. Other people are not and just want to cut corners. This is the one major flaw of PBL in undergrad and the main reason why I think the lecture format should not be totally exchanged for PBL.

All I can conclude from all my experiences over 3 years in BioPharm is that it has given me guidance, purpose and ambition – who could ask for more?

The survey indicates that learners rate PBL quite high in areas that have particular relevance to real-world working environments where communication skills, initiative and working well in groups are of fundamental importance (Toulouse et al. 2012 as cited in Bridges et al, 2014:31).

<table>
<thead>
<tr>
<th>Items</th>
<th>Lecture format (Mean±SD) N = 88</th>
<th>PBL format (Mean±SD) N = 88</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ABILITIES</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Learn on your own</td>
<td>3.69±1.00</td>
<td>4.88±0.33***</td>
</tr>
<tr>
<td>2. Contribute as a group member</td>
<td>2.13±1.04</td>
<td>4.81±0.45***</td>
</tr>
<tr>
<td>3. Make decisions</td>
<td>2.78±1.13</td>
<td>4.34±0.75***</td>
</tr>
<tr>
<td>4. Solve problems</td>
<td>2.78±1.10</td>
<td>4.69±0.49***</td>
</tr>
<tr>
<td>5. Gather information</td>
<td>2.89±1.14</td>
<td>4.91±0.28***</td>
</tr>
<tr>
<td>6. Analyse information</td>
<td>2.93±1.07</td>
<td>4.73±0.43***</td>
</tr>
<tr>
<td>7. Evaluate your own performance</td>
<td>2.35±1.24</td>
<td>4.59±0.57***</td>
</tr>
<tr>
<td>8. Work effectively with different personalities</td>
<td>2.25±1.01</td>
<td>4.56±0.62***</td>
</tr>
<tr>
<td>9. Function in a high-stress environment</td>
<td>3.67±1.05</td>
<td>4.31±0.67***</td>
</tr>
<tr>
<td><strong>SKILLS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Time management</td>
<td>3.85±1.00</td>
<td>4.54±0.72***</td>
</tr>
<tr>
<td>2. Oral communication</td>
<td>2.26±1.02</td>
<td>4.64±0.49***</td>
</tr>
<tr>
<td>3. Written communication</td>
<td>3.54±0.96</td>
<td>4.47±0.64***</td>
</tr>
<tr>
<td>4. Presentation</td>
<td>2.90±1.01</td>
<td>4.56±0.71***</td>
</tr>
<tr>
<td>5. Critical analysis</td>
<td>2.45±1.05</td>
<td>4.67±0.49***</td>
</tr>
<tr>
<td><strong>OTHER</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Higher grades</td>
<td>3.81±0.83</td>
<td>4.16±0.81***</td>
</tr>
<tr>
<td>2. Higher self-esteem</td>
<td>3.69±1.13</td>
<td>4.06±0.95***</td>
</tr>
<tr>
<td>3. Close peer network</td>
<td>2.49±1.13</td>
<td>4.39±0.95***</td>
</tr>
<tr>
<td>4. Knowledge in general concepts</td>
<td>3.91±1.04</td>
<td>4.59±0.64***</td>
</tr>
<tr>
<td>5. Specific knowledge in a given area</td>
<td>3.75±1.11</td>
<td>4.64±0.57***</td>
</tr>
</tbody>
</table>

Note: differences significant (** p < 0.01  *** p < 0.001) using a Wilcoxon Sign-Rank Test Data gathered from nine different batches of students (96, 98, 99, 2000, 2001, 2002, 2003, 2004, 2005)

Figure 2. Response to questionnaire Toulouse et al. 2012
4.8. Experimental Learning / 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).

“A key goal for the study of engineering in achieving higher level aims is to facilitate students’ development as autonomous, lifelong learners…an important general goal for the laboratory-based learning …is to foster students’ understanding of the process of scientific enquiry and the ways in which knowledge is created and validated, fitting well with a common institutional goal of linking research and teaching” (Gibbs et al. 1997 as cited in Davies, 2008:5).

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, Table 1 shows five design options that differ in the extent to which they foster student choice and autonomy and considered ‘open’ or given by the lecturer (Hazel & Baillie, 1998 as cited in Davies, 2008).

<table>
<thead>
<tr>
<th>Autonomy</th>
<th>Type of laboratory activity</th>
<th>Givens Aims</th>
<th>Givens Material</th>
<th>Method Given in part or whole</th>
<th>Answer Open</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Demonstration</td>
<td>Given</td>
<td>Given</td>
<td>Given</td>
<td>Given</td>
</tr>
<tr>
<td>1</td>
<td>Exercise</td>
<td>Given</td>
<td>Given</td>
<td>Given</td>
<td>Open</td>
</tr>
<tr>
<td>2</td>
<td>Student enquiry</td>
<td>Given</td>
<td>Given in part or whole</td>
<td>Given in part or whole</td>
<td>Open</td>
</tr>
<tr>
<td>3</td>
<td>Open-ended enquiry</td>
<td>Given</td>
<td>Open</td>
<td>Open</td>
<td>Open</td>
</tr>
<tr>
<td>4</td>
<td>Project</td>
<td>Open</td>
<td>Open</td>
<td>Open</td>
<td>Open</td>
</tr>
</tbody>
</table>

Table 1. Levels of autonomy for types of laboratory activity (Hazel & Baillie, 1998 as cited in Davies, 2008)

Clara Davies (2008) suggests possible uses and design considerations for different approaches to laboratory activities (Davies, 2008:11):

**Demonstrations**

- To show features of a piece of equipment and how it works
- To demonstrate a particular concept by theory
- Effectively ‘show and tell’ approach but could be made more interactive by students being asked questions to prompt thinking
Exercise

- To use a skill or technique accurately
- Students follow a procedure to obtain a known outcome – a traditional approach that cannot achieve all goals for practical work and tends to focus on procedure rather than enquiry
- Students need to know the aims and why it is important to them, their learning and to potential careers

Student enquiry

- To foster a deep approach to laboratory learning by encouraging students to take personal initiative (e.g. planning, experimental design, choice of variables, selection of materials and methods)
- Students are presented with a problem or series of research questions that can be based on real life, together with suggestions for resource materials and a range of equipment/ materials to choose from
- The range of possible outcomes produces individual student solutions and opportunities for collusion and plagiarism are reduced

Open-ended enquiry

- As student enquiry but with more decisions and experimental design considerations resting with the student

Project

- As above but more major pieces of work that simulate real-life research and development

A study of teaching engineering in laboratories by Ciocanel & Elahinia (2008) conducted at the University of Toledo, Ohio, USA proved significantly enhanced understanding of fundamental engineering principles when they transformed the learning process of a senior mechanical engineer course from subject-based learning in PBL in laboratories over three semesters. The redevelopment of the class was built up on fundamental PBL principles, instead of following a step-by-step procedure, the students were required to design the procedure themselves and solve a problem by testing the problem from different scenarios, as engineers, solving practical issues and analyzing the problem from multiple perspectives. After each experiment, students presented their process and results for the lecturer and peers to provide feedback, improving student presentation skills significantly. A draft of a written lab-report was also submitted, evaluated by the lecturer and returned to students with written comments addressing suggested revisions before resubmitting a final report. The contribution to the final grade was 40% of the first draft and 60% for the final report. The outcome of this redevelopment of the course, exposing students to real life like engineering experiences proved to be a suitable platform to improve students’ learning. However, the analysis of this specific study indicates that the implementation methodology can be improved regarding reducing students’ time consumption of report writing and presentation (Ciocanel & Elahinia, 2008).
Report writing is a skill highly relevant to the engineering profession, but laboratory reports can often be time consuming to produce and to mark and perhaps unrealistic to evaluate the full report for every laboratory activity undertaken. The following alternatives can be taken into consideration to traditional report writing (Gibbs et al. 1997 as cited in Davies, 2008:16):

- Group reports
- Presentation
- Writing a user manual / guide
- Poster
- Laboratory work book
- Instant report submitted after the lab
- Laboratory exam

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).

4.9. 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).

Bringing technology into the classroom can offer infinite possibilities, here is a selection of accepted aid used in TEL (Goodhew, 2010, Preville 2016, Kharbach, 2014, McGuire, 2016):

- **Podcasts**: episodic series of digital media files, usually audio or video formats
- **Wikis**: websites that provides collaborative modification of its content and structure directly from the web browser.
• **Educational blogs**: can be discussions or informational websites published online consisting of discrete, often informal diary-style text entries ("posts")

• **Social media**: computer-mediated technologies that allow the creating and sharing of information, ideas, career interests and other forms of expression via virtual communities and networks (Ex: Facebook, LinkedIn).

• **Twitter**: an online news- and social networking service where users post and interact with messages, "tweets," restricted to 140 characters. Registered users can post tweets, but those who are unregistered can only read them.

• **Youtube**: the world's largest website to upload, view and share videos. Huge variety, a lot of educational oriented videos / animations etc.

• **Slideshare**: a global hub of professional content with over 18 million presentations, infographics, videos and documents.

• **Flickr**: an image- and video hosting website and web services.

• **Online surveys tools**: a type of survey that is conducted online mostly due to its convenience and efficiency. Ex: Questback, SurveyMonkey, Typeform, Google Forms, Qalitrics.

• **Online Quizzes and polls**: create and share online quizzes. Ex: Socrative, Google Forms, Fluraboo, ThatQuiz, ExamTimeQuizzes.

• **Google Doc**: online word processor that lets students create and format documents and work with other people in the classroom.

• **Visual digital presentation tools**: Ex: MS Power, Point Prezi, SlideRocket.

• **Trello**: tool to organize and streamline assignments. Trello is a free and user-friendly tool students can use to create workflow charts. Multiple students can be added to the same board, great for collaboration on projects.

• **TopHat**: cloud based teaching platform for colleges and universities.

In the matter of fact, the 2016 Professor Pulse Survey with more than 21,000 university faculty respondents worldwide found that 69% of faculty use technology and e-learning management systems, while 49% use social media such as Facebook, Twitter and YouTube. And while many classrooms maintain a taboo against using smartphones during class, 37% of survey respondents incorporate mobile devices into their learning (Preville, 2016:3).

Preville (2016) proposes that class material and instruction must be constantly updated and improved to keep student engaged:

• Use digital textbooks and incorporate up-to-date relevant links and reference material

• Break up the lecture with video content and social media case studies

• Record student presentations as a part of assessments and feedback
4.10. **The Power of Feedback**

A student satisfaction survey conducted among students in the UK between 2005-2010 showed that one of the consistent problems identified was inadequate feedback on assessments (Goodhew, 2010:75).

Feedback might take form in:

- Written marginal comments on each piece of work
- Boxes indicating common errors ticketed on a cover sheet
- Verbal feedback
- Comments posted
- Solution manual to problems
- Tutorial sessions

"Effective feedback on work submitted is crucial in helping students learn by pinpointing where they may be going wrong and what they need to improve" (Murphy, 2009:2).

Feedback should include positive comments as well as negative and written comments must be as clear and straightforward as possible, Goodhew (2010) also recommends the use of active feedback such as discussing problems in class or in smaller groups.

5. Syllabus

*Syllabus*: “the subject or topics studied for a particular course, it is a document which lists these subjects and state how the module will be assessed” (Goodhew, 2010:34).

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, see Appendix A.

5.1. **Constructing a 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, FSU, 2011).

5.2. The Purpose of a Syllabus

The purpose of a syllabus (FSU, 2011):

1. Aids the instructor in course design and development
   a. Provides the framework for the course
   b. Helps determine the course content
   c. Helps organize and structure course material
   d. Helps pace the course
   e. Clarifies course goals and strategies for achieving them

2. List general administrative and logistical information
   a. Provides information about the course and the prerequisites
   b. Contact information to the professor
   c. Schedule and meeting times and meeting places
   d. Textbooks and material, and where to find them
   e. Laboratory information

3. Delineates policies and expectations
   a. Course requirements, general policies like attendance, participation, late assignments, missed work
   b. Grading policies

4. Presents and overview of course content
   a. Course content, perspective, goals and learning outcomes
   b. Course scope, coverage, sequence, course structure and organization, goals
   c. Explains how course content fits within the context of discipline, careers

5. Provides information on schedules, assignments and exams
   a. Gives the specific course topics, when the topics will be covered and information about assignments and exam(s)
   b. Class schedule, assignment and exam due dates
5.3. Learning Outcomes and Course Goals

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)

Terms that might be used when defining LOs (UK-SPEC, 2004 as featured in Goodhew, 2010:20):

- **Knowledge** is information which can be recalled
- **Understanding** is the capacity to use concepts creatively, for example in problem solving, in design, in explanations and in diagnosis
- **Know-how** is the ability to apply learned knowledge and skills to perform operations intuitively, efficiently and correctly
- **Skills** are acquired and learned attributes which can be applied almost automatically
- **Awareness** is general familiarity, albeit bounded by the needs of the specific discipline

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
6. Student Survey

The class of 2017 that completed the course *Energy- and HVAC Technology* the spring semester of 2016 was asked 10 questions though 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.

In total, 20 students were asked to participate in the survey by personal email invitation as well as the survey-link was posted on the class’ Facebook group. The survey was made available online for 1 month and 66.7% of the graduating students of ‘17 responded. Ideally, a higher number of participants would have been more desirable, but considering the size of the class and the purpose of the survey in the search for ‘best practice’ these findings were highly compatible and established a good foundation for further work.

6.1. Student Survey Findings:

a. How satisfied are students with the lectures in the course STE6230 spring 2016 on a range from 1 very dissatisfied to 6 very satisfied?

Overall the students were somewhat satisfied with the course (3.7). The instructor’s level of knowledge was almost unanimous perceived as high (5.3) and students also seemed satisfied with his engagement (4.3). Elements ranked slightly more moderate was the form of lectures – the old fashion blackboard and overhead lectures (3.7) as well as the instructor’s ability to present the course content (3.8).

![Figure 3. Findings student survey question #1](image-url)

"How satisfied are you with the lectures in the course STE6230 spring ’16 from 1-6, where 6 is very satisfied"
b. Students evaluated their strength and weaknesses in a range of ventilation- and air conditioning skills and knowledge up against the course description and the course learning objectives ranking their skills on a scale from 1 poorly to 5 very strong:

The students felt most confident in ventilation systems and principals (3.5) and calculating air quantities (3.5) and cooling loads (3.4), followed by knowledge about the requirements to ventilation- and air conditioning systems (3.2) and Dimensioning energy efficient ventilation systems (3.2). The students evaluated their weaknesses to be; governmental requirements, codes and industry norms (2.7) and dimensioning and scaling ventilation- and air conditioning systems promoting acceptable indoor air quality (2.9).

c. Students evaluated several different parameters on a range from 1: not relevant to 5: should absolutely have been a part of the course, according to whether they thought these elements would increase the quality of the course.

Students ranked a physical inspection of an actual ventilation- and air conditioning system as the #1 parameter (4.3) they would have wished was a part of the course, followed by the ability to read actual technical drawings as a good follow up (3.9). Also, a laboratory demonstration (3.8), elements of video content in lectures (3.8) and more calculation examples (3.8) was ranked higher. In-class quizzes (2.3) and laboratory experiment with report-writing was the least popular. The survey also shows that an individual project (3.2) is more desirable that working on a project in groups (2.9).

d. A non-mandatory open question was asked to encourage students to share what elements students found to be working, what could have been better and suggestions and opinions, or tips to how to increase the quality of lectures.

Three students responded to this open question and here are their opinions:

Lecturer was very experienced, but used to be caught up in details spending several days sketching on the blackboard when this could easily have been shown in a simple PowerPoint slides to increase the efficiency of the lecture. I wish that we had a project linking theory and practice to get a deeper understanding of for example duct sizing. A physical inspection of an actual ventilation- and air conditioning system would have been encouraging for the understanding of the components. We got very many good assignments with specific answers, I think some of those should have been mandatory so one could figure out for one selves to understand the subject better. I would personally gain more if the assignments were in the form of a project. I wish it gave us slightly more solvent and basic knowledge of ventilation and air conditioning technology.

The lecturer had unquestionable knowledge of HVAC and ventilation- and air conditioning systems, but after my opinion somewhat monotonous with the respect of just having the old fashion blackboard teaching. I think that the physical inspection of a real HVAC-system which we had in the fall-course Operational Maintenance and Reconstruction (Norwegian title: ‘DVO’) and/or perhaps a lab experiment would have increased the understanding of what we were really calculating. It’s difficult for students to understand what a valve or a heat exchanger is before one gets to see one in real-life. Using computer tools could also be relevant.
e. A question about how satisfied students were you considering literature and resources ranking four different elements of the spring course on a scale from 1-6?

None of the four elements ranked gained top scores, but students seemed to be the most pleased with the non-mandatory assignments and calculating problems that was designed by the instructor (4.0). Access to books were also considered satisfying. Students seemed more dissatisfied with access to online and web-sources (3.4), and they ranked the quality of the compendium as the lowest among the 4 alternatives (3.2).

f. Out of 4 different alternatives on literature and resources, students ranked the alternatives after what they personally preferred on a scale 1-4.

Out of the 4 different alternatives; books, literature as pdf-files, student license on online courses or compendium the students ranked books (3.0) and pdf-files (3.0) as their top choices of definitively preferred, access to online resources (2.7) was a close follow-up also considered as highly preferable. There was a more neutral attitude about having a course compendium (2.5) regarding both alternatives ‘as main literature source’ or as ‘supporting literature’, but it was placed more towards the positive this is preferable than not desirable.

g. If there was made a course compendium to this specific course, students evaluated different elements to what in that case should be included on a range from 1-4.

As an ‘obvious must have’ all the students in the survey evaluated formulas and diagrams (4.0) as a their #1. Governmental requirements and codes either listed in the compendium (3.7) or referral to where to find them (3.5) as well as a summary of the theory (3.3) theory and practice (3.5) was considered important elements. Calculation examples (3.0) and exercise questions (3.0) was also desirable. Course relevant articles from technical magazines, etc. was not a ‘must have’. Relevant articles (1.8) and web-links to online resources (2.5) did prove to be less important in this context.

h. Students evaluated in the number of lectures and office hours were sufficient.

The majority of students were split between two alternatives regarding the number of in-class lectures. 36.4% of students thought that lectures from 8.15 am – 11.30 am was sufficient, but only if they had assignments after class and another 36.4% would prefer +1 hour more lecture time.

i. The students were asked to evaluate what different grading policies they preferred the most and what type of examination they would see fit to this specific course on a scale from 1-3.

Out of the different forms of grading, a combination between 5-hour written exam and project or laboratory-report was ranked the highest by the students in this survey. Both the alternative with 60/40 (2.5) and 80/20 (2.2) was preferable compared to grading based 100% on a 5-hour written exam (1.7). Among the forms of examination, there was no clear preferable alternative regarding examination aids and what type of exam. Exam with compendium (2.4) were slightly ranked higher than all aids allowed (2.3) and examination without any form of aid except hereinafter (2.1). It was clear that students wanted
to be tested in some form of calculation, exam centered around calculations (2.4) and 50/50 calculation and theory (2.4) was weighed equally.

j. Open question - Comments or tips regarding everything you have been questioned with?
One student responded to this open question.

An examination, for example, has 60% examination and 40% exercises are preferable to me. In addition, I personally favor having the examination-aid/utilities, but only under "controlled conditions". This means that one can have with a compendium or a sheet of formulas and diagrams. Examination should include both theory and dimensioning. A new compendium of the discipline is crucial!

6.2. Survey Summary and Conclusion

The main conclusions that can be draw 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%

See Appendix B for detailed results and summaries.
7. 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.

7.1. The use of Textbooks

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. Wankat & Oreovicz (2015) argues that 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. Some literature might be too difficult and not ‘student friendly’ since the text’s purpose was not written for study purposes, however, assuming students will benefit from textbooks, a “student friendly” book should contain (Robinson, 1994, as cited in Wankat & Oreovicz, 2015):

- Objectives
- Question for the students
- Transitions between topic that show the relationship among the topics
- Signals (e.g., italics) that indicate that the material is important
- Advance organizers (e.g., an outline or flow sheet) to help provide global picture

Considering an appropriate textbook for a higher level course, it does not necessarily be limited to printed textbooks, it includes all forms of books, also electronic books such as pdf-versions or E-books. For the matter of fact, 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. The students valued it to be: easily accessible, less expensive, quick availability as well as convenient than printed textbooks.

7.2. Reader

Engineering books might not be reasonable priced, and this can be a reason to use readings from the original literature. The use of readers on the other hand need to be cautious of the copyright law when providing students copies of copyrighted material. However, students can instead access material such as articles/e-journals legally themselves from the university’s database (Wankat & Oreovicz, 2015:65).
7.3. 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.

11 syllabi and 10 course descriptions from 18 universities and colleges were collected, see Appendix C for overview. The textbooks / literature that was chosen to be reviewed in this study was a required textbook at more than two independent universities and colleges, in total 5 books. A book specifically recommended by the industry (ASHRAE) for graduate-level text for a university course in HVAC system design, and the newly published Ventilasjonsteknikk II has also been deliberated in addition to the 5 textbooks selected from the collected syllabi.

The following textbooks have been reviewed and evaluated:

1. **Refrigeration and Air Conditioning Technology, 8th ed.**
   Tomczyke, J., Silberstein, E., Whitman, B., & Johnson, B.

2. **AHRI Fundamentals of HVAC/R, 3rd ed.**
   Stanfield C., & Skaves, D.P.E.

3. **Heating, Ventilation and Air Conditioning Analysis and Design 6th ed.**
   McQuiston F. C., Parker J. D., & Spitler, J. D.

4. **ASHRAE Air Conditioning System Design Manual, 2nd ed.**
   Grondzik, W.

5. **2013 ASHRAE Handbook Fundamentals**
   ASHRAE – American Society of Heating, Refrigerating and Air-Conditioning Engineers

6. **Ventilasjonsteknikk I, 3rd ed.**
   (English title: Ventilation Technology I)
   Ingebrigtsen, S.

7. **Ventilasjonsteknikk II**
   (English title: Ventilation Technology II)
   Ingebrigtsen S.

See Appendix D for complete information (price, chaptering etc.) about the textbooks in this study.

The textbooks reviewed were evaluated with the respect of the course’s goals and learning outcomes in order to find the best suitable literature to fit the course. Table 2 makes a comparison of what textbooks
covers the learning outcomes and course goals the best from an academic perspective, Table 3 compares the texts to how well suited the content is to gain the skills defined in the syllabus.

**Learning outcomes and course goals**

A. Know the regulatory requirements, regulations, rules and industry standards for HVAC-installations
B. Have knowledge of energy and indoor environment calculations
C. Have knowledge of ventilation principles and how to ventilate living spaces

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<th>A</th>
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<tbody>
<tr>
<td>Refrigeration and Air Conditioning Technology</td>
<td>–</td>
<td>✓</td>
</tr>
<tr>
<td>AHRI Fundamentals of HVAC/R</td>
<td>–</td>
<td>✓</td>
</tr>
<tr>
<td>Heating, Ventilation and Air Conditioning Analysis and Design</td>
<td>–</td>
<td>✓</td>
</tr>
<tr>
<td>ASHARE Air Conditioning System Design Manual</td>
<td>–</td>
<td>✓</td>
</tr>
<tr>
<td>2013 ASHARE Handbook - Fundamentals</td>
<td>–</td>
<td>✓</td>
</tr>
<tr>
<td>Ventilasjonteknikk I</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Ventilasjonteknikk II</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

*Table 2. Literature compared to learning outcomes and course goals*

✓ Covers the required material
– Does not cover the required material

**Course skills**

I. Manage to draw up specifications for ventilation systems
II. Be able to design and size an energy efficient ventilation system, including ventilation unit and duct network
III. 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

<table>
<thead>
<tr>
<th>I</th>
<th>II</th>
<th>III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refrigeration and Air Conditioning Technology</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>AHRI Fundamentals of HVAC/R</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Heating, Ventilation and Air Conditioning Analysis and Design</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>ASHRAE Air Conditioning System Design Manual</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>2013 ASHRAE Handbook Fundamentals</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Ventilasjonteknikk I</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Ventilasjonteknikk II</td>
<td>–</td>
<td>✓</td>
</tr>
</tbody>
</table>

*Table 3. Literature compared to course skills*

✓ Covers the required material
– Does not cover the required material
7.4. Literature Summary and Conclusion

This summary is a critical analysis with positives and negatives compared to this specific course’s goals and learning outcomes first in the form a scholarly evaluation, however a literature review will to some extent be influenced of personal preferences, listed below is a short summary of the seven books in evaluated in this study.

**Refrigeration and Air Conditioning Technology, 8th ed.**
Tomczyke, J., Silberstein, E., Whitman, B., & Johnson, B. Cengage Learning, Boston, USA
+ Very illustrative plenty of illustrations and pictures in color throughout
+ Easily read, despite being approximately 1700 pages, good design and use of colors
+ Summary and review questions after each section
+ Available instructor’s manual, lab-manual, workbook, DVD resources, online training simulations and more
+ Mainly in IP but some tables are listed with SI-units as well
  – Uses Psychrometric chart and not Mollier’s Diagram, but when that is said, a very good and illustrative chapter learning how to read the psychrometric chart
  – Size of book (large and heavy)
  – Specially aimed towards HVACR installers- and technicians than engineering education (very tool-specific, and a broad focus on installation, maintenance, troubleshooting, safety tips etc. which is not relevant / too specific to this course)

**AHRI Fundamentals of HVAC/R, 3rd ed.**
Stanfield C., & Skaves, D.P.E. Pearson Education, Boston, USA
+ Very similar built, both content and design wise like ‘Refrigeration and Air Conditioning Technology’ by Tomczyke et al. which implies many of the same advantages/ disadvantages
+ Very illustrative plenty of illustrations and pictures throughout
+ Easily read despite being approximately 1500 pages, good design and use of colors
+ Short summary after each unit
+ Review questions after each section
+ Available teaching- and learning tools such as lecture material (PP-presentations), lab-manual, blog etc. linked to the book
  – In IP-units
  – Uses Psychrometric chart and not Mollier’s Diagram
  – Size of book (large and heavy)
  – Specially aimed towards HVACR installers- and technicians than engineering education (very tool-specific, and a broad focus on installation, maintenance, troubleshooting, safety tips etc. which is not relevant / too specific to this course)
McQuiston F. C., Parker J. D., & Spitler, J. D. Wiley, New Jersey, USA

+ Good illustrations
+ Can also to some extent be used in:
  o STE 6194 Heat Transfer (Heat Transmission in Buildings, Direct Contact Heat and Mass Transfer, Extended Surface Heat Exchangers)

– Not available in SI-units
– Not as thoroughly in the ventilation chapters compared to the other books due to the fact this book also contains heating (heat transfer, heat exchangers and so on) and refrigeration
– Uses Psychrometric chart and not Mollier’s Diagram.
– Lacks the main principles of ventilation- and air conditioning and does not emphasize how to ventilate living spaces, which is an important topic in this course
– Overall this book concentrates more on the mathematics and physics rather than theoretical ventilation theory.

ASHRAE Air Conditioning System Design Manual, 2nd ed.
Grondzik, W. ASHRAE, Georgia, USA

– Load Calculations in IP-units referring to American codes and standards
– Several illustrations and figures are “outdated”
– Uses Psychrometric chart and not the Mollier’s diagram
– Lacks the main principles of ventilation- and air conditioning and does not emphasize how to ventilate living spaces, which is an important topic in this course

Overall, this book represents a higher level of air conditioning technology (more system specific) in judgement to the course goals and in comparison, to the other books in this literature review

2013 ASHRAE Handbook Fundamentals
American Society of Heating, Refrigerating and Air-Conditioning Engineers, Georgia, USA

+ Available as book and CD, reduces prices for ASHRAE members with additional discount for students
+ Available in IP and SI-units
+ Good illustrations and beneficial diagrams
+ Easily read, logic built in terms of design
+ Reasonable size, compact in terms of contain approximately 1200 pages, on the flip side, very thin paper, which easily can break/ fold
+ Index also refers to topics covered in the other books in the same series
+ Useful chapter about Abbreviations & Symbols and Units & Conversions
+ Can also be used in:
o STE 6194 Heat Transfer (Heat Transfer, Fenestration),
 o STE 6198 Building Physics (Sound and Vibrations/ Fenestration, Heat, air and Moisture Control in Buildings, Measurements and instruments)
 o STE 6228 Indoor Environment (Indoor Environment Quality)
 o STE 6197 Fluid Mechanics (Air flow around buildings)

- Uses Psychrometric Chart and not Mollier’s Diagram.
- Energy modeling, Cooling and Heat Load Calculations and a chapter about Codes and Standards applies to American standards

**Ventilasjonsteknikk I, vol. 1.**
Ingebrigtsen, S., Skarland Press, Oslo, Norway

+ Available as printed textbook and e-book (online or app), both reduces prices for students
+ Good illustrations, relevant diagrams and tables
+ Contains useful formulas
+ Good examples
+ Refers to legislation /Norwegian building law and relevant codes and standards
+ Uses Mollier’s Diagram, well explained chapter as well
- Only available in Norwegian text (not English)
- Does not cover all the learning outcomes and goals of this course, must have both volumes
- The book is slightly disordered /cumbersome given the orders of the chapters
- E-book requires internet access, not downloadable as pdf

**Ventilasjonsteknikk II, vol. 2.**
Ingebrigtsen, S., Skarland Press, Oslo, Norway

+ Based on the same design as volume 1, Ventilasjonsteknikk I, many of the same advantages and disadvantages for as book I applies for this second volume as well
+ A central topic of this book is dimensioning and scaling sustainable and energy effective ventilation- and air conditioning systems. In comparison to all the other books in this review, is this book evaluated to undoubtingly cover this important topic the best (Bahcos 1/3-method etc.)
- The book does not repeat content of Ventilasjonsteknikk I, so it is essential to have both in order to get a deep understanding of subjects emphasized in this book

With the respect of the course goals, four of seven reviewed books were considered as appropriate texts; Heating, Ventilation and Air Conditioning Analysis and Design, 2013 ASHRAE Fundamentals and Ventilasjonsteknikk I & II. Ventilasjonsteknikk I, also used at; 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 goals and learning objectives the best, see Tables 2 and 3. 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, referring to the research conducted by the Chronicle of Higher Education Almanac (2013, as featured in Wankat & Oreovicz, 2015) were over 89% of all students were satisfied or very satisfied with the use of electronic books. Both books are also fairly reasonable priced (discounted for students) in comparison to many of the other books evaluated in this study, and are accessible from the online e-learning portal Kompetansebiblioteket, which consist of numerous and various literature related to the HVAC-industry. In addition to ventilation technology, it also covers relevant literature for the course Energy- and HVAC-technology as a whole, including: heat- and energy systems, sanitary-installations, waterborne energy- and cooling systems, operation- and maintenance of HVAC-systems, climate-data, HVAC- technical drawings, HVAC-calculation tool and more.

Based on the American books reviewed, one book excelled from the others, 2013 ASHRAE Fundamentals proved to cover a lot of material, not only related to ventilation and HVAC-technology, but also heat- and mass transfer, building physics and fluid mechanics in addition to a well-defined chapter in indoor environmental quality. The text is well designed and easily read, and it is available both in Inch-Pound (IP) and System-International (SI)-units, which is crucial considering the fact IP cannot easily be transferred to metric units used in Europe and Norway. The book is fairly compact relative to contain over 1200 pages, and is available both as printed text and electronic in form of a CD-version. For ASHRAE members the book can be purchased at reduced prices, and for students it is even an additional discount. From an academic perspective and 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, 2013ASHRAE Fundamentals is therefore a greatly recommended textbook used in this master program in general, or optionally as a substitute text which can be beneficial in several courses which should be made available for students to access through the university’s library.
8. 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 the spring 2016 Energy- and HVAC-technology course, there has consequently not been a printed course compendium for the ventilation- and air conditioning part of the course, but a handwritten compendium with a collection of ventilation theory, calculation examples and problems by the lecturer has been available for copying. However, the survey shows that the compendium of 2016 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.

8.1. Content of Compendium

Based on the survey, and as a central supplement to this thesis work in order to upgrade of the course, 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 not designed to be used as a main source literature, but as a supplement to the required textbooks. It is constructed to reflect upon the syllabus and course’s goals and 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.

Learning outcomes and conclusions of the survey have clearly been a central part in the compilation of the compendium. As a part of the survey, students identified their strengths and weaknesses based on the course’s goals and learning outcomes, and these findings have also been taken into consideration when designing the compendium. For example, students primarily lacked knowledge about; ‘governmental requirements, codes and industry norms’ and ‘dimensioning and scaling ventilation- and air conditioning systems, promoting acceptable indoor air quality’, these topics in particularly are therefore specially highlighted in the new compendium.

Students also evaluated the following elements as the most important in ascending order, where #1 is the most significant when considering having designed a new enhanced course compendium:

1. Formulas and diagrams
2. Requirements – copy / extract of the central codes
3. Requirements – referral to what codes are relevant
4. Theory – summary
5. If possible relate theory to practice
6. Example – problem solving
7. Relevant practice problems
8. Theory – detailed
9. Web-link to online recourses
10. Theory – relevant articles

A lot of work is put into the design of the course compendium, focusing on a logic structure with easy-read, brief paragraphs, the use of color and illustrations and the use of electronic table of contents and cross-references for easy maneuvering in a pdf-format. Referring to relevant theory, like Sintef Byggforsk and Norsk Standard is intentionally emphasized to encourage students to use the available resources. The chapters reflect the topics emphasized in the syllabus, and is structured logically to how theory would be lectured. Considering that regulatory requirements change periodically, references to the law’s technical regulation (TEK) in the text itself is highlighted for easy revision. The relevant chapters of TEK are intentionally enclosed as an attachment in the back, as the requirements change rapidly. There is work and effort put into constructing it, the intention must be for it to not become quickly outdated, the department must therefore make sure lecturers add and revise the text if necessary.
9. Presentation material

The survey shows that lectures with PowerPoint presentation material (3.4/5) and elements of videos, animations or illustrations in lectures (3.8/5) will increase the quality of the course. Preparation of presentation material is not included in this thesis because it is generally considered to be very much personal. A lecturer should have the freedom to decide how he or she want to present the material to the class, and a certain autonomy to decide how topics should be emphasized. The style of teaching also varies greatly from lecturer to lecturer, both based on personal and professional background. When that is said, the course must be upgraded from black board lectures with up-to-date classroom aids such as visual digital presentation tools with some form of creative elements incorporated in the presentation.

9.1. Power Point

The use of Microsoft PowerPoint (PP) for teaching presentations has considerable potential for encouraging more professional presentations, but it has its advantages and disadvantages, the benefits and problems with its use should be considered Jones lists some good reasons to use PP and some common barriers to its use (Jones, 2003:1):

- Appropriate use can enhance the learning experience
- Support staff by facilitating the structuring of a presentation in a professional matter
- By mixing media, a presentation can appeal to a number of different learning styles and be made more stimulating
- Can speed up the delivery of lecture content
- Electronic file format allows distribution and modification for/by students unable to be present
- Editing is very easy
- Availability of the files before lecture provides an opportunity for preparation and allows students to take notes of the verbal content during lecture
- Extra information can be hidden within the file to answer predicted questions or to provide feedback
- Presentations can be set up to run automatically if necessary, for example in context of demonstrations/ instructions within a laboratory
- Requires time to convert material to an appropriate PP format, however, most of those who do decide to develop a PP find that a relatively short-term investment of time, receive a long-term benefit in both the quality of presentations and in the ease of maintaining and updating lectures
- Danger of encouraging students to sit passively through the session since they may perceive that they already got the notes
- When the files contain all the lecture material in detail there is a possibility of many students not feeling the need to attend lectures
- The fact that is speeds up the delivery it can causes some students difficulties to follow
There are many and varied sources of information on the do’s and don’ts of constructing an educational PP-presentation, but many agree upon that a successful presentation includes a clear structure and be careful not having too much textual material or detail on each slide (avoid more than 6 lines). The key is to provide primarily structural headings and subheadings or bullet points instead of long sentences as a complement to the verbal presentation so students still require to be active and take notes of detail. To enhance the presentation ‘a picture can say more than a thousand words’, the use of graphic illustrations, pictures or even video-clips as a supplement can increase the understanding of the content. Too many slides should be avoided, 15-20 per 50 minutes are a good rule of the thumb (Jones, 2003:8).

9.2. Video Content

Like mentioned earlier showing shorter videos can be introduced as active elements to breaking up classic lectures (ref. ch.4.6 & 4.9). 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. Appendix E lists a few suggestions to useful free YouTube videos which can easily incorporated into a PP presentation.

10. Lab / Project

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 (ref. 4.6 - 4.8). 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.

10.1. Laboratory Work

The collected syllabi show that laboratory work is a central part of almost all the HVAC / ventilation technology courses, also counting it as a percentage of the course, see Table 4. 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.

<table>
<thead>
<tr>
<th>University</th>
<th>Cr</th>
<th>Course name</th>
<th>Lab work</th>
</tr>
</thead>
<tbody>
<tr>
<td>University of Alaska, AK</td>
<td>3</td>
<td>Mechanical and Electrical Technology</td>
<td>N/D</td>
</tr>
<tr>
<td>Baker College, MI</td>
<td>4</td>
<td>Air Conditioning and Heat Pump</td>
<td>Y (40%)</td>
</tr>
<tr>
<td>College of Southern Nevada, NV</td>
<td>3</td>
<td>Introduction to HVAC and Refrigeration</td>
<td>Y 3h/week</td>
</tr>
<tr>
<td>Dunwoody College of Technology MN</td>
<td>3</td>
<td>Refrigeration &amp; Air Conditioning Systems</td>
<td>Y (1 cr)</td>
</tr>
<tr>
<td>Dunwoody College of Technology MN</td>
<td>3</td>
<td>Designing for Indoor Comfort</td>
<td>Y (1 cr)</td>
</tr>
<tr>
<td>Dunwoody College of Technology MN</td>
<td>5</td>
<td>Packaged Air Conditioning Systems Design</td>
<td>Y (3 cr)</td>
</tr>
<tr>
<td>Dunwoody College of Technology MN</td>
<td>5</td>
<td>HVAC Systems Integration &amp; Controls</td>
<td>Y (3 cr)</td>
</tr>
<tr>
<td>Ferris State University, MI</td>
<td>5</td>
<td>Heating, Ventilating, Air Conditioning and Refrigeration (HVACR)</td>
<td>Y</td>
</tr>
<tr>
<td>Massachusetts institute of Technology, MA</td>
<td>12</td>
<td>Analysis and Design of Heating, Ventilation and Air Conditioning Systems</td>
<td>Y</td>
</tr>
<tr>
<td>Mt. San Antonio College, CA</td>
<td>4</td>
<td>Fundamentals of HVAC/R</td>
<td>Y (2 cr)</td>
</tr>
<tr>
<td>North Dakota State University, ND</td>
<td>4</td>
<td>HVAC</td>
<td>N</td>
</tr>
<tr>
<td>NOVA Southeastern, FL</td>
<td>4</td>
<td>Air Conditioning Systems I &amp; II</td>
<td>Y</td>
</tr>
<tr>
<td>Norwegian University of Science and Technology (NTNU)</td>
<td>10*</td>
<td>Ventilation Technology (Nor: Ventilasjonsteknikk)</td>
<td>Y</td>
</tr>
<tr>
<td>Oakland Community College, CA</td>
<td>4</td>
<td>Heating, Ventilation, Air Conditioning and Refrigeration Design I</td>
<td>Y</td>
</tr>
<tr>
<td>Scott Community College, IA</td>
<td>5</td>
<td>Heating, Ventilation and Air Conditioning</td>
<td>Y</td>
</tr>
<tr>
<td>University College of Applied Sciences (HiOA)</td>
<td>20*</td>
<td>Heat, Ventilation and Sanitary Technology (Nor: Varme, Ventilasjon og Sanitærteknikk)</td>
<td>N/D</td>
</tr>
<tr>
<td>University of Kentucky, KY</td>
<td>3</td>
<td>Heating, Ventilating and Air-Conditioning</td>
<td>N</td>
</tr>
</tbody>
</table>

Table 4. Laboratory exercise at different universities and colleges
Y = Yes, N = No, N/D = Not Defined, *Study-points (1 credit = 2 study points)

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. An example, obtained from the University College of Applied Sciences (HiOA) is investigation of pressure drops in duct network, where data from physical measurements and theoretical simulations are compared. It is also possible to facilitate a computer lab independent of a physical experiment, and compare calculations and simulated data, for example, the effect of optimizing components to reduce pressure drop in ducts. Due to time limitations, it may be considered to simplify the scope of the lab.


10.2. Student 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 teamwork 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.

11. 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). Examination form and grading systems is not a central part of this study, but 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. When studying the grading systems of the collected syllabi, see Table 5, 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 / mandatory homework
- Quizzes
• Project or laboratory-report
• Exam(s)

<table>
<thead>
<tr>
<th>University</th>
<th>Course name</th>
<th>Part.</th>
<th>Assign</th>
<th>Quiz</th>
<th>Project/lab</th>
<th>Wr. Exam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alaska State University AK</td>
<td>Mechanical and Electrical Technology</td>
<td>15%</td>
<td>20%</td>
<td>–</td>
<td>20%</td>
<td>45%</td>
</tr>
<tr>
<td>Dunwoody College of Technology MN</td>
<td>All four classes in HVAC technology</td>
<td>10%</td>
<td>10%</td>
<td>25%</td>
<td>30%</td>
<td>15%</td>
</tr>
<tr>
<td>Massachusetts institute of Technology, MA</td>
<td>Analysis and Design of HVAC systems</td>
<td>10%</td>
<td>30%</td>
<td>30%</td>
<td>–</td>
<td>30%</td>
</tr>
<tr>
<td>North Dakota State Un. ND</td>
<td>HVAC</td>
<td>–</td>
<td>–</td>
<td>45%</td>
<td>25%</td>
<td>30%</td>
</tr>
<tr>
<td>Norwegian University of Science and Technology (NTNU)</td>
<td>Ventilation Technology</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>Req. participation</td>
<td>100%</td>
</tr>
<tr>
<td>Scott Community Col. IA</td>
<td>HVAC</td>
<td>52.78%</td>
<td>47.22%</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>University College of Applied Sciences (HiOA)</td>
<td>Heat, Ventilation and Sanitary Technology</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>100%</td>
</tr>
</tbody>
</table>

*Table 5. The form of examination at different universities and colleges*

However, these differences are found to be a general tendency, not only limited to HVAC- and engineering courses, but a typical trend across various programs and disciplines. The explanation why we see these differences are hard to define, it might be justified being cultural differences, but it might as well be the Norwegian educational system’s lack of resources (financial) due to the fact the majority of universities are being publicly funded? Regardless, 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.

“Assessment not only measure achievement of learning outcomes but they also classify or grade student achievement” (Murphy, 2009:2)

Brown & Smith (2005 as featured in Murphy, 2009) have defined some of the advantages and disadvantages with different forms of assessments.

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional exam, time constrained</td>
<td>Often just measures exam technique</td>
</tr>
<tr>
<td>Relatively economical</td>
<td>Tests memory sometimes more than understanding</td>
</tr>
<tr>
<td>Equality of opportunity</td>
<td>No feedback to students as the exam is over</td>
</tr>
<tr>
<td>Less chance for plagiarism</td>
<td>Can encourage surface learning</td>
</tr>
<tr>
<td>Fixed dates forces students to learn</td>
<td>Not a complete picture of student’s performance</td>
</tr>
<tr>
<td>Open book exams</td>
<td>Can require more desk space</td>
</tr>
<tr>
<td>Less stress on memory</td>
<td>Students need access to the allowed books/resources</td>
</tr>
<tr>
<td>Slower writers not penalized</td>
<td>Discourages use of memory</td>
</tr>
<tr>
<td>Measures what students can do with resources</td>
<td></td>
</tr>
<tr>
<td>not just what they can remember</td>
<td></td>
</tr>
</tbody>
</table>
Open notes exam
Encourages students to take good notes Discourages use of memory
Not a test for memory or technique Bad note takers are penalized
Structured MCQ exam (multiple choice questions)
Can be very reliable Student may be guessing
Excellent validity test Takes skills to design good questions – especially questions to test higher level skills
Can be used to test interpretation and decision skills as well as more basic skills Needs carefully planning to ensure that the answer choices are clear
Can show how fast students think Risk of impersonators
Cab be carried out quickly
Greater syllabus coverage

Oral exam
High degree of authenticity Not all candidates perform well tested orally
Good practical experience towards later interview situations / presentation skill The use of the same questions may lead to later candidates being prepared for questions
Good for isolating particular areas of skills Can only deal with a narrow range of skills
Exams are not anonymous

Essays
Allow for individual expression Very time consuming, cannot test a candidate in the entire syllabus
Can show depth of learning Plagiarism can be hard to detect
Test written communication skills well Essays require a certain technique
Examine students’ ability to form coherent arguments Grading can vary from marker to marker, grades can be subjective

Reports
Develop a key transferable skill Can be time consuming for students
Can involve a wide range of skills that are hard to directly access Using the same format and structure may decrease its effectiveness

Presentations
No doubt re authenticity of presenter Can be time consuming especially with large groups
Students take presentations seriously Cannot be anonymously
Can be used for individuals and group Grading can be difficult
Students learn from their own presentation and everyone else’s presentation

Student projects
Helps link theory to practice Time consuming to assess and supervise
Very good for students aiming towards research and postgrad programs Challenging to set the difficulty level if there are different sets of projects
Can identify the best students

Table 6. Advantages and disadvantages with different assessment forms (Brown & Smith, 2005, featured in Murphy, 2009)

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 (2.5 and 2.2 /3) high in comparison to 100% written exam (1.7/3). 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.
12. Conclusion

The purpose of this paper was to redesign and make suggestions for a new educational program with an enhanced syllabus for the ventilation- and air conditioning part of the course Energy- and HVAC Technology. With today’s accelerating knowledge and rapid change in technology the current course is outdated both in terms of ventilation technology itself and how to teach engineering in the modern classroom. In search for ‘best practice’, this work presents a different variety of research on different teaching theories, especially focusing on teaching engineering and learning methods which students gain higher order skills, as well as how to best benefit from technology in the classroom. In addition to exploring theory how to best teach and learn higher lever engineering, a survey was conducted to investigate previous students’ views and opinions about the current course, revealing its strengths and weaknesses as well as collecting valuable data to construct and make suggestions to a new and improved course program. A collection of syllabi and course descriptions from universities and colleges teaching HVAC/ventilation technology across Norway and the U.S. laid the foundation for finding appropriate literature for the course, and uncover what topics were emphasized. In total, 7 textbooks were evaluated in a comprehensive literature review to find a text who best matched the syllabus and the course’s goals and learning outcomes.

#1 Breaking up 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. 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. It might be expedient to choose either one, laboratory work or project.

**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 (Solibri Model Viewer) 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 (ref X) 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 undoubtingly be the best suited texts, it also has its advantages being available as e-books through Kompetansebiblioteket’s online website, 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.
13. Future Work

There are numerous ways, and a great spectrum of variation of constructing and designing a course, or a new educational program, and it is no exact solution. This work represents suggestions based on a broad research of learning theory and how to teach and learn engineering, a questionnaire limited to one cohort students, and information built on a collection of syllabi of universities teaching similar courses. The work in this thesis is an overall recommendation, and further work will be to; tailor and specify what type of laboratory work/demonstration, or/and computer lab suitable for ventilation and air conditioning technology that can be incorporated with the university’s laboratory facility and available resources, and define a suitable ‘real life’ engineering problem suitable to arrange a student project. The extent relative to lectures and other course activities must be determined, and goals and learning outcomes relative to the syllabus, and what theory is to be covered through facilitating a lab or/and project must be further defined. Specific content, time-frame, resources, assessment, etc. also need to be determined. After successfully having incorporated PBL into the course program, assessment, feedback and measures for improvement need to be evaluated so one can constantly adjust and making the educational program and learning experience better.
Bibliography


Appendix A. Syllabus

Ventilation- and Air Conditioning (5 ECT)

a part of the course STE 6230 Energy- and HVAC Technology (10 ECT)

Department of Energy, Building and Material Technology

Integrated Building Technology

Spring Semester

Instructor(s) name(s) and contact information, e.g. [text]
Email address [text]
Office location; phone [text]
Office hours [text]

Recommended prerequisites

- SMN6194 Heat Transfer
- SMN6197 Fluid Mechanics
- STE6228 Indoor Environment
- STE6278 House Building Techniques

Language

Norwegian

Course Description

The ventilation- and air conditioning part of the course Energy- and HVAC Technology provides knowledge of; how to ventilation living spaces with the respect of good indoor environmental quality, moist air and fundamental processes in the enthalpy-entropy diagram (Mollier’s), air distribution- and air handling methods, air handling unit and its components, functional and governmental requirements, as well as knowledge about dimensioning, sizing and design ventilation- and air conditioning systems.

Course Goals

The overall goal is to be able to plan, design, dimensioning and control energy-efficient HVAC systems.
Students who complete this course successfully will be able to:

- Know the regulatory requirements such as the appropriate building codes, regulations, rules and industry standards for designing energy efficient ventilation systems.
- Gain knowledge of energy and indoor environment calculations
- Gain knowledge about different ventilation principles and how to ventilate living spaces
Skills gained in this class

- 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

Required Texts, Materials, or Equipment

2. The Norwegian Plan and Building Act (PBL) with technical regulations - Teknisk byggeforskrift TEK10
3. Supporting literature:
   - Norwegian Building code - Norsk Standard NS3031
   - Sintef Byggforsk bygdetaljblader
   - ASHRAE Fundamentals
   - Ventilasjonteknisk Håndbok (håndbok 48), Skåret, E., Sintef Byggforsk, 2000

Daily Work/Homework

[text]

Major Assignments: Descriptions

[text]

Class Participation

[text]

Course Grading

Format: Letter grade A-F, which F is failing.

- 4. Assignments: [X]% of total grade or maximum points
- 5. Laboratory report: [X]% of total grade or maximum points
- 6. Project: [X]% of total grade or maximum points
- 7. Final written Exam 4: [X]% of total grade or maximum points

Grade Cutoffs

<table>
<thead>
<tr>
<th>Grade Cutoff</th>
<th>Grade Letter</th>
<th>Percentage Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent / Outstanding</td>
<td>A</td>
<td>90% – 100%</td>
</tr>
<tr>
<td>Very good / above average</td>
<td>B</td>
<td>78% – 89%</td>
</tr>
<tr>
<td>Good / average</td>
<td>C</td>
<td>62% – 77%</td>
</tr>
<tr>
<td>Fairly good / below average</td>
<td>D</td>
<td>50% – 61%</td>
</tr>
<tr>
<td>Sufficient / pass</td>
<td>E</td>
<td>40% – 49%</td>
</tr>
<tr>
<td>Not passed / fail</td>
<td>F</td>
<td>0% – 39%</td>
</tr>
</tbody>
</table>
Course Policies and Information for Students

- ATTENDANCE POLICY [text]
- PENALTIES FOR LATE WORK and REQUESTS FOR EXTENSIONS [text]
- POLICIES ON MISSED EXAMS, MAKE-UP EXAMS OR QUIZZES [text]
- ETHICS/VIOLATIONS OF ACADEMIC INTEGRITY: Ethical behavior is an essential component of learning and scholarship. Students are expected to understand, and adhere to, the University’s academic integrity policy: https://result.uit.no/plagiat/ Students who violate this policy will be referred to the Academic Integrity Policy Committee. Penalties for violating the policy will be determined by the Academic Integrity Policy committee, and can include failure of the assignment, failure of the course, suspension or expulsion from the University. If you have any doubts about what constitutes a violation of the Academic Integrity policy, or any other issue related to academic integrity, please ask your instructor.

Resources for Students

1. DISABILITY RESOURCES: If you have a disability that requires an accommodation, please visit https://uit.no/utdanning/art?p_document_id=338676&dim=179017 for more information.

2. LIBRARY RESOURCES: Visit the university library’s main website https://uit.no/ub for more information about resources related to access to literature, citation guide writing aid, access to electronic articles etc.

3. THE UNIVERSITY’S PREFERRED NAME POLICY FOR STUDENTS, with additional resources and information, may be found here: https://uit.no/utdanning/art?p_document_id=338681&dim=179017

4. MENTAL HEALTH: Mental Health Services’ professional staff members work with students to resolve personal and interpersonal difficulties, many of which can affect the academic experience. These include conflicts with or worry about friends or family, concerns about eating or drinking patterns, and feelings of anxiety and depression. See: Studentskipnaden http://samskipnaden.no/tromso/helse for more information.

Disclaimer

The instructor reserves the right to make modifications to this information throughout the semester.
**Preliminary Schedule of Topics, Readings, and Assignments**

**Energy- and HVAC Technology**

- Ventilation systems 5 ECT  Week 1 & 2
  - Sanitary systems 2.5 ECT  Week 3
  - Heat systems 2.5 ECT  Week 4

<table>
<thead>
<tr>
<th>Day</th>
<th>Topics</th>
<th>Readings / Assignments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(referring to chapters in course compendium)</td>
<td></td>
</tr>
<tr>
<td><strong>Week 1</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| 1 | Lecture:  
1. Indoor environment quality with the respect of ventilation  
2. Moist air and the processes of enthalpy-entropy diagram (Mollier’s diagram) | Chapter 2 & 3  
*Exercise on processes Mollier’s* |
| 2 | Lecture:  
3. Ventilation and air distribution of living spaces  
4. Distribution and exhaustion of air | Chapter 7  
Chapter 8 |
| 3 | Lecture:  
5. CAV and VAV ventilation  
6. Ventilation unit and its components  
11. Central Processing system *(Norwegian: SD-anlegg)*  
Inspection of University’s ventilation systems | Chapter 1  
Chapter 11 |
| 4 | Discussion from inspection  
Introducing project assignment, assigning groups  
Lecture:  
7. Calculation of air volumes, cooling and heat loads  
8. Energy use and ventilation systems  
Codes, requirements, relevant standards, Simien | Chapter 6 & 10  
TEK 10  
*Exercise calculation air volumes* |
| 5 | Lecture:  
9. Projecting and dimensioning ventilation systems  
10. Sound and vibration in ventilation systems  
Calculation example of Bahcos 1/3 | Chapter 5, 9 & 12  
*Exercise Bahcos 1/3 method* |
| **Week 2** | | |
| 1 | Laboratory work / demonstration * | *Brief individual lab-rapport* |
| 2 | Discussion laboratory work – recap theory related to the experiment | |
| 3 | Project presentations * | Presentation |
| 4 | Project discussion  
Proposed solution on project *(Nor: løsningsforslag)* | |
| 5 | Summary of the main learning outcomes in ventilation technology | |

*Mandatory participation*
Appendix B. Student Survey

1. How satisfied are you with the lectures in the course STE6230 spring 2016 from 1 not satisfied at all to 6 very satisfied?

2. Drawn directly from the course description and the course learning objectives, how strong will you evaluate your skills in:
   a. Ventilation systems and principles
   b. Requirements to ventilation- and air conditioning systems
   c. Governmental requirements, codes and industry norms
   d. Dimensioning and scale ventilation systems
   e. Dimensioning and scale systems promoting acceptable indoor air quality
   f. Calculate airflows
   g. Calculate cooling loads

3. Do you think some of these parameters would have increased the quality of the course?
   a. Lectures with power point slides
   b. Elements of videos, animations, illustrations in lecture
   c. More calculations by lecturer during lecture
   d. Physical inspection of an actual ventilation- and air conditioning system
   e. Lab-experiment - demonstration
   f. Lab-experiment with written report / summary
   g. Computer software demonstration how to dimension and scale
   h. Computer software demonstration BIM-modelling
   i. Be able to / gain skills to read actual blue prints and real construction drawings
   j. Elements of pop-quiz during lecture
   k. Quiz available online after class – summary of lecture
   l. Project – individual
   m. Project – Group

4. Open Question – Considering lecture, what was good, what could have been done better? Do you have any tips to increase the quality of lectures?

5. How satisfied were you considering literature and recourses?
   a. Access to textbooks, articles, library etc.?
   b. Access to online recourses / E-learning?
   c. Quality on the compendium?
   d. Quality and content of take-home problems?
6. If you focus on literature and resources, what do you personally prefer?
   a. Books (printed/E-book)
   b. Literature in pdf-format that can be printed
   c. Student-access to online resources and E-learning tools.
   d. Compendium as required reading
   e. Compendium as a supporting / recommended literature

7. If the university makes a compendium for the class, what should it contain?
   a. Theory – detailed
   b. Theory – summary
   c. Theory – relevant articles
   d. If possible relate theory to practice
   e. Requirements – copy / extract of the central codes
   f. Requirements – referral to what codes are relevant
   g. Web-link to online recourse
   h. Formulas and diagrams
   i. Example – problem solving
   j. Relevant practice problems

8. For maximal learning outcomes, are 3-4 hours of daily lectures enough?
   a. Yes, more than satisfying
   b. Yes, but only if the lecturer/ professor is available for office hours after class
   c. Yes, but only if we have individual problems to solve / projects etc.
   d. Yes, but only if we have individual readings
   e. I’d like one hour more lecture (+ 1 x 45 minutes after lunch)
   f. I’d like two hours more lecture (+ 2 x 45 minutes after lunch)

9. How would you prefer the course being graded?
   a. 100 % - 5 hours written exam
   b. 60 % - 5 hour written exam / 40 % - mid-term or project
   c. 80 % - 5 hour written exam / 20 % - mid-term or project
   d. Exam with only pencil and calculator
   e. Exam with compendium
   f. Exam all written notes and printed texts allowed
   g. Exam with main-focus on calculations
   h. Exam 50/50 calculations and theory
   i. Exam with main-focus on theory / understanding for principles

10. Open question - Comments or tips regarding everything you have been questioned with?
1. How satisfied are you with the lectures in the course STE6230 spring 2016 from 1 not satisfied at all to 6 very satisfied?
   a. Blackboard / overhead lectures
   b. The hourly quantity of lectures 05.15 am – 11.30 am
   c. The instructor’s ability to present the course content
   d. The instructors level of knowledge
   e. The instructor’s engagement
   f. The lectures overall spring 2016

Summary:

![Graph showing satisfaction levels for different aspects of the lectures.](image)

a. Blackboard / overhead lectures
b. The hourly quantity of lectures 05.15 am – 11.30 am

c. The instructor’s ability to present the course content

d. The instructors level of knowledge
e. The instructor’s engagement

f. The lectures overall spring 2016

2. Drawn directly from the course description and the course learning objectives, how strong will you evaluate from your skills in:
   a. Ventilation systems and principles
   b. Requirements to ventilation- and air conditioning systems
   c. Governmental requirements, codes and industry norms
   d. Dimensioning and scale ventilation systems
   e. Dimensioning and scale systems promoting acceptable indoor air quality
   f. Calculate airflows
   g. Calculate cooling requirements
1) No, not at all
2) No, Basically not
3) Yes, but I wanted to learn more
4) Yes, essentially, I know the principles
5) Yes, absolutely
6) I don’t remember

Summary:

![Graph showing responses](image)

- **Ventilation systems and principles**

  - Nei, ikke i det hele tatt. 8.3%
  - Nei, i stor grad. 41.7%
  - Ja, men ønsket å lære mer. 33.3%
  - Ja absolutt. Dette kan jeg. 8.3%
  - Vet ikke / Husker ikke. 8.3%
h. Requirements to ventilation- and air conditioning systems

i. Governmental requirements, codes and industry norms

j. Dimensioning and scale ventilation systems
k. Dimensioning and scale systems promoting acceptable indoor air quality

l. Calculate airflows

m. Calculate cooling requirements
3. Do you think some of these parameters would have increased the quality of the course from 1-5?
   a. Lectures with power point slides
   b. Elements of videos, animations, illustrations in lecture
   c. More calculations by lecturer during lecture
   d. Physical inspection of an actual ventilation- and air conditioning system
   e. Lab-experiment - demonstration
   f. Lab-experiment with written report / summary
   g. Computer software demonstration how to dimension and scale
   h. Computer software demonstration BIM-modelling
   i. Be able to read actual blue prints and real construction drawings
   j. Elements of pop-quiz during lecture
   k. Quiz available online after class – summary of lecture
   l. Project – individual
   m. Project – Group

1) Not relevant at all
2) No, this is too time consuming
3) Yes, but only to a limited extent
4) Yes, I believe this should be included
5) Yes, I believe this absolutely should be included

Summary:
a. Lectures with power point slides

b. Elements of videos, animations, illustrations in lecture

c. More calculations by lecturer during lecture
d. Physical inspection of an actual ventilation- and air conditioning system

![Bar chart for d. Physical inspection of an actual ventilation- and air conditioning system]

<table>
<thead>
<tr>
<th>Option</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nei, dette er helt urelevant / uaktivt</td>
<td></td>
</tr>
<tr>
<td>Nei, dette har vi ikke tid til</td>
<td></td>
</tr>
<tr>
<td>Ja, men kun i begrenset grad</td>
<td>16.7%</td>
</tr>
<tr>
<td>Ja, i stor grad synes jeg dette burde vært med</td>
<td>33.3%</td>
</tr>
<tr>
<td>Ja, dette burde absolutt vært med</td>
<td>50.0%</td>
</tr>
</tbody>
</table>

e. Lab-experiment – demonstration

![Bar chart for e. Lab-experiment – demonstration]

<table>
<thead>
<tr>
<th>Option</th>
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<tbody>
<tr>
<td>Nei, dette er helt urelevant / uaktivt</td>
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</tr>
<tr>
<td>Nei, dette har vi ikke tid til</td>
<td></td>
</tr>
<tr>
<td>Ja, men kun i begrenset grad</td>
<td>33.3%</td>
</tr>
<tr>
<td>Ja, i stor grad synes jeg dette burde vært med</td>
<td>50.0%</td>
</tr>
<tr>
<td>Ja, dette burde absolutt vært med</td>
<td>16.7%</td>
</tr>
</tbody>
</table>

f. Lab-experiment with written report / summary

![Bar chart for f. Lab-experiment with written report / summary]

<table>
<thead>
<tr>
<th>Option</th>
<th>Percentage</th>
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</thead>
<tbody>
<tr>
<td>Nei, dette er helt urelevant / uaktivt</td>
<td>16.7%</td>
</tr>
<tr>
<td>Nei, dette har vi ikke tid til</td>
<td>41.7%</td>
</tr>
<tr>
<td>Ja, men kun i begrenset grad</td>
<td>25.0%</td>
</tr>
<tr>
<td>Ja, i stor grad synes jeg dette burde vært med</td>
<td>8.3%</td>
</tr>
<tr>
<td>Ja, dette burde absolutt vært med</td>
<td>8.3%</td>
</tr>
</tbody>
</table>
g. Computer software demonstration how to dimension and scale

h. Computer software demonstration BIM-modelling

i. Be able to read actual blue prints and real construction drawings
j. Elements of pop-quiz during lecture

k. Quiz available online after class – summary of lecture

l. Project – individual
4. Open Question – Considering lecture, what was good, what could have been done better? Do you have any tips to increase the quality of lectures?

Three students responded to this open question and here are their opinions:

Lecturer was very experienced but used to be caught up in details spending several days sketching on the blackboard when this could easily have been shown in a simple PowerPoint slides to increase the efficiency of the lecture. I wish that we had a project linking theory and practice to get a deeper understanding of for ex. duct sizing. A physical inspection of an actual ventilation- and air conditioning system would have been encouraging for the understanding of the components. We got very many good assignments with specific answers, I think some of those should have been mandatory so one could figure out for oneself to understand the subject better. I would personally gain more if the assignments were in the form of a project.

I wish it gave us slightly more solvent and basic knowledge of ventilation and air conditioning technology. The lecturer had unquestionable knowledge of HVAC and ventilation- and air conditioning systems, but after my opinion somewhat monotonous with the respect of just having the old fashion blackboard teaching. I think that the physical inspection of a real HVAC-system which we had in the fall-course Operational Maintenance and Reconstruction (Norwegian title: ‘DVO’) and/or perhaps a lab experiment would have increased the understanding of what we were really calculating. It’s difficult for students to understand what a valve or a heat exchanger is before one gets to see one in real-life. Using computer tools could also be relevant.

5. How satisfied were you considering literature and recourses from 1 not satisfied at all to 6 very satisfied?

1) Access to textbooks, articles, library etc.?
2) Access to online recourses / E-learning?
3) Quality on the compendium?
4) Quality and content of take-home problems?
6. If you focus on literature and resources, what do you personally prefer?
   a. Books (printed/E-book)
   b. Literature in pdf-format that can be printed
   c. Student-access to online resources and E-learning tools.
   d. Compendium as required reading
   e. Compendium as a supporting / recommended literature

   1) Not, not preferred by me personally
   2) Neutral, not a must-have
   3) Yes, this is preferred by me personally
   4) Yes, but only if the cost is reasonable or if it’s free
- Books (printed/E-book)

- Literature in pdf-format that can be printed

- Student-access to online resources and E-learning tools
*Deviation notice:
Only 4 participants answered questions d. and e. may due to technical problems with the online survey. The answers are therefore might be misleading or misrepresenting compared to the rest of the survey.

- Compendium as required reading*

- Compendium as a supporting / recommended literature*
7. If the university makes a compendium for the class, what should it contain?
   a. Theory – detailed
   b. Theory – summary
   c. Theory – relevant articles
   d. If possible relate theory to practice
   e. Requirements – copy / extract of the central codes
   f. Requirements – referral to what codes are relevant
   g. Web-link to online resources
   h. Formulas and diagrams
   i. Example – problem solving
   j. Relevant practice problems

1) No, this is totally irrelevant, I consider it “fill”
2) Not if we already have the content in form of a book etc.
3) Yes, this should be included
4) Yes, I consider this important, it should be included

Summary:

8. For maximal learning outcomes, are 3-4 hours of daily lectures enough?
1) Yes, more than satisfying
2) Yes, but only if the lecturer/ professor is available for office hours after class
3) Yes, but only if we have individual problems to solve / projects etc.
4) Yes, but only if we have individual readings
5) I’d like one hour more lecture (+ 1 x 45 minutes after lunch)
6) I’d like two hours more lecture (+ 2 x 45 minutes after lunch)
9. How would you prefer the course being graded?
   a. 100 % - 5 hours written exam
   b. 60 % - 5 hour written exam / 40 % - mid-term or project
   c. 80 % - 5 hour written exam / 20 % - mid-term or project
   d. Exam with only pencil and calculator
   e. Exam with compendium
   f. Exam all written notes and printed texts allowed
   g. Exam with main-focus on calculations
   h. Exam 50/50 calculations and theory
   i. Exam with main-focus on theory / understanding for principles

1) No, rather not
2) Neutral, no strong opinions for or against
3) Yes, my personally opinion
10. Open question - Comments or tips regarding everything you have been questioned with?

An examination for example has 60% examination and 40% exercises are preferring to me. In addition, I prefer personally to have the utilities, but only under "controlled conditions". This means that one can have with a compendium or sheet of formulas and diagrams. Examination should include both theory and dimensioning. A new compendium of the discipline is crucial!
# Appendix C. Overview - Collected Syllabi

<table>
<thead>
<tr>
<th>University / College</th>
<th>Course</th>
</tr>
</thead>
<tbody>
<tr>
<td>University of Alaska, AL</td>
<td>Mechanical &amp; Electrical Technology</td>
</tr>
<tr>
<td>Baker College, MI</td>
<td>Air Conditioning and Heat Pumps</td>
</tr>
<tr>
<td>Blackhawk Technical College, WI</td>
<td>Refrigeration &amp; Air Conditioning Technology</td>
</tr>
<tr>
<td>College of Southern Nevada (CSN), NV</td>
<td><em>Introduction to HVAC and Refrigeration</em></td>
</tr>
<tr>
<td>Dunwoody College of Technology, MN</td>
<td>Refrigeration &amp; Air Conditioning Systems</td>
</tr>
<tr>
<td></td>
<td>HVAC Installation &amp; Duct Fabrication</td>
</tr>
<tr>
<td></td>
<td>Designing for Indoor Comfort</td>
</tr>
<tr>
<td></td>
<td>HVAC Layout &amp; Systems Design</td>
</tr>
<tr>
<td>Elign Community College (ECC), IL</td>
<td><em>Air Conditioning and Refrigeration I &amp; II</em></td>
</tr>
<tr>
<td></td>
<td>Commercial Air Conditioning</td>
</tr>
<tr>
<td>Ferris State University, MI</td>
<td>Heating, Ventilating, Air Conditioning and Refrigeration (HVACR)</td>
</tr>
<tr>
<td>Fresno City College, CA</td>
<td>Air Conditioning</td>
</tr>
<tr>
<td>Massachusetts Institute of Technology, (MiT), MA</td>
<td>Heating, ventilating, and air-conditioning (HVAC) systems.</td>
</tr>
<tr>
<td>Mt. San Antonio CA</td>
<td>Refrigeration Fundamentals</td>
</tr>
<tr>
<td>North Dakota State University, ND</td>
<td>HVAC</td>
</tr>
<tr>
<td>Nova Southeastern University, FL</td>
<td>Air Conditioning Systems I</td>
</tr>
<tr>
<td></td>
<td>Air Conditioning Systems II</td>
</tr>
<tr>
<td>Norwegian University of Science &amp; Technology (NTNU)</td>
<td>Ventilation Technology</td>
</tr>
<tr>
<td></td>
<td><em>(Nor: Ventilasjonsteknikk)</em></td>
</tr>
<tr>
<td>Oakland Community College, CA</td>
<td>Heating, Ventilation, Air Conditioning and Refrigeration Design I</td>
</tr>
<tr>
<td>Scott Community College, IA</td>
<td>Heating, Ventilation and Air Conditioning</td>
</tr>
<tr>
<td>State Technical College of Missouri, MO</td>
<td><em>Fundamentals of Refrigeration and Air Cond. I &amp; II</em></td>
</tr>
<tr>
<td>University of Applied Sciences in Oslo (HiOA)</td>
<td>Heating, Ventilaion and Sanitary Technology</td>
</tr>
<tr>
<td></td>
<td><em>(Nor: Varme, Ventilasjon og Sanitærteknikk)</em></td>
</tr>
<tr>
<td>University of Kentucky (UK), KY</td>
<td>Heating, Ventilating and Air-Conditioning</td>
</tr>
</tbody>
</table>

*Courses in cursive = Not ‘complete’ syllabus, but course description (may contain, books, topics emphasized, assessment, etc.)*
Appendix D. Book Information - Literature Review

<table>
<thead>
<tr>
<th>Title / Author / Price / Chapters</th>
<th>Book cover / ISBN</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Refrigeration and Air Conditioning Technology, 8th edition</strong></td>
<td>[Image]</td>
</tr>
<tr>
<td>Tomczyke, J., Silberstein, E., Whitman, B., &amp; Johnson, B.</td>
<td></td>
</tr>
<tr>
<td>1619 / 1728 pages with charts, glossary and index</td>
<td></td>
</tr>
<tr>
<td>☐ Printed version: USD 184.95</td>
<td>ISBN-13:</td>
</tr>
<tr>
<td>☐ Buy E-book: USD 91.99</td>
<td>978-1305578296</td>
</tr>
<tr>
<td>☐ Rent E-book: USD 39.32 (4 months)</td>
<td></td>
</tr>
<tr>
<td>Review on Amazon: 4.5 / 5.0 (152 reviews)</td>
<td></td>
</tr>
</tbody>
</table>

**Table of contents**

- **Ch. 1 Theory of heat**
  - 1 Heat, temperature and pressure
  - 2 Matter and energy
  - 3 Refrigeration and refrigerants
- **Ch. 2 Safety, tools, equipment and shop practices**
  - 4 General safety practices
  - 5 Tools and equipment
  - 6 Fasteners
  - 7 Tubing and piping
  - 8 Leak detection, system evacuation and system cleanup
  - 9 Refrigerant and oil chemistry and management – recovery, recycling, reclaiming and retrofitting
  - 10 System charging
  - 11 Calibrating instruments
- **Ch. 3 Automatic Controls**
  - 12 Basic electricity and magnetism
  - 13 Introduction to automatic controls components
  - 14 Troubleshooting basic controls
  - 15 Automatic control components and applications
  - 16 Advanced automatic controls (DDCs) and pneumatics
- **Ch. 4 Electric motors**
  - 17 Types of electric motors
  - 18 Application of motors
  - 19 Motor controls
  - 20 Troubleshooting electric motors
- **Ch. 5 Commercial refrigeration**
  - 21 Evaporators and refrigeration systems
  - 22 Condensers
  - 23 Compressors
  - 24 Expansion devices
  - 25 Special refrigeration system components
  - 26 Applications of refrigeration systems
  - 27 Commercial ice machines
  - 28 Special refrigeration applications
  - 29 Troubleshooting and typical operating conditions for commercial refrigeration
- **Ch. 6 Air Conditioning (Heating and Humidification)**
  - 30 Electric heat
  - 31 Gas heat
  - 32 Oil heat
  - 33 Hydronic heat
  - 34 Indoor air quality
- Ch. 7 Air Conditioning (Cooling)
  - 35 Comfort and psychrometrics
  - 36 Refrigeration applied in air conditioning
  - 37 Air distribution and balance
  - 38 Installation
  - 39 Residential energy auditing
  - 40 Typical operating conditions
  - 41 Troubleshooting
- Ch. 8 All-Weather systems
  - 42 Heat gains and heat losses in structures
  - 43 Air source heat pumps
  - 44 Geothermal heat pumps
- Ch. 9 Domestic appliances
  - 45 Domestic refrigerators and freezers
  - 46 Room air conditioners
- Ch. 10 Commercial Air-Conditioning and Chilled Water systems
  - 47 High pressure, low pressure and absorption chilled water sys.
  - 48 Cooling towers and pumps
  - 49 Operation, maintenance and troubleshooting of chilled water air conditioning systems
  - 50 Commercial, packaged rooftop, variable refrigerant flow and variable air volume systems
- Appendix A Alternative heating (stoves and fireplaces inserts)
- Appendix B Temperature conversion chart

Blackhawk Technical College Wisconsin &
Dunwoody College of Technology Iowa

AHRI Fundamentals of HVAC/R, 3rd edition
Carter Stanfield & David P.E. Skaves
1462 pages / 1520 with index and glossary
- Printed version: USD 186,60
- Buy E-book: USD 111,99
- Rent E-book: USD 46,99 (7 months)
Review on Amazon 4.2 / 5.0 (31 reviews)

Table of contents
- Ch. 1 Fundamentals
  - 1 Introduction to heating, ventilation, AC and refrigeration
  - 2 Being a professional HVAC technician
  - 3 Safety
  - 4 Hand and Power tools
  - 5 Screws, rivets, staples and other fasteners
  - 6 Measurements
- Ch. 2 HVACR Science
  - 7 Properties of matter
  - 8 Types of energy and their properties
  - 9 Temperature measurement and conversion
  - 10 Thermodynamics – The study of heat
  - 11 Pressure and vacuum
  - 12 Calibrations and instruments
- Ch. 3 Refrigeration systems and components
  - 13 Types of refrigeration systems
  - 14 The refrigeration cycle
  - 15 Compressors
  - 16 Condensers

ISBN-13:
978-0134016160
• Ch. 4 Refrigeration practices
  o 22 Refrigerant safety
  o 23 Refrig. systems servicing and testing equipment
  o 24 Piping and tubing
  o 25 Soldering and brazing
  o 26 Refrigerant system piping
  o 27 Accessing sealed refrigeration systems
  o 28 Refrigerant management and the epa
  o 29 Refrigerant leak testing
  o 30 Refrigerant system evacuation
  o 31 Refrigerant system charging

• Ch. 5 HVACR Electrical Systems and Components
  o 32 Electrical safety
  o 33 Basic electricity
  o 34 Alternating current fundamentals
  o 35 Electrical measuring and testing instruments
  o 36 Electrical components
  o 37 Electric motors
  o 38 Electrical diagrams
  o 39 Control systems
  o 40 Communicating control systems

• Ch. 6 Air Conditioning Systems
  o 41 Fundamentals of psychometrics and airflows
  o 42 Air filters
  o 43 Ventilation and dehumidification
  o 44 Residential air conditioning
  o 45 Residential split system air conditioning installations
  o 46 Duct installation
  o 47 Trouble shooting air conditioning systems

• Ch. 7 Heating Systems
  o 48 Principles of combustion and safety
  o 49 Gas furnaces
  o 50 Gas furnace controls
  o 51 Gas furnace installation
  o 52 Troubleshooting furnaces
  o 53 Oil-fired heating systems
  o 54 Oil furnace and coiler service
  o 55 Residential oil heating installations
  o 56 Trouble shooting oil heating systems
  o 57 Space heaters
  o 58 Humidifiers

• Ch. 8 Heat Pump Systems
  o 59 Electric heat
  o 60 Electric heat installations
  o 61 Trouble shooting electric heat
  o 62 Heat pump system fundamentals
  o 63 Air source heat pump applications
  o 64 Geothermal heat pumps
  o 65 Heat pump installation
  o 66 Trouble shooting heat pump systems

• Ch. 9 System Design, Sizing and Layout
  o 67 Basic building construction
  o 68 Green building and systems
  o 69 Indoor air quality (IAQ)
- 70 Residential load calculations
- 71 Duct design
- 72 Zone control systems
- 73 Testing and balancing air systems

- **Ch. 10 Commercial Environmental Systems**
  - 74 Commercial air conditioning systems
  - 75 Fans and air handling units
  - 76 Single zone rooftop unit installation
  - 77 Zoned systems
  - 78 Commercial control systems
  - 79 Chilled water systems
  - 80 Hydronic heating systems
  - 81 Boilers and related equipment
  - 82 Cooling towers
  - 83 Thermal storage systems

- **Ch. 11 Commercial Refrigeration Systems**
  - 84 Food preservations
  - 85 Commercial refrigeration systems
  - 86 Supermarket equipment
  - 87 Ice machines
  - 88 Trouble shooting refrigeration systems

- **Ch. 12 Installation, Maintenance, Service & Troubleshooting**
  - 89 installation techniques
  - 90 Planned maintenance
  - 91 Refrigeration system cleanup
  - 92 Troubleshooting

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Scott Community College, Iowa &
Mt. San Antonio State, California

**Heating, Ventilation, and Air Conditioning Analysis and Design 6th ed.**
McQuiston, F.C., Parker, J.D. & Spitler, J.D.

680 pages / 742 with index and appendices.

- Printed version: USD 141.96
- Not available as E-book
- Review on Amazon 3.4 / 5.0 (34 reviews)

**Table of contents**

- List of Symbols
- List of Charts

- **Chapter 1 Introduction**
  - 1-1 Historical notes
  - 1-2 Units and dimensions
  - 1-3 Fundamental concepts
  - Problems

- **Chapter 2 Air Conditioning Systems**
  - 2-1 The system
  - 2-2 The air conditioning and distribution system
  - 2-3 Central mechanical equipment
  - 2-4 All-air systems
  - 2-5 Air and water systems
  - 2-6 All-water systems
  - 2-7 Unitary air conditioners
  - 2-8 Heat pump systems
  - 2-9 Heat recovery systems
  - 2-10 Summary
  - Problems

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• Chapter 3 Moist Air Properties and Conditioning Processes
  o 3-1 Moist air and the standard atmosphere
  o 3-2 Fundamental parameters
  o 3-3 Adiabatic saturation
  o 3-4 Wet bulb temperature and the psychrometric chart
  o 3-5 Classic moist air processes
  o 3-6 Space air conditioning – design conditions
  o 3-7 Space air conditioning – off design conditions
  o Problems
• Chapter 4 Indoor Air Quality – Comfort and Health
  o 4-1 The basic concerns
  o 4-2 Common containments
  o 4-3 Method to control containments
  o 4-4 Comfort – physiological considerations
  o 4-5 Environmental comfort indices
  o Problems
• Chapter 5 Heat Transmission in Building Structures
  o 5-1 Basic heat transfer modes
  o 5-2 Tabulated overall heat transfer coefficients
  o 5-3 Moisture transmission
  o Problems
• Chapter 6 Solar Radiation
  o 6-1 Thermal radiation
  o 6-2 The earth’s motion about the sun
  o 6-3 Time
  o 6-4 Solar angles
  o 6-5 Solar irradiation
  o 6-6 Heat gain through fenestrations
  o 6-7 Energy calculations
  o Problems
• Chapter 7 Space Heat Load
  o 7-1 Outdoor design conditions
  o 7-2 Indoor design conditions
  o 7-3 Transmission heat losses
  o 7-4 Infiltration
  o 7-5 Heat loss from air ducts
  o 7-6 Auxiliary heat sources
  o 7-7 Intermittently heated structures
  o 7-8 Supply air for space heating
  o Problems
• Chapter 8 The Cooling Load
  o 8-1 Heat gain, cooling load, and heat extraction rate
  o 8-2 Outdoor and indoor design conditions
  o 8-3 The transfer function method
  o 8-4 Determination of heat gain
  o 8-5 Conversion of heat gain into cooling load
  o 8-6 Heat extractions rate and room temperature
  o 8-7 The extraction rate and room temperature
  o 8-8 The CLTD/SCL/CLF method
  o 8-9 Supply air quantities
  o Problems
• Chapter 9 Energy Calculations
  o 9-1 The degree day procedure
  o 9-2 Bin method
  o 9-3 Comprehensive simulation methods
  o Problems
• Chapter 10 Flow, Pumps and Piping Design
  o 10-1 Fluid flow basics
  o 10-2 Centrifugal pumps
- Chapter 10: Combined system and pump characteristics
- Chapter 11: Piping system design
- Chapter 12: Control of hydronic systems
- Chapter 13: Large system design
- Chapter 14: Problems
- Chapter 15: Space Air Diffusion
  - 11-1 Behavior of jets
  - 11-2 Air distribution system design
  - Chapter 16: Problems
- Chapter 17: Fans and Building Air Distribution
  - 12-1 Fans
  - 12-2 Fan performance
  - 12-3 Fan selection
  - 12-4 Fan installation
  - 12-5 Field performance testing
  - 12-6 Fans and variable air volume systems
  - 12-7 Air flow in ducts
  - 12-8 Air flow in fittings
  - 12-9 Turning vanes and dampers
  - 12-10 Duct design – general considerations
  - 12-11 Design of low velocity duct systems
  - 12-12 High velocity duct design
  - Chapter 18: Problems
- Chapter 19: Direct Contact Heat and Mass Transfer
  - 13-1 Combined heat and mass transfer
  - 13-2 The air washer
  - 13-3 The spray humidifier
  - 13-4 Cooling towers
  - Chapter 20: Problems
- Chapter 21: Extended Surface Heat Exchangers
  - 14-1 The LMTD method
  - 14-2 The NTU method
  - 14-3 Heat transfer single component fluids
  - 14-4 Transport coefficient inside tubes
  - 14-5 Transport coefficient outside tubes and compact surfaces
  - 14-6 Design procedures for sensible heat transfer
  - 14-7 Combined heat and mass transfer
  - Chapter 22: Problems
- Chapter 23: Refrigeration
  - 15-1 The performance of refrigeration systems
  - 15-2 The theoretical single stage compression cycle
  - 15-3 Refrigerants
  - 15-4 Compression cycle components
  - 15-5 The real single-stage cycle
  - 15-6 Absorption refrigeration
  - 15-7 The theoretical absorption system
  - 15-8 The aqua-ammonia absorption system
  - Chapter 24: Problems
- Appendix A: Thermodynamic Properties
- Appendix B: Thermophysical Properties
- Appendix C: Weather Data
- Appendix D: Pipe and Tube Data
- Appendix E: Useful Data
- Appendix F: Symbols

University of Kentucky College of Engineering (KU), Massachusetts Institute of Technology (MiT) & North Dakota State University (NDSU)
Table of Contents

- Chapter 1 - 8 Principles
  - 1 Psychometrics
  - 2 Thermodynamics and Refrigeration Cycles
  - 3 Fluid Flow
  - 4 Heat Transfer
  - 5 Two-Phase Flow
  - 6 Mass Transfer
  - 7 Sound and Vibration

- Chapter 9-13 Indoor Quality
  - 9 Thermal Comfort
  - 10 Indoor Environmental Design
  - 11 Air Containments
  - 12 Odors
  - 13 Indoor Environment Modeling

- Chapter 14-19 Load and Energy Calculations
  - 14 Climatic Design Information
  - 15 Fenestration
  - 16 Ventilation and Infiltration
  - 17 Residential Cooling and Heating Load Calculations
  - 18 Nonresidential Cooling and Heating Load Calculations
  - 19 Energy Estimation and Modeling Methods

- Chapter 20-24 HVAC Design
  - 20 Space and Air Diffusions
  - 21 Duct Design
  - 22 Pipe Sizing
  - 23 Insulation for Mechanical Systems
  - 24 Airflow Around Buildings

- Chapter 25-27 Building Envelope
  - 25 Heat, Air and Moisture Control in Buildings
    - Assemblies – Fundamentals
  - 26 Heat, Air and Moisture Control in Buildings Assemblies – Material Properties
  - 27 Heat, Air and Moisture Control in Buildings Examples

- Chapter 28-33 Materials
  - 28 Combustions and Fuels
  - 29 Refrigerants
  - 30 Thermophysical Properties of Refrigerants
  - 31 Physical Properties of Secondary Coolants (Brines)
  - 32 Sorbents and Desiccants
  - 33 Physical Properties of Materials

- Chapter 34-39 General
  - 34 Energy Recourses
  - 35 Sustainability
  - 36 Measurement and Instruments
  - 37 Abbreviations and Symbols
  - 38 Units and Conversions
  - 39 Codes and standards

Dunwoody College of Technology, Iowa & University of Kentucky College of Engineering (KU)
ASHRAE Air Conditioning Design Manual 2nd ed.
Ashrae special publications, Butterworth-Heinemann, Grondzik, W.T.
274 pages / 319 pages with appendices and index
- Printed: USD 89.95 (student ASHRAE member USD 45)
- E-book: USD 89.95 (student ASHRAE member USD 45)

Table of contents
- Chapter 1 Introduction
- Chapter 2 The Design Process
- Chapter 3 Occupant Comfort and Health
- Chapter 4 Load Calculations
- Chapter 5 Components
- Chapter 6 All-Air HVAC Systems
- Chapter 7 Air- and Water Systems
- Chapter 8 All-Water Systems
- Chapter 9 Special HVAC Systems
- Chapter 10 HVAC&R Controls
- Appendices

Recommended by the “industry” (ASHRAE)
“Fundamental HVAC&R resource material - as a senior - or graduate-level text for a university course in HVAC system design”

Ventilasjonsteknikk I, 3rd ed. (Vol. 1/2)
Ingebrigtsen, S.
(Based on Leif I. Stenaas’ Ventilasjonsteknikk I, 1999)
Printed I: NOK 1040 / student NOK 620
E-book I: NOK 515 / student NOK 305
Printed: I + II: NOK 1560 / student NOK 930
E-book: I + II: NOK 772 / student NOK 475

Table of Contents
- Chapter 1 Introduction to Ventilation
- Chapter 2 Indoor Climate
- Chapter 3 Moist Air
- Chapter 4 Heat Transfer
- Chapter 5 Fluid mechanics Air Flow – Fundamentals
- Chapter 6 Air Volumes
- Chapter 7 Ventilation Systems – The Main Systems
- Chapter 8 Air Flow in rooms

(Sub-chapters are not included due to the number of capsules)

The University College of Applied Sciences in Oslo (HiOA),
The Norwegian University of Science & Technology, Trondheim (NTNU)
Ventilasjonsteknikk II, 1st ed. (Vol. 2/2)
Ingebrigtsen, S.

Printed I: NOK 1040 / student NOK 620
E-book I: NOK 515 / student NOK 305
Printed: I + II: NOK 1560 / student NOK 930
E-book: I + II: NOK 772 / student NOK 475

Table of contents
- Ch. 9 Sound and noise dampers in ventilation systems
- Ch. 10 Energy consumption, fans, heating and cooling
- Ch. 11 Demand controlled ventilation (DCV)
- Ch. 12 Ducts
- Ch. 13 Fire protection in ventilation systems
- Ch. 14 In-regulation of ventilation systems

(Sub-chapters are not included due to the number of capsules)
Appendix E. Suggested Video-Clips

**Fundamentals of HVAC** by Osama Khayata:
1) Introduction [https://www.youtube.com/watch?v=eN1losQsV-g](https://www.youtube.com/watch?v=eN1losQsV-g)
2) Basics of HVAC [https://www.youtube.com/watch?v=fqvo7bSr6t8](https://www.youtube.com/watch?v=fqvo7bSr6t8)
3) Comfort Criteria [https://www.youtube.com/watch?v=qZ3RwH018Qw](https://www.youtube.com/watch?v=qZ3RwH018Qw)
4) Space Air Diffusion [https://www.youtube.com/watch?v=zePhL3PIdMI](https://www.youtube.com/watch?v=zePhL3PIdMI)
5) Pressure Measurement [https://www.youtube.com/watch?v=YmKhE1d1Wws](https://www.youtube.com/watch?v=YmKhE1d1Wws)
6) Noise Control Fundamentals [https://www.youtube.com/watch?v=F_OcbCN-Tpo](https://www.youtube.com/watch?v=F_OcbCN-Tpo)
7) Air Outlet selection [https://www.youtube.com/watch?v=OvVCCjuluY&t=32s](https://www.youtube.com/watch?v=OvVCCjuluY&t=32s)
8) Displacement ventilation [https://www.youtube.com/watch?v=kB7zMJaFlcw](https://www.youtube.com/watch?v=kB7zMJaFlcw)
9) Air Outlet selection [https://www.youtube.com/watch?v=OvVCCjuluY](https://www.youtube.com/watch?v=OvVCCjuluY)
10) Variable Air Volume Diffusers [https://www.youtube.com/watch?v=GMVq3jwbL8M](https://www.youtube.com/watch?v=GMVq3jwbL8M)
11) Terminal Silencer [https://www.youtube.com/watch?v=vC0l2cduKVw](https://www.youtube.com/watch?v=vC0l2cduKVw)

**Air Conditioning** by TL Lai:
1) Introduction [https://www.youtube.com/watch?v=rUjjj6Fnhz4](https://www.youtube.com/watch?v=rUjjj6Fnhz4)
2) Air Cycle [https://www.youtube.com/watch?v=nDU7rUGjADE](https://www.youtube.com/watch?v=nDU7rUGjADE)
3) Chilled & Condenser Water Systems [https://www.youtube.com/watch?v=Ilzv1TjPYQ](https://www.youtube.com/watch?v=Ilzv1TjPYQ)
4) Constant Air Volume Systems [https://www.youtube.com/watch?v=ZJB5DTpwUpY](https://www.youtube.com/watch?v=ZJB5DTpwUpY)
5) Variable Air Volume Systems [https://www.youtube.com/watch?v=YCo6V3XOw](https://www.youtube.com/watch?v=YCo6V3XOw)
6) Fan Coil Unit (FCU) [https://www.youtube.com/watch?v=Q1005x2z3ll](https://www.youtube.com/watch?v=Q1005x2z3ll)

**Ventilation air handling unit** by WIKA Group:
WIKA - Measuring instruments for ventilation and air-conditioning [https://www.youtube.com/watch?v=VhqdzesCLIQ](https://www.youtube.com/watch?v=VhqdzesCLIQ)