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Teaching and learning fundamental geotechnics through implementation of active learning

An experiment on how the implementation of active learning on an ordinary lecture affects students learning.

Master's thesis in Learning and Leadership

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CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2019

MASTER’S THESIS 2019: CLSX35

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Abstract

The goal of teaching any subject is, of course, to achieve the most effective learning. There are several ways to implement teaching and also many different ways to improve the way any subject is taught by using the variety of different teaching models available. This depends on what kind of knowledge a teacher wants to mediate. Fundamental geotechnics is a subject were new methods of teaching could be prosperous. This conclusion is drawn from personal experience from studying the course “Geoteknik med grundläggning” on Chalmers (Chalmers, 2016) and from being part of the course as a teacher for two years. I am studying to become both a civil engineer and a teacher. This combination of experience gives me a rather unique perspective as I have knowledge both in the area of teaching and learning in general, as well as in teaching and learning fundamental geotechnics.

The aim of this project is to create a method usable by teachers with no assumed pedagogical education and with which active learning can be implemented to an ordinary lecture in geotechnics. Further, the project aims to investigate whether active learning is conductive to learning in geotechnics.

A teaching method for implementing active learning to an ordinary lecture was developed. Active learning was implemented on an ordinary lecture in fundamental geotechnics which was used in the investigation that consisted of an experiment. In the experiment an experiment group attended a lecture with active learning implemented and afterward answered an online survey. The survey contained questions regarding both the students´ remembrance of the lecture´s content and their perception of the lecture’s arrangement. The answers from the experiment group was compared to the answers from a control group that attended a lecture with the same content but with no active learning implemented. The control group answered the same online survey as the experiment group.

According to the result from the performed experiment it is possible to use the developed method in order to implement active learning to an ordinary lecture. The implementation of active learning is appreciated by students participating. Whether this experiment shows that active learning contributes to students remembering more of the content of a lecture cannot be established in this case as the number of control questions and participants were too few.

Keywords: geotechnics, active learning, teaching, teaching models

Acknowledgements

First, I would like to thank my classmates and especially Sara Juul for inspiring and tolerating me during this time. Your help and support have been crucial in finishing this report.

Secondly, I would like to thank Mats Karlsson, Jens Kabo and Samuel Bengmark for taking time from their busy schedules and assisting me when I needed expert advice in order to proceed.

Johanna Larsson
Gothenburg, May 2019

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1 Introduction

The goal of teaching any subject is, of course, to achieve the most effective learning. There are several ways to implement teaching and also many different ways to improve the way any subject is taught by using the variety of different teaching models available, depending on what kind of knowledge a teacher wants to mediate.

Some kind of fundamental geotechnics is studied by all civil engineer students (TopUniversities, 2019). Geotechnics is a subject with uncertainty in characteristic of material properties which makes it different to the major part of the remaining courses (Sällfors, 2009). I personally have experiences from both learning and teaching fundamental geotechnics and also from teaching and learning in general as I am studying to become both a civil engineer and a teacher. This unique perspective has made me aware that new methods of teaching could be prosperous

In this report, teachers will be referred to as "she" instead of "he/she/else" to simplify the reading. This however, does not necessarily mean that the teacher is a woman, the reader is welcome to apply whatever gender that seems suitable, a teacher's gender does not affect the methods described.

1.1 Glossary

Since the meaning of a few words or expressions can differ between persons, the following glossary in Table 1 explains how some words are to be interpreted in this report.

Teaching	The teacher mediates facts
Learning	The students containing knowledge
Procedure	The ability to apply a known method on a given issue
Relevance	The ability to relate theory to reality
Ordinary lecture	A lecture where the lecturer is the only one talking and the students passively receives information
Teacher	The person supposed to mediate knowledge, this includes lecturers

Table 1: Glossary

1.2 Background

Geotechnical engineering has, compared to others subject taught while studying civil engineering, some deviant characteristics, it is well understood to be one of the branches of civil engineering that requires most engineering judgment (Kumar, 2008). When receiving the compression modulus or the ground water level for a soil, these values cannot be assumed to be correct for all soil or the entire area. To calculate an exact value without exact input data is impossible. This uncertainty in characteristic of material properties is one major thing that separates geotechnics from other technical subjects. Geotechnical engineers have to make many assumptions while making calculations. This way of approximately thinking is new to many of the students taking their first course of geotechnics. A majority of the students have not even heard about geotechnics before taking their first course in the subject (Sällfors, 2009). In subjects such as mathematics and mechanics a student can manage by relying on procedure (applying a known method on a given issue). When calculating mathematics or the deflection of a beam with known properties, students are expected to find that one exact and correct answer. For example, when receiving the elastic modulus for a steel beam, this value is known to be correct and applicable on the entire beam. In geotechnics, the material property uncertainty increases the importance of the ability of relevance (the ability to relate theory to reality). It can therefore be discussed whether these subjects should be taught in the same way as each other. It is common knowledge that teaching in universities mostly consists of ordinary lectures where a teacher talks and students listen while (maybe) taking notes. Further, exercises where students work with given assignments and can ask a teacher for help if getting stuck is part of the education too.

In Table 2 it is displayed how Chalmers University of Technology (CUT), KTH Royal institute of technology (KTH), LTH Faculty of Engineering (LTH) and Uppsala University (UU) distributed the arrangement of their respective first course in geotechnics.

Lectures	CUT	LTH	KTH	UU
Exercises	CUT	LTH	KTH	UU
Lab experiments		LTH	KTH	UU
Study visit/excursion		LTH	KTH	UU
Hand in assignment	CUT	LTH	KTH	UU
Written exam	CUT	LTH	KTH	UU

Table 2: Display of the course arrangement of four universities

By studying the first course in geotechnics on four of the biggest universities in Sweden with a civil engineering program it is concluded that they all have the same basic arrangement. The courses all consist of lectures combined with exercises and are examined through a hand in assignment and a written exam. The geotechnics courses at mentioned universities are all placed at the second half of the bachelor which means that the students have already taken several courses in mathematics, mechanics, construction etc. establishing a mindset of calculating for an exact answer and using constant material properties (Chalmers, 2018), (LTH, 2018) , (KTH, 2019), (Uppsala University, 2018). Opinions exists about what the content of the first course of geotechnics should contain (what the teaching should contain) (Larsson, Johansson, Spross, & Wersäll, 2014) but opinions on how the teaching should be executed (how to turn the teaching into learning) are more scarce.

My personal experiences, from studying the course “Geoteknik med grundläggning” on Chalmers (Chalmers, 2016) and from being part of the course as a teacher for two years, correspond with the above. I am studying to become both a civil engineer and a teacher. While studying to become a teacher several pedagogical studies are naturally included. This combination of experience gives me a rather unique perspective as I have knowledge both in the area of teaching and learning geotechnics and also in the area of teaching and learning in general. I have personally experienced the struggle of not being able to rely on procedure and I have witnessed my classmates go through it as well. The struggle became even more distinguishable when I observed the students from the perspective of a teacher. The students had major trouble with not being given exact input data before starting calculations and the majority became very unsecure when being told to assume a reasonable value when missing data. They also became very frustrated when two calculations with different answers both were judged to be correct. The calculations could both be correct according to the different assumptions made in each calculation, but this was something many students had major trouble to accept. My personal belief is that the current used teaching methods of fundamental geotechnics are better adapted for courses where it is possible or even advantageously to rely on procedure. To better achieve theoretical understanding and relevance new methods of teaching geotechnics could therefore be prosperous.

1.3 Aim

The aim of this project is to create a method usable by teachers with no assumed pedagogical education and with which active learning can be implemented to an ordinary lecture in geotechnics. Further, the project aims to investigate whether active learning is conductive to learning in geotechnics.

1.4 Question at issue

Can active learning be implemented on an ordinary lecture and how will the implementation affect the learning in fundamental geotechnics?

A. Does the implementation of active learning make the students remember more of the content compared to an ordinary lecture?
B. How does the implementation of active learning to a lecture affect students' perception of the lecture's arrangement?

1.5 Limitations

- This investigation only focuses on the intro course to geotechnics on technical universities
- The content of fundamental geotechnics is based on established technical universities in Sweden
- The teaching method is adapted to the limitations of an ordinary lecture
- The teaching method does not contain methods that are judged to be too complicated to use by teachers with no pedagogical education
- The chapter "Fundamental geotechnics" will only be described theoretically, meaning no use of equations to describe conditions
- Only teaching methods considered usable or relevant to teaching in a common lecture room will be studied and presented.
- The experiment that evaluates the teaching method will only be performed in the subject fundamental geotechnics
- The context of an ordinary lecture is assumed to be a common lecture room

2 Background

Following chapter presents the concept of active learning is presented based on methods and research relevant for this investigation. Furthermore, a basic theoretical description of fundamental geotechnics is presented in order to give the unaware reader a basic perception of the subject.

2.1 Active learning

"True learning results from doing things and reflecting on the outcomes, not from passively receiving information" (Felder & Brent, 2016).

The goal of all teaching is to achieve learning. How this is best executed is an ongoing discourse and differs from case to case. A teaching model is a model that explains how learning is generated and how the teaching can be designed. Several teaching models are available and it is concluded that a variation of models are necessary as different types of models are suitable for different types of learning (Phillips & Soltis, 2004). The following chapter will describe teaching methods that are useful in the development of the teaching method for applying active learning on an ordinary lecture of fundamental geotechnics. The methods described are all connected to activating students and are applicable on teaching and learning in the context of university studies in lecture rooms.

The main goal and foundation of active learning is to achieve engaged students whom are active participants in their learning during class compared to passive receivers of information. There are a broad range of activities and teaching strategies applicable on active learning (University Of Minnesota, 2019). Cooperative learning is considered to be a key strategy to change students from passive to active learners. According to Johnson, R. T. and D. W. Johnson (2008) engaging students in active and cooperative learning results in higher self-esteem, higher achievement, greater retention, and more positive feelings between students and towards the subject in matter. Working cooperatively also forces students to participate more as they are all expected and required to participate and contribute to the group discussion (Johnson & Johnson, 2008). Active learning does also enhance longer lasting memory retention (Bligh, 1998) and several studies have proved that active learning outperforms traditional lecturing in promoting almost every learning outcome examined (Freeman et al., 2014). To achieve learning it is necessary for the students to be attentive, it is however difficult to stay attentive for a long time while being passive in an ordinary lecture. Researchers have measured students´ attention to a lecturer during different times at lectures. In Figure 8 the attentiveness during a typical lecture with no activities included is visualized. The attentiveness during a lecture with activities included is presented in Figure 9.

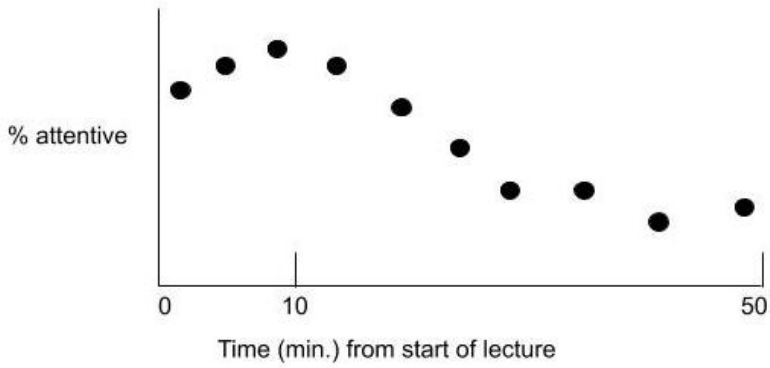


Figure 1: Attentiveness versus Time in Lecture - No Activities (Felder & Brent, 2016)

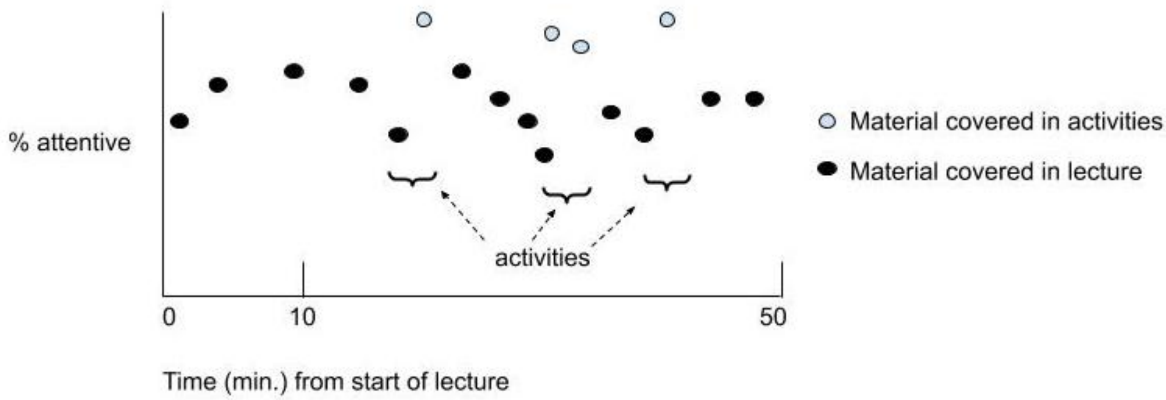


Figure 2: Attentiveness versus Time in Lecture - Activities Interspersed (Felder & Brent, 2016)

As figure 8 and 9 shows, the attentiveness of students greatly improves after an activity during the lecture. The overall attentiveness in the lecture without activities (Figure 8) can be seen to be much lower than the attentiveness in a lecture with activities (Figure 9).

Peer discussion is a usable activity and an evident part of active learning. It can be implemented to an ordinary lecture. It is proved that the use of peer discussion enhances student´s understanding. Results also indicates that even if none of the students in a group discussion initially knows the correct answer, their understanding is promoted. This was concluded from an investigation at the University of Colorado-Boulder where students, in an undergraduate introductory genetics class, were asked an average of five clicker questions per 50-min class through-out the semester. The students were encouraged to discuss the questions with their neighbors. (To motivate the students to answer the clicker questions they were given participation points just for answering, regardless of whether the answers were correct or not. To increase the student's motivation to take the clicker questions seriously they were informed that the exam questions were going to be similar to the clicker questions). Six times during the semester the students were asked to answer a set of isomorphic questions to asses how much student learned from peer discussion. Students were asked to answer a question, Q1, individually. Then they were invited to discuss the same question in a group and if they wanted they could change their answer. Of all students who answered Q1 wrong, 42% answered Q1ad (after discussion) correct. After answering Q1 and Q1ad the students got to answer an isomorphic question Q2 individually. The results showed that of all students answering both Q1 and Q1ad wrong 44% still managed to answer Q2 correct. This investigation indicates that peer discussion strongly enhances learning. It also shows that it is not necessary for a group to have one person knowing the correct answer to benefit from peer discussion, even though no one in the group knows the correct answer beforehand students still seems to benefit from the discussion. Also, the students answering both Q1 and Q1ad wrong seems to have achieved learning from the peer discussion as so many of them managed to answer Q2 correct (Smith et al., 2009). Figure 10 shows a breakdown of students´ responses from questions Q1, Q1ad and Q2.

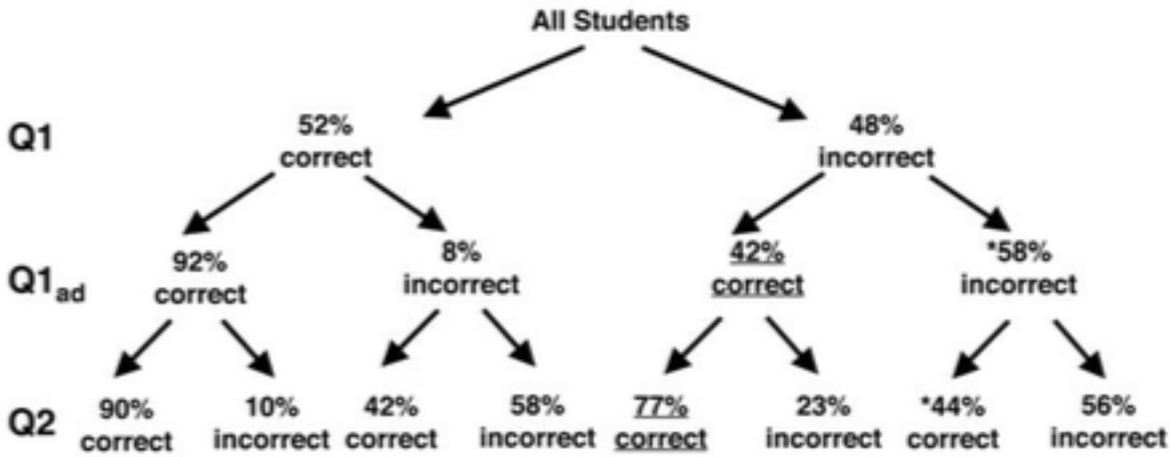


Figure 3: Breakdown of students' responses from peer discussion

The study by Smith, Wood et al. (2009) indicates the advantages of using peer discussion as a tool for learning and implementation of active learning in an ordinary lecture.

A meta-meta-analysis made by Hattie. J (2012) identified and ranked 138 different factors which all might affect students' abilities to perform. The study included a meta study of 800 meta studies which in total involved around 50 000 surveys and more than 80 million students. The survey stresses six factors for successful learning.

1. The single teacher has a crucial impact on students' performances.
2. The teacher showing leadership, influence, care and emotional commitment in her teaching.

3. The teacher showing interest for what individual students think and understand as well as continuously working with giving each student feedback on an appropriate level. The teacher does not only expect progress from students with talent but also the students whom have to struggle.
4. The teacher is aware of the intention of the teaching and the concreate goals. The teacher structures her teaching based on the question “what happens next?” in order to decrease the distance between the student’s current level of knowledge and the existing goals.
5. The teacher customizes the teaching and offers the students a wide repertoire of methods to achieve learning. The central part being that the teacher visible the intention of the teaching and the criteria’s to reaching the goal to the students.
6. The teacher participates in creating an environment where mistakes are welcomed as an opportunity to learn and where students feel safe to learn and explore.

A conclusion worth emphasizing is that nothing competes with a skilled teacher and that the interaction between student and teacher has a major impact in the student´s ability to perform. These factors can all be implemented to an ordinary lecture in order to achieve a more active and effective learning. Hattie stresses the fact that knowing your subject and wanting to teach, or having students wanting to learn, is not enough to achieve learning (Hattie, 2012). Students´ learning benefits from active practice and feedback both in and out of class. The teacher should always recall prior material, answer a question, think of questions about covered material to ask the students and summarize lectures and/or parts of lectures (Felder & Brent, 2016).

2.1.1 Active learning implemented in geotechnics

The method that was implemented in the following study (Donohue, 2014) is challenging to implement in a lecture room as it depends on students sitting in groups of 4-6 persons and requires the access to clickers. The study is however relevant for this project since it gives a clear indication of the positive effects of using active learning in a geotechnical course. In the study, audience response systems (ARS) in the form of quizzes with clickers to answer where implemented in an undergraduate civil engineering course on foundation design. A number of summary quizzes where incorporated into the course and executed in small groups. Only one clicker was provided for each group and the students therefore had to discuss the questions before agreeing on a mutual answer. After the course the students answered an online survey containing eight multiple choice questions. In the survey the students indicated their agreement with each statement on a scale from 1 to 5 where 1 represented strongly negative response and 5 strongly positive response. The results from this survey is stated in Table 4 below.

Questions	Mean
1. Did you find the quizzes to be useful activities?	4.61
2. Did the quizzes help you to improve your understanding of the course materials?	4.39
3. Did participation in the summary quizzes improve your exam preparation when compared to other courses?	4.30

4. Did the quizzes help to improve your interest in the subject area (Foundation Design)?	3.96
5. Did the quizzes encourage you to participate more in class?[1]	4.30
6. During the quizzes how much interaction did you have with your peers?	4.78
7. How did you find the level of difficulty of the quizzes?[2]	3.26
8. Would you recommend that the summary quizzes are used again next year?	4.78

Table 3: Results from survey of ARS in course on foundation design

Table 5 displays the Failure rate of the examination from when the ARS quizzes where implemented compared to the year before when they were not used.

	Failure rate (%)
(1) Course incorporating ARS summary quizzes	7.7
(2) Previous year without ARS summary quizzes	14.1

Table 4: display of exam results

The results from the survey clearly indicates that the majority of the students considered the quizzes as useful activities which helped them to improve their understanding of the course content. The activity was considered easy to manage even though the class size was relatively large (around 70 students). The quizzes created a lively atmosphere but students indicated that they enjoyed the competitive part of the activity. (Donohue, 2014)

2.2 Fundamental geotechnics

Geotechnics deals with the technical characteristics for building on soil and rock as well as different ways of founding before and during construction. The intention of the following chapter is to give the reader an overview of fundamental geotechnics. The chapter contains information based on the content of the first course in geotechnics on four major universities in Sweden. The main parts of the course on the different schools are displayed in table 3 below (Chalmers, 2018),(LTH, 2018), (KTH, 2019), (Uppsala University, 2018).

Soil mechanics	CTH	LTU	KTH	UU
Settlements	CTH	LTU	KTH	UU
Slope stability	CTH	LTU	KTH	UU
Bearing capacity		LTU	KTH	UU
Excavation and soil pressure	CTH	LTU	KTH	UU

Table 5: Description of content in the first geotechnical course on four major universities in Sweden

Within the subject "Geotechnics", knowledge of how to accomplish a safe underground construction is regarded. When constructing buildings and other things on the ground, the load from the construction is brought down to the underlying ground material. This must

[1] Question 5 is based on a different scale: 1 represents no interaction and 5 a lot of interaction

[2] Question 7 is based on a different scale: 1 represents much too difficult, 3 Just right and 5 much too easy

occur without causing deformations in the ground that are big enough to compromise the function of the construction. A geotechnical engineer must therefore be able to decide the characteristics of a soil, the spreading of a load into the ground leading to an increased level of stress in the soil. A big part of a geotechnical engineer´s job is to create a model of the construction site making it possible to perform calculations upon. This can be a challenging as soil is a natural and inconstant material (Sällfors, 2009).

2.2.1 Soil characteristics

A soil is said to be idealized as a three-phase continuum of solid material, fluid and gas. The solid material consists of organic material such as plant residue in different states of decay and/or mineral particles which make up the soil skeleton. The fluid and gas phase are represented by the voids between the solid particles, the pores, which are filled with water and/or air. An enlarged illustration of the soil skeleton and pore system is shown in Figure 1.

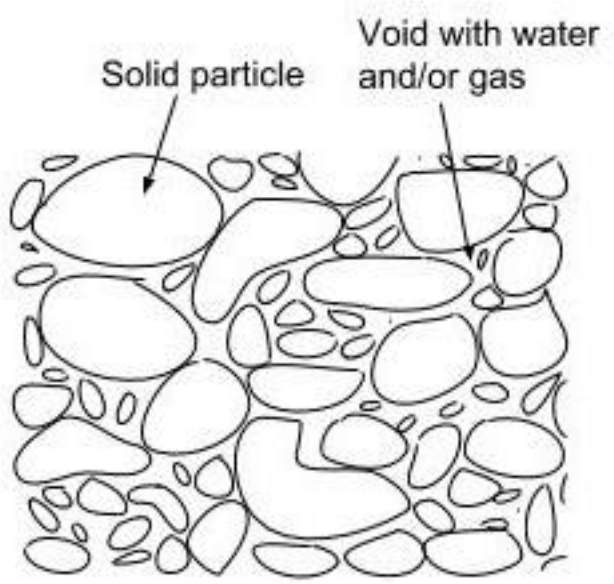


Figure 4: Illustration of the three phases of soil

When establishing the characteristics of a soil the volume and mass of the three phases can be modelled according to Figure 2. The internal distribution of these three phases combined with the particle size of the minerals strongly affects the characteristics of the soil. For example, very small sized minerals, such as clay particles, combined with a high water content could lead to the soil entering a fluid state. This would lead to a major decrease in soil stability.

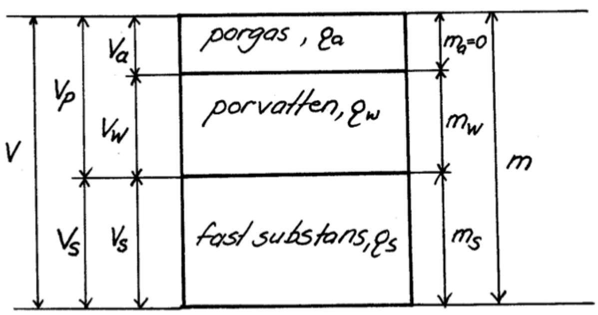


Figure 5: Illustration of relative quantity ratio within a soil. Porgas=Pore gas, Porvatten=Pore Water, Fast substans=Solid materiall (Sällfors, 2009)

The material property uncertainty of soil as a material is due to it being an inconstant material. The characteristics of a soil, affected by factors such as water content, amount of void spaces, particle size etc, must be taken into account while creating a model and making calculations (Knappett & Craig, 2012).

2.2.2 Settlements

The load from a construction on a ground will affect the soil beneath. The load will increase the effective stress in the ground material. When this occurs, it will lead to deformations such as settlements, meaning that the soil is compressed and decreases in volume so that the construction settles. If a construction settles it means that it sinks into the ground, this will of course affect the function of the construction. To understand fundamental geotechnics, it is essential to understand the concept of stress in a soil and to be able to make basic calculations on settlements for a given load and underground. As mentioned before, it is impossible to calculate an exact answer when calculating on a material with such material property uncertainty (Sällfors, 2009).

2.2.3 Slope stability

When calculating slope stability, the risk of the slope collapsing is established. A slope can for example fail due to its own weight, an external load on top of the slope or due to erosion on the bottom caused by for example a river. The soil in a slope can be more or less stable in different places. The task for the geotechnical engineer is to create a model of the slope as accurate as possible in order to find were (on which slip) the slope is most likely to fail. The stability can then be calculated. The critical slip could for example be assumed to be at a place where the soil meets solid rock and where the friction might be less than elsewhere. Figure 3 illustrates a slope and a slip interface, the chosen slip is an interface judged to be in risk of failure. A failure in the soil of a slope mainly results in a horizontal movement of the soil elements.

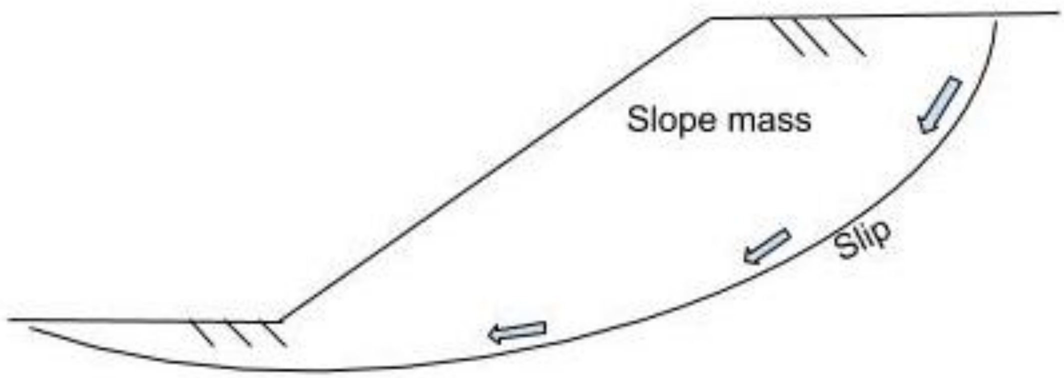


Figure 6: Illustration of a slope with a slip interface

The risk of failure can be calculated either according to a drained, undrained or combined analysis. Drained conditions mean the soil state where any excess pore water has fully dissipated (also known as long-term conditions). Undrained conditions is when the stress increment is carried as an increment of excess pore water pressure (short-term conditions) (Knappett & Craig, 2012).

2.2.4 Bearing capacity

Bearing capacity is the load (calculated per unit area on foundation level) which results in a global collapse in the soil beneath the foundation of the construction. The foundation must be designed in a way that the soil manages to take care of all the loads so that no collapse can occur. While calculating this it is important to consider plastic and elastic conditions. The calculations are also affected by for example foundation level, inclined load or ground level, impact of eccentric load and ground water level.

2.2.5 Excavation and soil pressure

During an excavation, different support constructions are used to keep the excavation from failure, these constructions could be different type of retaining walls, ex. gravity or piling wall (see Figure 6 and 7). To keep an excavation from failure it is important to understand the fundamentals of soil pressure. Soil pressure is divided in active- and passive pressure. During active soil pressure the soil actively contributes to the failure. Imagining a soil element during active pressure, it is loaded vertically (see Figure 4), this occurs due to the soils own weight or an external load. The load causes stresses in the soil which leads to horizontal deformations, this however does not mean that the horizontal pressure decreases. During passive pressure the horizontal stresses increases (see Figure 5). The stresses increase until failure, after failure the deformations can increase without an increase of the horizontal pressure. To simplify understanding, the active pressure is the pressure pushing and the passive pressure is the pressure resisting. (Sällfors, 2009)

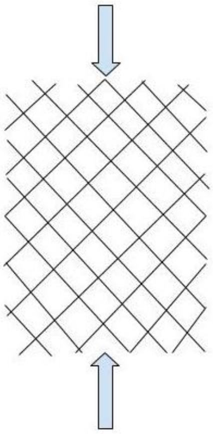


Figure 7: Active pressure

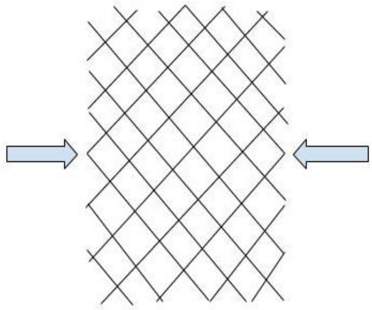


Figure 8: Passive pressure

In Figure 6 and 7 the active- and passive pressure is illustrated against a gravity and piling wall. A gravity wall is a support construction relying on gravity force due to its own weight (see figure 6). A piling wall is a support construction relying on the force from both the active and passive pressure to stand (see figure 7).

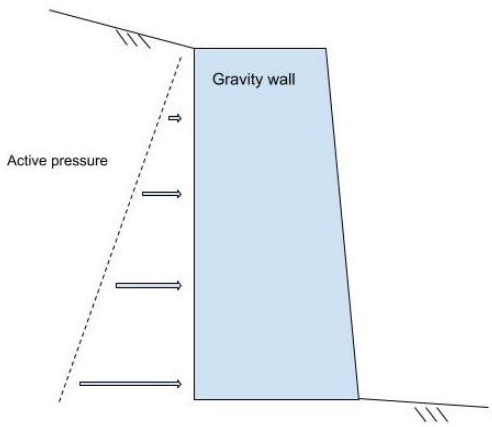


Figure 9: Gravity wall

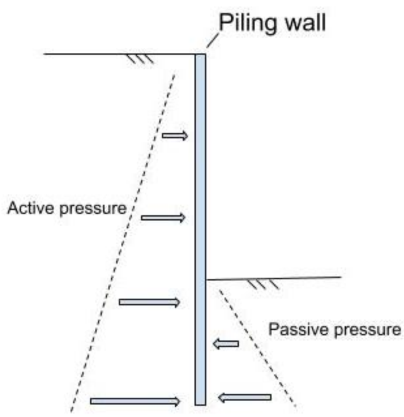


Figure 10: Piling wall

There are many types of support constructions that can be utilized during an excavation. To determine which one is mort suitable a variety of factors have to be considered. For example: Is the construction temporary or stationary? What are the soil characteristics? Does the construction need to be waterproof? What are the dimensions of the excavation? What kind of loads will the construction be exposed to? Etc.

3 Methodology

The following methodology explains the process in creating a teaching method on how to implement active learning to an ordinary lecture and then the use of this method while creating a lecture with active learning presented. Then further, the lecture is evaluated in an experiment with civil engineering students as participants.

In order to answer the research questions of the project, different types of data were necessary. Two literature studies had to be performed. Firstly, one on the benefits of active learning and different ways to implement it to an ordinary lecture and secondly one on fundamental geotechnics to create the content of the lecture. To further answer question A (Does the implementation of active learning make the students remember more of the content compared to a ordinary lecture?) and B (How does the implementation of active learning to a lecture affect students' perception of the lecture's arrangement?) an experiment based on the created lecture with active learning implemented was performed. The lecture was held for students that afterwards were asked to answer an online survey with questions regarding both the content and the arrangement of the lecture. As a control measure a second lecture was held with the same content but without active learning implemented. The students in the control group were then asked to answer the same online survey as the students in the experiment group.

3.1 Implementation of active learning on a lecture

The collection of data on how to implement active learning in a lecture were made from well-established papers on the subject and from course material from the master "Lärande och ledarskap". The selection of methods presented in chapter 2.2 was based on whether or not they were judged to be applicable on an ordinary lecture and possible to be used by lecturers with no pedagogical education. The method on how to implement active learning in an ordinary lecture was created based on the studies presented in chapter 2.

To create a lecture with active learning implemented for the experiment, the content of the lecture had to be established. The content was decided to be a part of the content of the introduction lecture of the course "Geoteknik med grundläggning" at Chalmers (Chalmers, 2016). This content was chosen because it was on an appropriate level for the participants in the experiment who (according to their study plan) had no previous experience from geotechnics except for a course in geology in year one (Chalmers, 2019b). Therefore, the content of the intro lecture was judged to be most fitting. With that content an ordinary lecture was first created. After creating the ordinary lecture, the method of implementing active learning to an ordinary lecture was used and a second lecture with active learning implemented was created.

3.2 Teaching method for implementing active learning to an ordinary lecture

When studying at a university a common learning situation is listening to a professor (often with no pedagogical education) trying to mediate knowledge through the structure of an ordinary lecture, meaning that the teacher is the one doing all the talking and the students

only listen and take notes. As we now know there are ways intended to streamline the teaching in order to increase the learning.
The method presented in Table 7 is a suggestion on how to implement active learning to an ordinary lecture. On order to enable lecturers without pedagogical education to use the method it is made as simple and clear as possible. Didactic motivations for each part of the method can be found in chapter 5.1.

DO	DON´T
Start-up	

• Focus on the introduction
  ○ Say hello
  ○ Smile
  ○ Introduce yourself
  ○ Look at the students
  ○ Describe aim/goal of lecture
  ○ Show an agenda for the lecture
	• Just start the lecture

Main part of lecture	

• Regularly activate the students
  ○ Encourage students to ask questions
  ○ Invite to peer discussion, plan beforehand what parts of the lecture that can be held as a discussion
• Give feedback to the students when commenting or asking questions
  ○ Ex: ”great thinking”, ”good question”, “interesting thought”
	• Just lecture
	• Answer questions with only answer

Ending	
• Repetition of aim/goal • Summary of lecture • Include a description of next lecture	• Just end with a new last fact

Table 6: Method on how to implement active learning to an ordinary lecture

3.3 Lectures for experiment

The two following lectures will be carried out in Swedish, but the descriptions are translated to English in this report. Both lectures will have the same aim, but their arrangement will differ. One lecture will be arranged according to the method produced (implementing active learning) and the other one will be an ordinary lecture.

The aim of both lectures is for the students to know the three main components of soil and to some extent how the variation in arrangement and distribution of these affect the characteristics of a soil. After the lecture the students should be able to answer the following questions:

- What are the main components of soil?

- What (amongst other) affects the characteristics of a soil?

3.3.1 Lecture with active learning implemented

This is an example of how the produced method can be applied in creating a more active lecture to teach geotechnics. The method can, of course, be applied in a vary of ways. The Power Point from this lecture is presented in appendix C.

Agenda of lecture:
1. Introduction
2. Description of aim/goal of lecture
3. Group discussions combined with lecture
4. Summary of lecture and repetition of aim

In Table 8 the content of each step of the agenda is described and supplemented with a didactic motivation. The didactic motivation is based on the produced method. This lecture went on for around 20-25 min.

Agenda	Content	Didactic motivation
1. Introduction	The lecture starts with the teacher introducing herself and trying to connect with the students. The connection could be achieved by the teacher focusing on smiling, emphasizing that she really wants the students to learn from the lecture and/or that questions are more than welcome of something is unclear.	A teacher showing interest for the students has a positive effect on the students learning. Encouraging the students to ask questions helps in creating an environment where mistakes are welcomed.
	The teacher explains what geotechnics is on a basic level. What the uses are and why it is necessary to learn.	To give the students a common perspective on what the word geotechnics means and to give the students a possibility to connect the upcoming content to a known context.
	The teacher thereafter presents the agenda of the lecture (step 2-4 in the agenda described) by using a prepared power point. The teacher will explain that she will use both the prepared power point and the whiteboard during the lecture.	Students performances increases with a clear structure and awareness according to the question: "what happens next?".
2. Description of aim/goal of lecture	The teacher presents the aim of the lecture.	Concrete goals benefits students in their learning.

3. Group discussions combined with lecture.	The teacher will start by asking the students to discuss for a few minutes in groups of 2-3 persons. Their first task is to name the different components of soil as they can come up with. All groups will be asked to write down their answers.	Make the students active participants of their learning. Offer students the possibility to receive thoughts from additional persons instead of only the teacher.
	After discussion the teacher asks some of the groups to share their components with the rest of the class while writing them on the board. Thereafter the teacher will explain which ones that are correct and why. The teacher completes the explanations with prepared slides on the power point to make sure that no facts are left out. For example, Figure 2 can be showed as an illustration of soil as a three-phase continuum of solid material, fluid and gas.	Continuing to keep the students active. The teacher shows interest in students' thoughts and opinions. Vary discussion and lecture to customize the teaching according to the level of the group.
	Next the teacher asks the students to discuss the concept "density" and what parts of the mentioned components are lost as only a "normal" density is calculated.	To give students the possibility of noticing by them self the need of different types of densities instead of just being told. To keep student's attentiveness according to Figure 9.
	The teacher once again let the students share their suggestions in a similar way as after the previous discussion. The power point is used to make sure that the different types are all presented in a clear way.	Continuing to keep the students active. The teacher shows interest in students' thoughts and opinions. Vary discussion and lecture to customize the teaching according to the level of the group.
	The rest of the time is used to explain each new concept as thoroughly as possible while making sure to regularly asking questions to the students.	To ensure that student leaves with complete and correct notes as they might be necessary to some of the students on order to study further. Continuing to asking questions according to Figure 9.
4. Summary of lecture and repetition of aim	The lecture ends with the teacher repeating the aims of the lecture and connecting it to a repetition of the the completed content.	Give students structure and the teacher shows commitment and interest in the students learning.

Table 7: Description of lecture with active learning implemented

3.3.2 Lecture without active learning

This is an example of an ordinary lecture. The Power Point from the lecture is presented in appendix D.

Agenda of Lecture:

1. Introduction
2. Lecture

In Table 9 each step of the agenda of the lecture are described. The lecturer followed the instructions of smiling, introducing herself and saying hello from the "Do´s" according to the method presented in Table 7. This lecture went on for around 15-20 min.

Agenda	Content	Didactic motivation
1. introduction	The lecture starts with the teacher by introducing herself.	Common courtesy to introduce oneself before a lecture.
2. Lecture	The teacher executes her lecture and answers questions when asked. The lecture contains all facts necessary to understand the aim of the lecture.	A prepared lecture is time efficient as a lot of content can be mediated through a short amount of time. It is easy to plan.

Table 8: Description of lecture without active learning implemented

3.4 Participants in experiment

The participants in the experiment are students studying the second year at the civil engineering program at Chalmers. The introduction course in geotechnics is taught during the first study period the third year (Chalmers, 2019a). This means that the students participating in the experiment are about to take their first course in geotechnics only a few months after this experiment was executed. The appropriate level of knowledge of the participants was the major reason why they were chosen. Participation of the experiment was completely voluntary. The students were informed that two intro lectures to geotechnics, as a part of a master´s thesis, were to be held during their lunch break two different days and that they, if they wanted could choose to participate on one of the occasions. A preferable consequence of this was that the distribution of the students was completely random and that there was no known difference between the two groups. As a way to attract students to attend the lectures they were offered free lunch. To offer students free lunch might lead to some of them attending the lecture only for that reason and not at all because they want to help or learn some geotechnics. The risk of not having any students at all attending was however judged to be higher. The participants did not know that there would be two different types of lectures. During the lectures and while answering the online survey, the students did not know the reasons behind them. The decision not to tell the students why the lectures were held was that that knowledge might affect the students answers in the survey.

3.5 Experiment

The experiment was designed according to an "only - after design" (Esaiasson, Gilljam, Oscarsson, & Wängnerud, 2007), illustrated in Table 6. The distribution of the students in the experiment and control group was done randomly all as the students have the same study background and chose one of the lectures to participate in without knowing that the lectures differed with each other. The experiment group consisted of seven students and the control group of six. At the time T_1 the two different lectures were held. The Experiment group had a lecture with the treatment of implemented active learning. The lecture held for the control group had the same content but with no active learning implemented. At the time T_2, directly after the lecture, the 1st measurement was made through an online survey. The students answered questions based on the content to get an understanding for how well they remembered it. They also answered questions regarding the arrangement of the lecture to get an understanding for how it was perceived. The 2nd measurement, at T_3, was done one week after the lectures. The purpose of the second survey was to get an indication on how active learning enhances longer lasting memory retention.

	T_1	T_2	T_3
Experiment group	Treatment	1st measurement	2nd measurement
Control group		1st measurement	2nd measurement

Table 9: Description of experiment

The online survey of the 1st measurement contained six questions, question 1-3 regarding the content and 4-6 regarding the arrangement. The 2nd measurement only contained question 1-3. Question 4-6 where only asked in the 1st measurement since there was no reason to believe that the students´ answer would change during the week that passed. Question 1-3 were distributed so that question 1 regarded content from the beginning of the lecture. The experiment group received the answer to question 1 directly through a peer discussion. Question 2 regarded content from the middle of the lecture and question 3 from the end. Question 2 and 3 did not regard questions directly connected to an organized peer discussion in the experiment group, the participants were however continuously asked do discuss and encouraged to ask questions throughout the lecture. This arrangement is motivated by figure 8 and 9 describing the attentiveness on lectures depending on the implementation of activities. While answering the survey the students were unaware which type of lesson they attended, or even that there were two different types to attend. The students of the experiment group did not know that active learning was implemented to the lecture and students of the control group did not know that the lecture was planned without any active learning implemented. The outline of the online surveys from both measurements can be seen in appendix A and B.

There was no initial measurement made to establish any eventual differences in knowledge before the lectures between the experiment and the control group. This was judged not to be necessary as the distribution was random and all students study the same program. To see questions regarding the content beforehand might also have affected the learning which would affect the answers in the online survey and then also the results of the experiment.

The lecturer performing the lecturers in the experiment was the same person who developed the method and created the lectures, the lecturer also had a pedagogical education. The reason for this was mainly because the intention of the experiment was to test the effects of implementing active learning on an ordinary and not whether or not the method was understandable for a lecturer without pedagogical education. To let another person lecture during the experiment would have led to increasing the risk of active learning not being implemented well enough.

4 Results

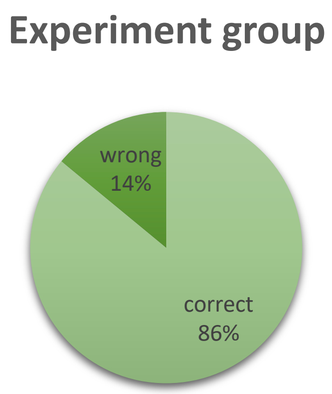
This chapter presents the results from both measurements through the online survey after the lectures.

4.1 Effect on students learning

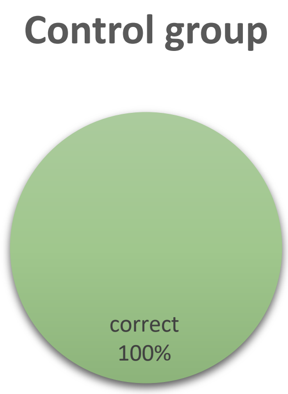
Below the answers from the questions of the online survey regarding the content of the lectures are displayed in pie charts. In the 1st measurement there were seven answering students in the experiment group and six in the control group. This means that one person equals 14% in the experiment group and 17% in the control group. Question 1 and 3 were short answer questions and Question 2 was a multiple-choice question. In the 2nd measurement there were six answering students in both the experiment and the control group. This means that one person then equals 17% in both groups.

4.1.1 Question 1

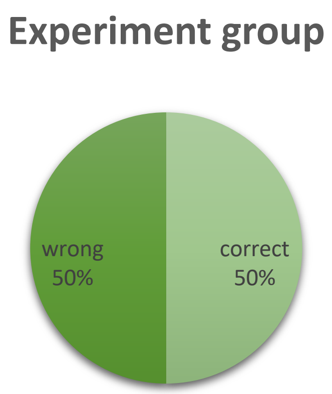
Question 1 was based on content from the beginning of both lectures. Figure 11 displays the results from the 1st and 2nd measurement.



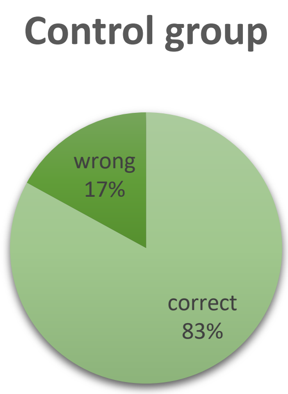
(a) Results from 1st measurement in the experiment group.



(b) Results from 1st measurement in the control group.



(c) Results from 2nd measurement in the experiment group.



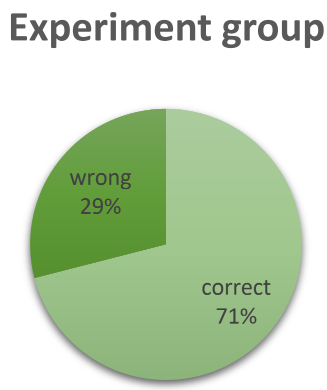
(d) Results from 2nd measurement in the control group.

Figure 11: Results from Question 1 for the experiment and control group

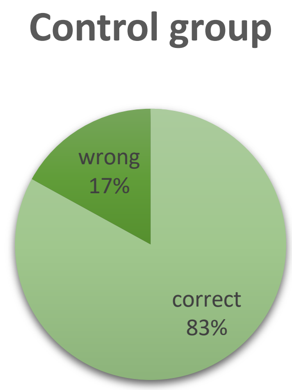
As Figure 11 shows, 6/7 of the students in the experiment group and 6/6 in the control group answered the first question correct in the 1st measurement. In the 2nd measurement 3/6 of the students in the experiment group and 5/6 in the control group answered question 1 correct.

4.1.2 Question 2

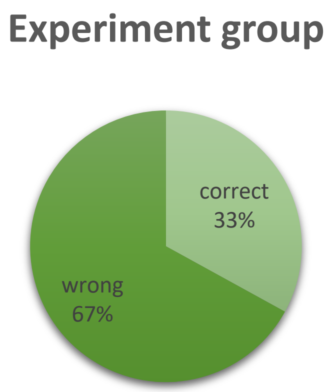
Question 2 was based on content from the middle of both lectures. Figure 12 displays the results from the 1st and 2nd measurement.



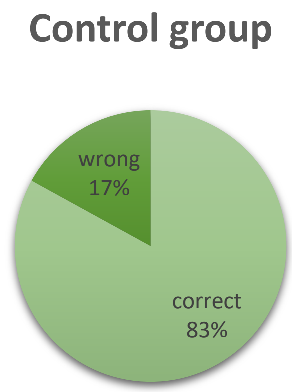
(a) Results from 1st measurement in the experiment group.



(b) Results from 1st measurement in the control group.



(c) Results from 2nd measurement in the experiment group.



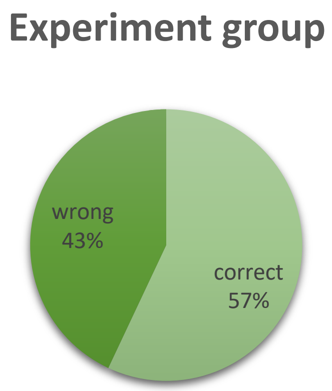
(d) Results from 2nd measurement in the control group.

Figure 12: Results from Question 2 for the experiment and control group

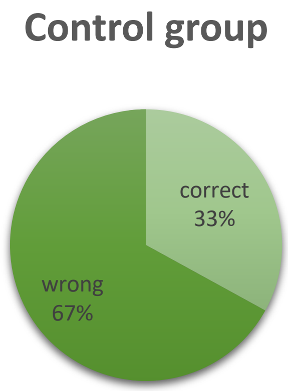
As Figure 12 shows, 5/7 of the students in the experiment group and 5/6 in the control group answered the second question correct in the 1st measurement. In the 2nd measurement 2/6 of the students in the experiment group and 5/6 in the control group answered question 2 correct.

4.1.3 Question 3

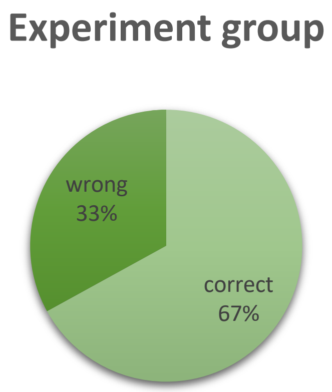
Question 3 was based on content from the ending of both lectures. Figure 13 displays the results from the 1st and 2nd measurement.



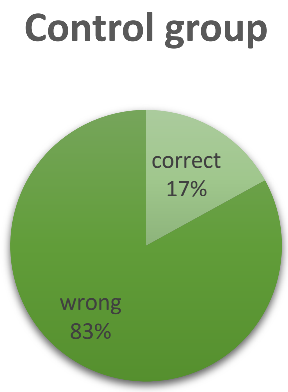
(a) Results from 1st measurement in the experiment group.



(b) Results from 1st measurement in the control group.



(c) Results from 2nd measurement in the experiment group.



(d) Results from 2nd measurement in the control group.

Figure 13: Results from Question 3 for the experiment and control group

As Figure 13 shows, 4/7 of the students in the experiment group and 2/6 in the control group answered the third question correct in the 1st measurement. In the 2nd measurement 4/6 of the students in the experiment group and 1/6 in the control group answered question 3 correct.

4.2 Effect on students perception

Below the results from the questions regarding the students´ perception of the arrangement of the lecture are displayed. Question 4 was a question where the student could rank their perception of the arrangement on a linear scale from 1 to 5 where 1 represented not good and 5 represented good. Question 5 and 6 where short answer questions which are translated below respective heading. Question 4-6 where only asked in the 1st measurement. While answering these questions the students are unaware which type of lesson they attended, or even that there were two different types to attend. The students of the experiment group did not know that active learning was implemented to the lecture and students of the control group did not know that the lecture was planned without any active learning implemented.

4.2.1 Question 4

Table 10 shows the result from Question 4 regarding the students' perception of the lectures arrangement where the students ranked their perception on a linear scale from 1 to 5. 1 represented not good and 5 represented good. It is visible that the students in the experiment group had a more positive opinion about the arrangement compared to the students in the control group.

What did you think of the arrangement of the lecture?	**Mean**
Experiment group	4,71
Control group	3,5

Table 10: Display of calculated mean for experiment and control group from Question 4

4.2.2 Question 5

In Table 11 below, the short answers from the students are displayed and translated from Swedish to English. The comments from the students in the experiment group clearly indicates that they were positive towards group discussions during the lecture.

What about the arrangement did you appreciate?
Experiment group
- To mix questions and Power Point - That you first got an overview of what the lesson was going to be about, to later in the end tie together what had been gone through during the hour. Only good! Good contact with the students (even though we were so few) - To be a part of the learning. Good slides with just right amount of information - Conclusion that answered the questions in the beginning - Clear Power Point - Clarity and the small discussions during the lecture, good conclusion - Clear what we were supposed to learn and the conclusion at the end!! Also good with practical/real examples
Control group
- Explained why we were supposed to know things - Good review of the concepts, nice with much pictures and little text in the Power Point, good with visual examples such as the sponge - Clear formulas and relevant pictures - Good red tread and good Power Point with not too much text but still clear and contains the essentials - Good information

- Clearly illustrated with the Power Point

Table 11: Display of short answers for experiment and control group from Question 5

4.2.3 Question 6

In Table 12 below, the short answers from the students are displayed and translated from Swedish to English.

What about the arrangement can be improved?
Experiment group
- Maybe better examples, was a little confused as so many of the thing mentioned are so much alike, ex 3 kinds of density and water content saturation ratio, even if it felt clear so is it so much alike that it is difficult to separate - Think it was good that you got small discussions during the lecture so that you don't just sit and listens all the time - Little slower tempo and a little more time on each slide - Don't know - A bit carelessly sometimes with the words, can of course be due to being unused or nervous - The only thing I can think of is to have the picture you went back to in direct contact with when you explained what it was, when you showed the diagram later in the Power Point
Control group
- That important words are on the Power Point - Little slower tempo - Some short explanation what the definition is, you said it, but it is nice to be able to read it as well, easier to remember then. Maybe an example where we list all the formulas which more clearly shows what they actually calculate - Maybe more clearly and not go through so fast - Much slower, continuously call on self-reflection - Maybe a bit fast

Table 12: Display of short answers for experiment and control group from Question 6

5 Concluding discussion

In this chapter the didactic motivations for the development of the teaching method for implementing active learning in an ordinary lecture will be described. The results of the experiment will be discussed and compared to the studies presented in previous research. The conclusion of the investigation will be summarized and some suggestions for further investigations will be presented.

5.1 Didactic motivations for created method

To motivate the design of the method a didactic motivation for each part of the method, representing the start, middle and ending of the lecture, will be presented. The didactic motivation is based on the presented previous research.

5.1.1 Start up

- Focus on the introduction
  - Say hello
  - Smile
  - Introduce yourself
  - Look at the students
  - Describe aim/goal of lecture
  - Show an agenda for the lecture

As the single teacher has such big impact on the students' performance it is important that the teacher shows interest from the beginning. The teacher should want to give the impression of caring about and being excited to see the students, something that has showed to have a positive impact on students' performance. This can be shown by the teacher saying hello, smiling, introducing themselves and looking at the students. The teacher should also describe the aim/goal and show an agenda for the lecture instead of just trying to immediately mediate facts without the students knowing what to expect from the lecture. This means that the teacher visible the intention of the teaching and the criteria's to reaching the goal, the teacher then customizes the teaching and offers the students a wider repertoire of methods to achieve learning. If the students know what they are supposed to learn the process of filtrate and prioritize information from the lecturer simplifies.

5.1.2 Main part of lecture

- Regularly activate the students
    - Encourage students to ask questions
    - Invite to peer discussion, plan beforehand what parts of the lecture that can be held as a discussion
- Give feedback to the students when commenting or asking questions

During the main part of the lecture there are a few things the teacher can do to increase the student´s learning opportunities. Peer discussion can activate the students (according to figure 9) and it also gives the students the possibility to receive explanations in a variation of ways. During an ordinary lecture the students will only hear one type of explanation, but if the students are invited to discuss amongst each other they will get a vary of explanations and therefore increasing the possibility to understand and learn. The use of peer discussions in small groups is manageable in a lecture room. The encouragement to ask questions contributes to create an environment where the students feel safe and welcome to explore. By telling students that they are welcome to ask question the teacher shows understanding for the fact that the students necessarily don't, and are not expected to, understand everything right away.

5.1.3 Ending

- Repetition of aim/goal
- Summary of lecture
- Include a description of next lecture

By repeating the aim/goals of the lecture and including a description of the next lecture the teacher clearly visible the intention of the teaching. Doing this shows the teachers awareness of the goals, not only for the specific lecture but for the entire course. Summarizing the lecture at the end enables the possibility for the students to hear the essentials one more time which only increases their chances of learning. It also gives the students an opportunity to check with them self if they understood what they were supposed to, and if they did not they will have a better change of fixing that until next lecture. Overall, doing this increases the students´ opportunity to ensure that they are leaving the lecture with the essential knowledge.

5.2 Discussion of results

An overall analysis from the experiment is that it would have benefitted from being performed on more students. All the differences in the answers between the experiment and the control group can almost only be analyzed on an individual level. This especially affects the survey regarding whether or not students remember more of the content with active learning implemented in a lecture. If only one student was having a bad day, and another was not interested at all to learn geotechnics but only participated in the lecture for the free lunch then that would mean 1/3 of the control group and almost 1/3 of the experiment group probably contributing with answers in the survey not valid for the study. As there were only thirteen students participating, circumstances like this might have had a major impact on the results and they are impossible to detect. The results from the survey regarding students' remembrance should be regarded as an unreliable result in the meaning of translating it to another context, as there are too many unsure variables having a crucial impact on the results. However, it can still be interesting to discuss these variables and to see if there are any differences regarding the answers and what they might have been caused by. The fact that there was only one question from each part of the lecture means that the characteristics of that single question strongly affects the results. Whether students answer a question right or wrong might have nothing to do with the arrangement of the lecture, it might just be because the question itself was on a non-appropriate level. In order to have more questions more time to execute the lectures and the survey would have been necessary. More time both to create longer lectures with more content and for students to fill out the online survey.

According to the presented studies in the chapter containing the previous research, regarding students´ attentiveness in class depending on whether or not activities were implemented in the lecture (Figure 8 and 9), the experiment and control group should have had a similar amount of right answers on question 1 in the 1st measurement. As question 1 was based on content from the beginning of the lecture the attentiveness in the two groups should not differ yet. Studies by Hattie. J (2012) however suggest that students´ learning clearly benefits from having concrete goals and customized teaching. This should mean that the experiment group had a clear advantage as they knew beforehand (thanks to the agenda and presented goal of lecture) what they were supposed to learn. They also had the chance to discuss the question with each other before receiving the correct fact. In the answers from question 1 in the 1st measurement all students except one in the experiment group answered correct (see (a) and (b) Figure 11). The reason for this single student not answering correct could be anything. The reason for most students answering correct could definitely be that the question was based on the content from the beginning, but it could also be that the question itself was very easy. As can be seen in (c) and (d) in Figure 11 two additional students in the experiment group and one in the control group answered question 1 wrong in the 2nd measurement. According to Bligh (1998) active learning enhance longer lasting memory retention. This would mean that the experiment group should have performed better in this case. Once again however the difference only regards one student and therefore cannot be considered significant.

In question 2 the main part of both groups answered correct in the 1st measurement. However, in the 2nd, two more students in the experiment group answered wrong and the control group answered the same as in the 1st measurement (see Figure 12). Reasons for this could be that these two students did not bother to focus during the 2nd survey, perhaps they did not find the subject interesting or maybe they did not feel supported enough by the teacher to retain facts according to the study by Hattie. J (2012). Perhaps it could be due to the fact that the answer to this question was not directly connected to a peer discussion (compared to question 1) and therefor the theory from Bligh (1998) could not be applied here as the learning was perhaps not part of an evident active process. Therefore, the difference in longer lasting memory retention might only depend on the initial differences within the groups. The result otherwise opposes the fact that active learning outperforms traditional lecturing in promoting almost every learning outcome examined (Freeman et al., 2014).

The students in the control group outperformed the students in the 1st measurement in both previous question 1 and 2 but performed clearly worse in question 3 (See (a) and (b) Figure 13). So why did the control group suddenly perform worse than the experiment group? The results from question 3 correspond with the study from Felder. R and Brent R (2016) regarding students´ attentiveness during a lecture (see Figure 8 and 9). This result might also indicate that the students, according to Donohue. S (2014), increase their understanding through active learning and were therefore able to answer the question correct because they understood the context rather than only remembered the fact. The reason for the control group to suddenly deteriorate could be that they were a part of a lecture without any implemented activities and that their attentiveness therefore decreased according to Figure 8. The experiment group were part of a lecture with activities implemented according to Figure 9 and could therefor retain their attentiveness at the end of the lecture. The 2nd measurement showed a percental increase in correct answers in the experiment group (see (a) and (c) Figure 13). This should not be possible if not assuming that the students´ answers are in anyway random or that they did not discuss the content between the measurements. In this case the result could be explained with the fact that there were one student less answering the survey the 2nd measurement compared to the 1st in the experiment group. If that student was of of the three answering question 3 wrong that would explain the increase in percental correct answers. In the control group one additional student answered question 3 wrong (see (b) and (d) Figure 13). The reason why only one additional student in the control group and none in the experiment group deteriorated can depend on several reasons. Perhaps question 4 was easy and logic which means that once you understood it and listened before the 1st measurement you would be likely to remember it for the 2nd measurement as well.

The study regarding the students´ perception of the arrangement would also have benefitted from more participants, but it is still to be considered as reliable. The perception of the arrangement is not as affected by a single moment of not listening or a lack of interest of the subject. Even if a student has not payed attention to what was said he or she would still most likely have noticed the basic arrangement.

In question 4 the students ranked their perception of the arrangement of the lecture on a scale from 1 to 5 where 1 represents not good and 5 represents good. The experiment group got a mean of 4,71 and the control group 3,5. This result indicates that the students who participated in the lecture with active learning implemented where more satisfied with the arrangement than the students in the control group. As there were a lot of variables that differed between the lectures it is difficult to know which variable or variables that were crucial for the students positive response in the experiment group. Which factors that affected the students´ perception was not answered with question 4 but question 5 and 6 might give an indication as the students then answered the questions “What about the arrangement did you appreciate?” and “What about the arrangement can be improved?”. (The answers from question 5 and 6 were only evaluated by me and all answers are presented in the results. I am the only person that has evaluated the answers and chosen how to interpret them). The students in the experiment group clearly indicated that they appreciated the peer discussions and being active during the lecture instead of just listening. They also mentioned that they liked the fact that the content was presented at the

beginning of the lecture and summarized at the end (see Table 11). The fact that they specifically mentioned the variables that was changed indicates that the change was clearly performed. This is even more clear as the students were not even aware of the fact that these were the factors especially changed for their lecture. This feedback from the students gives a positive indication for validating the reliability of this part of the investigation. The control group indicated that the Power Point was clear and contained good information. The feedback that the mediation of knowledge in the control group was performed well is established with the fact that the students of the control group performed similar to the students of the experiment group in question 1-3.
The answers from the experiment group on what could be improved regarding the arrangement differed from each other, never two same answers, which suggest that the opinions are mainly individual and therefore makes it difficult to draw any general conclusions. The control group indicated that the lecture was performed a little hasty. This opinion seems logic as the students had no time to reflect or discuss but were constantly receiving more and new information. The answers on question 6 clearly indicates that this was not appreciated. On student even commented specific that the teacher should "continuously call on self-reflection" (see Table 12).

5.3 Conclusion

Below the overall conclusions, based on the results and the discussion, are presented in order to answer the question at issue:

Can active learning be implemented on an ordinary lecture and how will the implementation affect the learning in fundamental geotechnics?

A. ***Does the implementation of active learning make the students remember more of the content compared to an ordinary lecture?***
B. ***How does the implementation of active learning to a lecture affect students' perception of the lecture's arrangement?***

According to the result from the performed experiment it is possible to use the developed method in order to implement active learning to an ordinary lecture. The implementation of active learning is appreciated by students participating. Whether this experiment shows that active learning contributes to students remembering more of the content of a lecture cannot be established in this case as the number of control questions and participants were too few.

5.4 Further investigations

Further investigations could be to let a teacher without any pedagogical education use the method of implementing active learning on a lecture and evaluate the students´ perception of the arrangement. As it could not be concluded whether the implement of active learning benefits the learning in fundamental geotechnics this would have to be investigated further. Such investigation could be done by implementing active learning to all lectures during an entire course and comparing the result to previous years with ordinary lectures.

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A Online survey 1st measurement

Enkät M1

Svara gärna kortfattat med (om möjligt) endast begrepp

1. **1. Vilka är jords huvudsakliga komponenter?**

   ____

2. **2. Vilken av följande kvoter beskriver kompaktdensiteten?**
   Mark only one oval.

   - fasta substansens massa / fasta substansens volym
   - fasta substansens massa / totala volymen
   - totala massan / totala volymen

3. **3. Nämn en skillnad på vattenkvot och vattenmättnadsgrad**

   ____

4. **4. Vad tyckte du om upplägget på lektionen?**
   Mark only one oval.

	1	2	3	4	5	
inte bra	◯	◯	◯	◯	◯	bra

5. **5. Vad med upplägget. uppskattade du?**

   ____

6. **6. Vad med upplägget kan förbättras?**

   ____
   ____
   ____
   ____
   ____

B Online survey 2nd measurement

Enkät M2

Svara gärna kortfattat med (om möjligt) endast begrepp

1. **1. Vilka är jords huvudsakliga komponenter?**

2. **2. Vilken av följande kvoter beskriver kompaktdensiteten?**
   Mark only one oval.
   - fasta substansens massa / fasta substansens volym
   - fasta substansens massa / totala volymen
   - totala massan / totala volymen

3. **3. Nämn en skillnad på vattenkvot och vattenmättnadsgrad**

Intro Geoteknik

1

GEOTEKNIK

”Geoteknik behandlar de byggnadstekniska egenskaperna hos jord och berg samt sätt att grundlägga inför och under byggnation”

Agenda

- Mål med dagens lektion
- Gruppdiskussioner blandat med föreläsning
- Sammanfattning och repetition av mål

3

Mål med dagens lektion

1. Vad består jord utav?
2. Vad (bl.a) påverkar jords egenskaper?

4

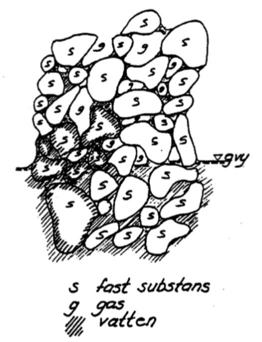
1. Vad består jord utav?

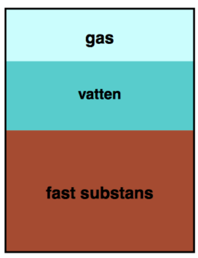
- Diskutera i grupper om 2-3 pers, skriv ner era förslag!!
- **Vilka komponenter bygger upp jord?**

5

1. Vad består jord utav?

Komponenter





- Gas
  - Oftast luft
- Vatten
- Fast substans
  - Organiskt
  - Mineral

6

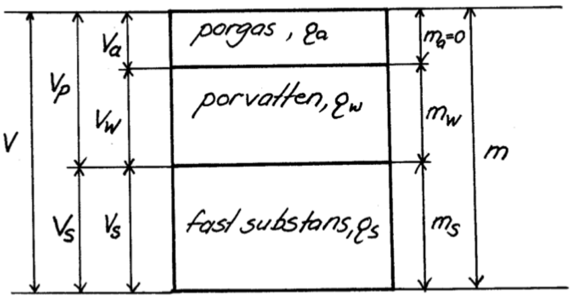
2. Vad (bl.a) påverkar jords egenskaper?

<u>Densitet</u>

$\rho = \frac{m}{V}$ (skrymdensitet)

- **Varför är endast denna densitet otillräcklig?**

  (Diskutera 2-3 pers. skriv ner förslag!)

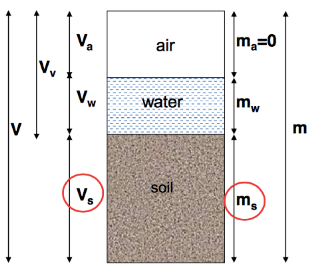


Densitet

$$\rho = \frac{m}{V} \text{ (skrymdensitet)}$$

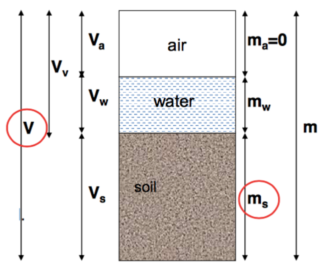
Kompaktdensitet

$$\rho_s = \frac{m_s}{V_s}$$



Torrdensitet

$$\rho_d = \frac{m_s}{V}$$

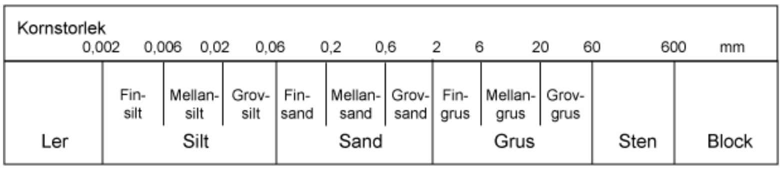


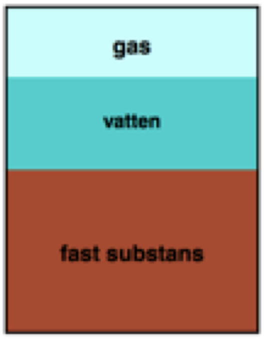
$$\rho' = \rho - \rho_w$$

ρ' kallas även effektiva densiteten.
ρ_w är vattnets densitet och är normalt 1 ton/m³.

2. Vad (bl.a) påverkar jords egenskaper?

Kornstorlek
Block>Sten>Grus>Sand>Silt>Lera





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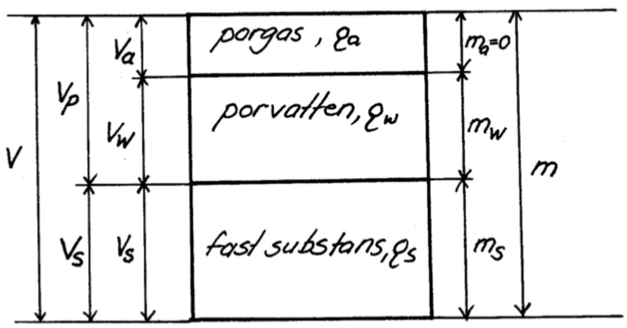
2. Vad (bl.a) påverkar jords egenskaper?

- Vattenkvot
- Vattenmättnadsgrad

- Portal
- Porvolym



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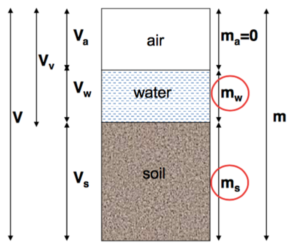
2. Vad (bl.a) påverkar jords egenskaper?

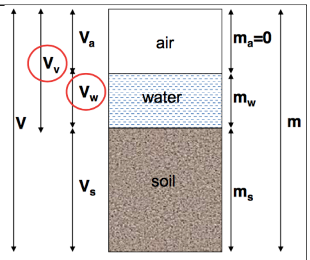
Vattenkvot

$w = \frac{m_w}{m_s}$



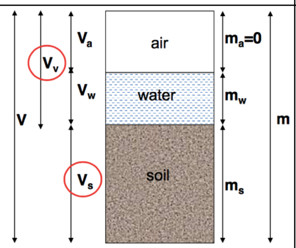
Vattenmättnadsgrad

$S_r = \frac{V_w}{V_v}$



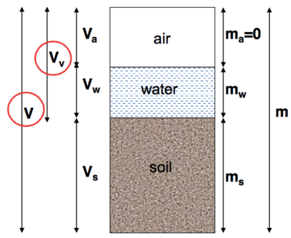
Portal

$e = \frac{V_v}{V_s}$

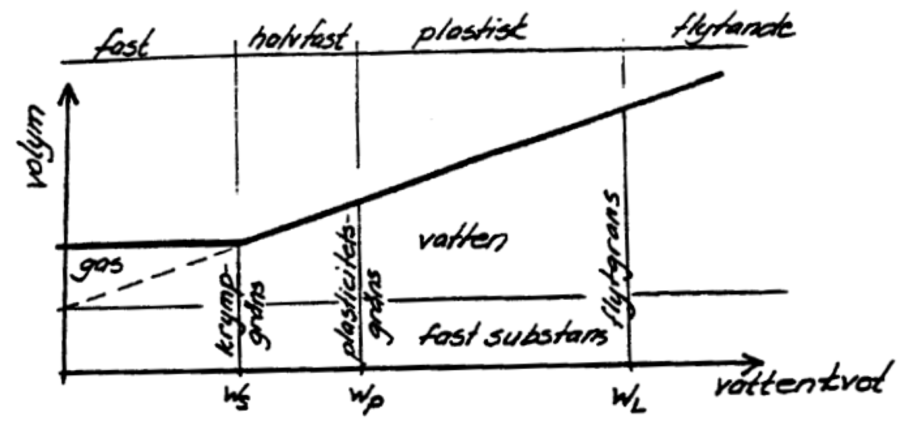


Porositet

$n = \frac{V_v}{V}$



Konsistengräser



Sammanfattning

- Vad består jord utav?
  - Fast substans, vatten, gas (luft)
- Vad (bl.a) påverkar jords egenskaper?
  - Densitet(er)
    - Skrymdensitet
    - Kompaktdensitet
    - Torrdensitet
  - Kornstorlek
  - Vattenkvot
  - Vattenmättnadsgrad
  - Portal
  - Porositet

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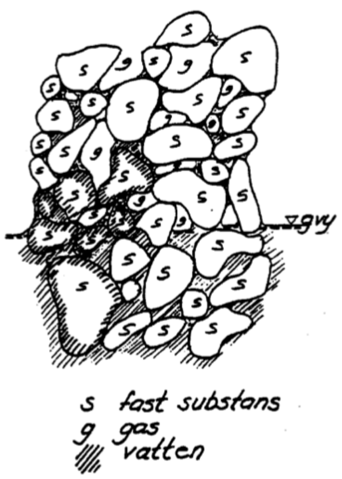
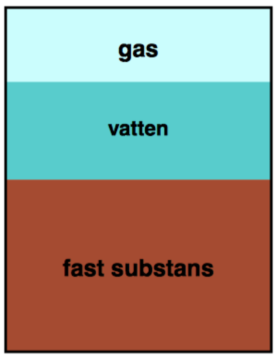
Intro Geoteknik

1

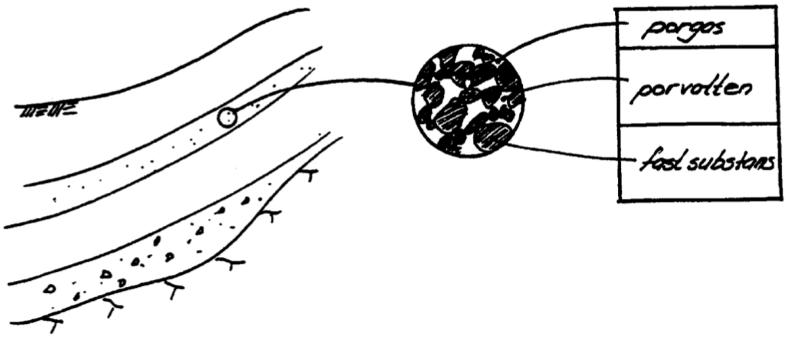
Komponenter





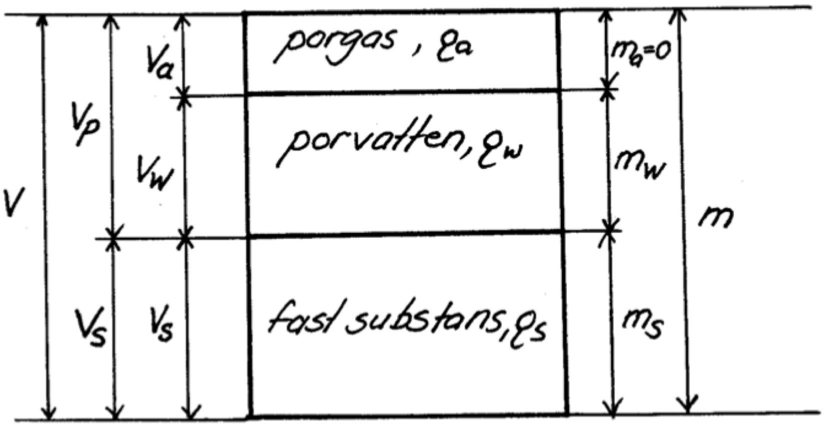
2

Jordarternas uppbyggnad, indelning och benämning



3

Begrepp och definitioner



4

Variation av kornstorlek

Grovkorniga jordar

Grus
Sand

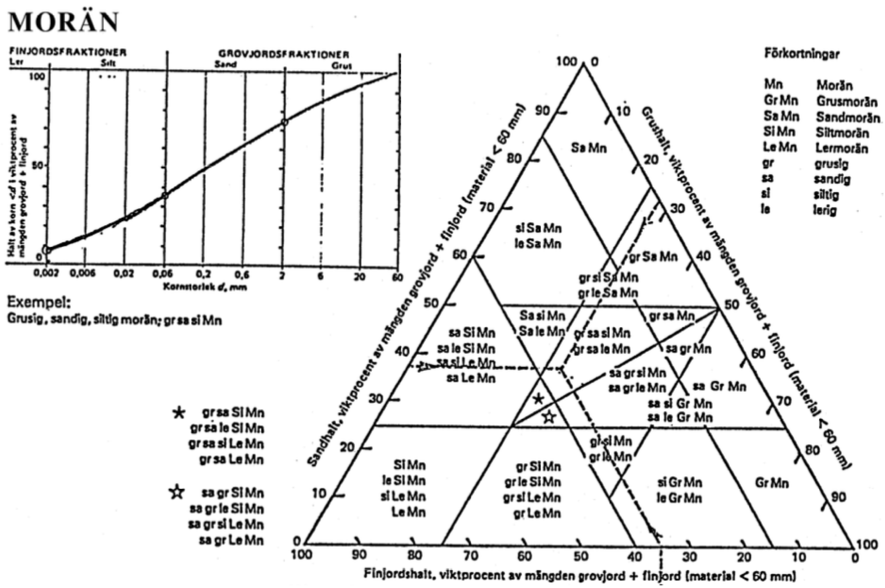
Finkorniga jordar

Silt
Lera

Kornstorlek	0,002	0,006	0,02	0,06	0,2	0,6	2	6	20	60	600 mm
	Fin-silt	Mellan-silt	Grov-silt	Fin-sand	Mellan-sand	Grov-sand	Fin-grus	Mellan-grus	Grov-grus		
Ler	Silt			Sand			Grus			Sten	Block

5

KLASSIFICERING AV JORD



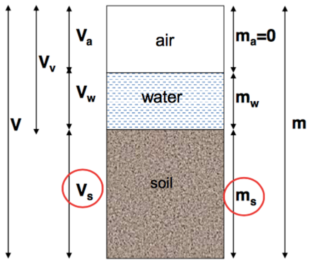
6

Densitet

$$\rho = \frac{m}{V} \text{ (skrymdensitet)}$$

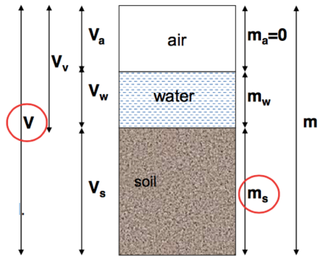
Kompaktdensitet

$$\rho_s = \frac{m_s}{V_s}$$



Torrdensitet

$$\rho_d = \frac{m_s}{V}$$



För vattenmättad jord under grundvattennivå, reducerar densitet på grund av lyftkraften (boyancy forces)

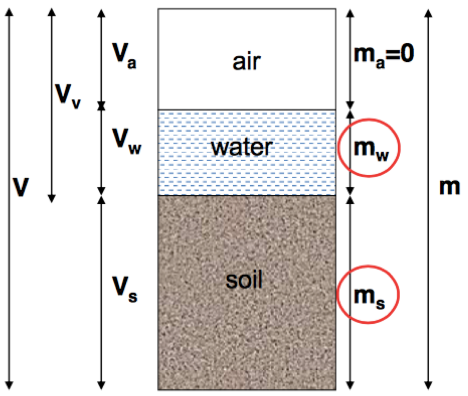
$$\rho' = \rho - \rho_w$$

ρ' kallas även effektiva densiteten.
ρ_w är vattnets densitet och är normalt 1 ton/m^3.

7

Vattenkvot

$$w = \frac{m_w}{m_s}$$



8

Konsistengräser (consistency limits)

Om ett jordprov som innehåller lera rörs om kommer dess egenskaper att vara starkt beroende av vilken vattenkvot provet har. Konsistensen kan vara allt från fast till plastisk eller flytande. De s.k. Atterbergs konsistensgränser anger övergången från ett tillstånd till ett annat.

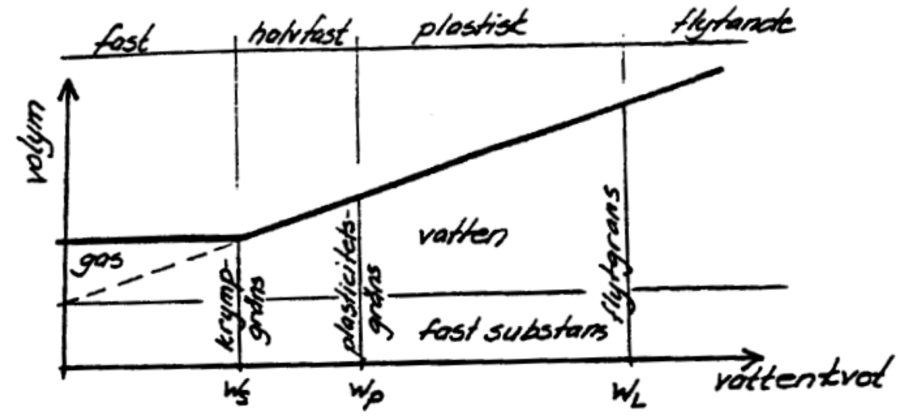
Krympgränsen w_s (skrinkage limit) anger den vattenkvot då provet vid ytterligare uttorkning inte längre minskar i volym.

Plasticitetsgränsen w_p (plastic limit), anger den vattenkvot då provet övergår från halvfast eller spröd till plastisk konsistens. Den bestäms som den lägsta vattenkvot för vilken materialet nätt och jämnt kan rullas till en 3 mm tjock tråd utan att spricka sönder.

Flytgränsen w_L (liquid limit) anger den vattenkvot då provet övergår från plastisk till flytande konsistens. Flytgränsen bestäms som den vattenkvot då materialet har en hållfasthet av 1,5 kPa.

9

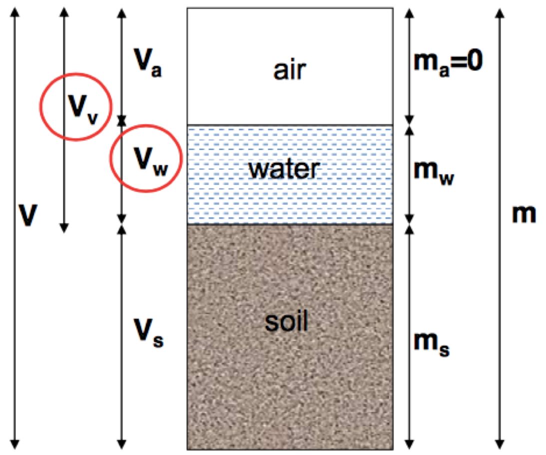
Konsistengräser



10

Vattenmättnadsgrad

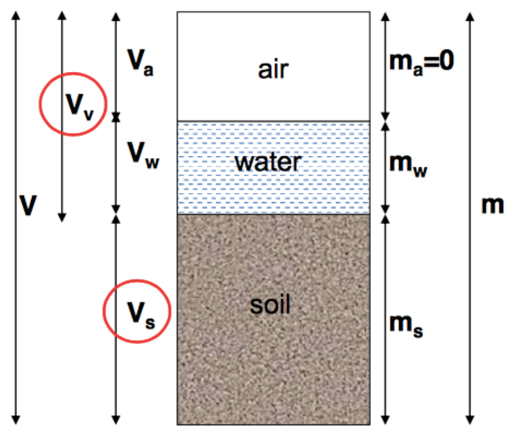
$$S_r = \frac{V_w}{V_v}$$



11

Portal

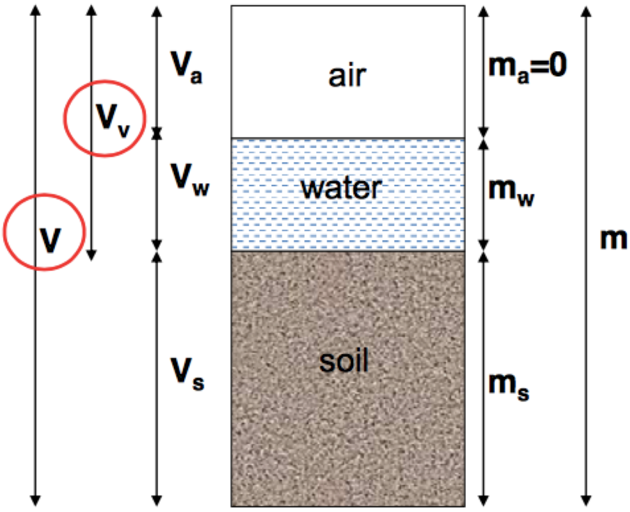
$$e = \frac{V_v}{V_s}$$



12

Porositet

$$n = \frac{V_v}{V}$$



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