Active Learning – a Supportive Teaching Method to Address Climate Change in Higher Education

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Summary

Universities worldwide do efforts to integrate education on climate change in the educational programs, but teaching about climate change is challenging: the climate system is complex, future prognoses include difficult terms of likeliness and the topic as such awakes emotions. Simulations and games are sometimes used to address climate change matters, and along with an increasing number of available interactive online simulations there is an on-going revolution in how online-material is used to provide students with information in higher education. Some practitioners move parts of the informative course material online in order to get more time for active learning – learning processes in which the student is participating more actively than just listening. This master thesis investigates if active learning can support students when learning about climate change in higher technical education.

Data for the research was collected through three case studies of interactive seminars, in climate related courses at the Royal Institute of Technology, Sweden, and at the University of Graz, Austria. The active learning was facilitated through gaming sessions with a climate board game, with exercises in vocabulary and discussions as well as explanations of the physical science basis. One student group was provided with a series of lectures prior to the board gaming session, whereas the other two groups were participating in a single seminar with the flipped classroom approach: students followed a study instruction with online material as well as reading of scientific papers on Earth’s climate system and climate change before the interactive gaming seminar took place. Analysis of survey responds (n=102), mind-map reflections (n=14) and interviews (n=5) led to the development of three key findings: (1) students’ attitudes toward learning about climate change involves emotions, (2) the active gaming seminar increased the students’ understanding of climate change and (3) students’ confidence - in their own understanding as well as in their ability to explain climate change – increased through the participation in the active learning seminar.

Moreover, a reflection drawn from the results in this study indicates that universities could play an important role in climate communication; if a university provides an introduction to climate change, the students can be “pushed over a threshold”, so that future participation in discussions on the topic may become less distant. Using games as an active learning tool in the introduction can increase student understanding and confidence in the topic of climate change - and doing so in a supportive and enjoyable manner.

Keywords: climate change, active learning, educational board games, serious games, flipped classroom, IPCC, teaching
Sammanfattning

Universiteten över hela världen gör ansträngningar för att integrera undervisning av klimatförändringarna i sina utbildningsprogram, men klimatförändringarna är ett utmanande ämne: klimatsystemet är komplex, framtidsprognoser innefattar svårtolkade sannolikhetsstunder och ämnet som sådant väcker många känslor. Simulationer och spel att en lärandemetod för att beröra ämnet, och samtidigt som det finns ett allt större utbud av undervisningsmaterial om klimatförändringarna på internet, sker en snabb förändring i hur online-material används för att förse studenter med information i den högre utbildningen. I vissa kurser flyttas en del av det informativa kursmaterialet till online-plattformar för att frigöra mer tid för aktivt lärande – lärande, i vilket studenten är mer aktiv än att enbart lyssna. I den här masteruppsatsen utreds huruvida aktivt lärande kan stödja studenter i lärandet om klimatförändringarna i högre teknisk utbildning.

Data till studien samlades från tre studentgrupper som deltog i interaktiva klimatseminarier på Kungliga Tekniska Högskolan, KTH, och på Universitetet i Graz. För att uppnå aktivt lärande användes ett klimatbrädspel, med övningar i begrepp, vokabulär och diskussioner samt bearbetning av vetenskapliga förklaringar kring klimatförändringarna. En studentgrupp lyssnade till en föreläsningsserie före deltagandet i spelseminariet, de andra två grupperna deltog däremot enbart i ett seminarium med flipped classroom metod: studenterna följde en instuderingsinstruktion med online-material och vetenskapliga skrifter innan de kom till spelseminariet. Analys av enkätsvar (n=102), mind-map-reflektioner (n=14) och intervjuer (n=5) ledde till tre huvudsakliga slutsatser: (1) studenternas attityder kring lärandet av klimatförändringarna påverkas av känslor, (2) studiens spelseminarier ökade studenternas förståelse av klimatförändringarna och (3) efter den aktiva lärandemetoden var studenterna mer bekväma med att förklara klimatförändringarna samt fick större förtroende till sin kunskap i ämnet.

Vidare kan resultaten i den här studien tolkas som att klimatundervisning i högre utbildning kan utgöra en viktig roll för mottagandet av klimatkommunikation; om ett universitet förser studenter med en introduktion till vetenskap om klimatförändringarna kan studenterna ”tvingas över en tröskel”, så att framtida deltagande i diskussioner i ämnet kan bli mindre avlägsna. Studenterna i studien upplevde nämligen en brist på trovärdig information om klimatförändringarna i det dagliga nyhetsflödet, därför uppskattade de att ta del av vetenskaplig information och komplexa diskussioner under spelseminariet. Att använda utbildande brädspel som en aktivt-lärande-metod kan öka studenters självförståelse och förståelse av klimatförändringarna – på ett stödjande och glädjejällt sätt.

Nyckelord: klimatförändringar, aktivt lärande, utbildande brädspel, flipped classroom, IPCC, undervisning
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“Climate change is not ‘a problem’ waiting for ‘a solution’. It is an environmental, cultural and political phenomenon which is reshaping the way we think about ourselves, our societies and humanity’s place on Earth.” (Hulme, 2009, p.V)
Abbreviations and Terms

IPCC  Intergovernmental Panel on Climate Change
COP21  The 21st annual Conference of the Parties (COP) for the international environmental agreement on climate change called the *United Nations Framework Convention on Climate Change (UNFCCC)*
EE  Environmental Education
ESD  Education for Sustainable Development
IT  Information Technology
ICT  Information and Communications Technology
ECTS  European Credit Transfer and Accumulation System

Industrial ecology  The study of material and energy flows through industrial systems.
Pollution prevention  Practices that reduce, eliminates or prevents pollution at its source.
Cleaner production  Preventive, company-specific environmental protection initiatives with the intention to minimize waste and emissions and maximize product output.
Sustainable development  Sustainable development is often mentioned as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs”.
Climate change  Here referred to as the human-induced (anthropogenic) changes in the Earth’s climate system.
Concept map  Graphical tools for organizing and representing knowledge with concepts and linking relationships between them.
Mind map  Graphical tools for visual organisation of information associated to a concept.
Likert scale  A scale used to represent people’s attitudes to a topic.
Temporal motivation theory  An integrative motivational theory, in which time is emphasized as a critical motivational factor.
Active learning  Processes in which students engage in activities that promote analysis, synthesis and evaluation of class content.
Flipped classroom approach  Pedagogical model in which lecture and homework elements are reversed.
Zone of proximal development  The distance between the possible developmental level if working independently and the level of potential development if collaborating or being guided.
Scaffolding  Learning with a sort of guidance, similar to how a temporary structure on the outside of a building can be removed bit by bit, once the building is steady to stand independently.
1. Introduction

Human-induced climate change is gaining more and more recognition in the world. Elizabeth Sawin, co-director of the awareness rising organization Climate Interactive, mean that future climate mitigation and adaptation challenges need "multisolvers": collaborative and system-thinking innovators (Sawin, 2015). Much confidence is put on green technology and the industry’s launching of “Solutions Revolution” during COP21 is one sign of an ever-growing expectations on engineers’ capabilities to solve complex, sustainability related challenges (World Climate, 2015). Ordinances at international\(^1\) as well as national\(^2\) levels intend to improve the education for sustainable development, and many universities, the Royal Institute of Technology (KTH) among them, work actively with improving the education for sustainable development (Finnveden & Strömberg, 2013; ISCN, 2016). However, a KTH education assessment from year 2011 conclude that sustainable development aspects require yet more attention to meet the demands of the labour market (KTH, 2011).

Universities aiming at improving their climate education as part of sustainability education may face challenges of how to communicate. Communicating climate science to non-specialists is known to be problematic; complex findings are difficult to simplify and the way scientists communicate does not align with the way most people receive information (Lynn, 2016). The reports from the Intergovernmental Panel on Climate Change (IPCC) – including the summary written for policy makers – have been criticized for being hard to understand. In February 2016, the IPCC held an expert meeting in order to provide recommendations on communication work for the sixth, upcoming, assessment report and one conclusion from the meeting is the recognition of a legible role for third parties to communicate the contents of the IPCC reports. Knowing the addressed audience is important in communication, hence, third parties could e.g. contribute with a better understanding of local audiences and by adjusting communication to different situations – therefore complementing the scientific, credible messages of the IPCC (Lynn et al., 2016). This indicates a possibility to explore how universities could include climate education for the future problem solvers and decision makers, now studying at their universities.

If drawing parallels to climate communication guidelines, developed to overcome obstacles for climate education outside the academic world, universities might as well encounter challenges in communicating findings of climate science as it must tackle limitations of human risk management; it is a struggle to balance future concerns and immediate threats. A consequence of restricted risk perception is that motivation to active climate mitigation and adaptation not solely occur from understanding the graphs of the IPCC (Center for Research on Environmental Decisions 2009). Steel and König (2006) argue that the time-discounting function of human behaviour must not be forgotten when trying to understand prioritisation and processes of decision making. According to their Temporal Motivation Theory, courses of action can be better understood if the expectancy of a potential reward, as well as the supposed delay to that reward are taken into account. In the context of successfully trying to reach learning outcomes in climate education, this aspect implies a need for consciousness when choosing teaching strategies.

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\(^1\) UN Decade of Education for Sustainable Development.

\(^2\) Swedish Higher Education Ordinance.
In the literature on teaching strategies, scholars are debating the learning effects of various methods, one discussion is whether active learning is a better alternative to traditional lecturing or not (Freeman et al., 2014; Hora, 2014). Active learning is used as a broad concept for teaching techniques that encourage student participation and for methods that emphasis development of students’ skills, rather than merely focusing on information transmittance (Keyser, 2000). A meta analysis of 225 studies, in which active learning and traditional lecturing are compared, suggests an increase in student performance as well as a lower risk for withdrawal (Freeman et al., 2014). Moreover, Freeman Herreid (1998) argue that students learn more if enjoying studying and when explaining ideas to one another, compared to if only listening to lectures.

In accordance with the advocates of active learning, it has become increasingly popular to develop games as an active learning tool for sustainable development education (Katsaliaki & Mustafee, 2015). One example of gaming in higher education is an existing sustainability course module, successfully introducing the topic of sustainable development at KTH by using board games (Dahlin et al., 2013). One main reason for using games in educational purposes is that gaming can help increase understanding and enhance student knowledge (Katsaliaki & Mustafee, 2015). Games and simulations are particularly interesting when aiming at “translating” scientific results into a language understood by the general public (Reckien & Eisenack, 2013). Within the field of games addressing climate, Wu and Lee (2015) illuminate a couple of areas with a lack of research today, one of their invokes for further research concerns whether climate games have influences on players’ attitudes towards scientific explanations of climate processes.

This study aims to investigate if an active learning method can support student learning of climate change in higher technical education. A board game, designed to provide familiarity with the scientific approach and messages of the IPCC, is used to facilitate active learning in the three cases conducted within the study. Surveys, mind-map analysis and interviews are used to collect data in three student groups in Sweden and Austria, respectively. The study does neither examine whether education leads to individual behaviour change, nor comparing active learning with traditional teaching methods. Instead, this study has a focus on (1) students’ attitudes toward learning about climate change, (2) the effects of the active gaming seminar on students’ understanding of climate change and (3) on students’ confidence, in their own understanding as well as in their ability to explain climate change.
2. Theoretical Framework and Delimitations

This chapter gives a theoretical framework of the role of climate change as part of education for sustainable development. Furthermore an overview of some teaching methods (Flipped classroom approach and Active learning) are discussed. Delimitations and the underlying ideas of the choices made in this study are presented with respect to climate change and the complexity of the topic.

2.1 Climate Change Education as Part of Education for Sustainable Development

Debates about teaching for sustainable development include discussions about the role education should have. Some mean that the very idea that education should be for something is questionable per se, others mean that education only is useful when reflecting upon the type and purpose of it (Jickling & Wals, 2012). Nonetheless, there are ordinances at international as well as national levels intending to improve education for sustainable development; over 400 university leaders in more than 50 countries have signed a ten-point action plan (called “Talloires Declaration”) for incorporating sustainability in the education. Many universities are nowadays beginning to reorient their activities and community outreach activities towards sustainability. Students’ positive associations to sustainability can be seen as an opportunity for universities to profile themselves in a new way (UNESCO, 2012). One example on this type of university marketing is information on a KTH-webpage, which guide students who want to create a sustainability profile (KTH, 2015a). KTH has divided the education for sustainable development into having educational programmes focusing on sustainable development on the one hand, and ensuring integration of sustainability in all education programs on the other hand (Finnveden & Strömberg, 2013). As part of these strategies a “toolbox” with material and support for teachers has been developed, e.g. are course modules in sustainable development, sustainable business development and ethics made available for the different programmes to use (KTH, 2015b). However, an education assessment from year 2011 stresses that sustainable development aspects require yet more attention in the education (KTH, 2011).

An underlying idea to this study is that all education of sustainable development need caution; it is important to tailor the communication and to find suitable teaching methods in order to reach sufficient and successful learning. This is in line with Keirstead (2013), who suggests that mathematical sustainability models could be one way to approach engineers with the issues of sustainability. Keirstead proceeds from the view that engineers traditionally have been trained in rigorous and clearly defined problems, therefore the introduction to complexly diverse topics - such as sustainability - need thoughtfulness (Keirstead, 2013). There are further indicators that the market has an increased demand on engineers’ capability to handle complexity, namely if looking at the development of environment strategies used over time in Sweden: from being passive (waste dumping), thereafter reactive (external cleaning and recycling) and lastly, to the proactive way of thinking strived for today (with pollution prevention, cleaner production and industrial ecology as some key words) (Persson, 2011). Although the author of this thesis highly recognise the need to cover many different sustainability areas in engineering education, in order to empower students’ ability in solving future problems, this study is delimited to specifically address climate change education. The choice to address climate change is out of multiple reasons: broadly defined sustainability courses already exists at KTH, climate change involves other sustainability aspects and the nature of the topic (involving physics, chemistry, modelling etc.) is thought to suit engineering education well.
2.2 Re-imagination of Education to Address Climate Change

“Clearly, living in times of uncertainty, complexity and contestation, but also in times of ICT-mediated hyper-connectivity and information overload, inevitably has consequences for education, learning and the role of research and science and society. This will be the post ‘post-Rio’ challenge for educators and researchers with a planetary consciousness. In the years to come, this challenge will require a re-imagining of education and the development of new forms of learning that require the fields of EE and ESD to enter unknown terrain.” (Jickling & Wals, 2012, p.54).

The quote above works as an example of the on-going discussion of the need to address sustainability oriented education in the research. Further indicators on the topic’s relevancy is the establishment of the international conference Engineering Education for Sustainable Development (EESD), taking place for the eighth time this year (Mazijn, 2016). The association Educause (supporting the use of information technology (IT) as part of advancing higher education) means that there is an on-going “knowledge revolution” today. The revolution is not about how much information is available, rather how fast knowledge can “grow” by travelling through connected people. IT is called to be a “game changer” in higher education, since it facilitates learning to no longer be bound by classrooms, libraries and physical instructors. Furthermore IT-solutions provide opportunities for new learning experiences through simulations, gaming and online-collaboration (Oblinger, 2012).

One teaching method, using the opportunities with IT in education, is called the Flipped classroom approach. The “flip” refers to the reversed order of homework and university activity; course material is moved outside of the classroom (being available on the Internet) hence, instructors are meant to get more time to actively work with the students. Studies have been made on the outcomes of using the flipped classroom approach in higher education, the method is e.g. suggested to: help students become more comfortable with the subject, increasing student performance (Fautch, 2015), leading to less stress as well as lower failure rates (Maxfield, 2013) and increasing the student ownership of their learning. Khan Academy is one example of a “success story” often being mentioned in the context of web-based lecture technologies (Mok, 2014). Downsides with flipped classroom approach can occur if students have unequal access to technological equipment and if the students feel safe to skip some parts of the out-of-class elements, due to a lack of integration of the course parts. Another potential drawback, from the universities point of view, would be if the student motivation is lowered in pace with less exclusiveness to knowledge access; online-videos may be less valued if the students feel that they could have accessed the knowledge without being enrolled to their study program (Educause, 2012).

A key concept drawn on in the flipped classroom approach is active learning. Time is set free for lecturers/instructors to actively work with the students, so that they can function as coaches during class by encouraging students in collaboration as well as with individual requests. As mentioned in the introduction, active learning is used as a broad concept for teaching techniques which encourage student participation and emphasis development of students’ skills, rather than merely focusing on information transmittance (Keyser, 2000). Shown positive aspects of active learning (such as that students learn more if enjoying studying, if explaining ideas to one another and if getting peer support (Freeman Herreid, 1998), that activity increase student performance as well as a lower odds ratio for failing (Freeman et al., 2014)) are working as the basis for the choice of using active learning in the climate education designed for this study.
The author of this thesis does not argue that flipped classroom and active learning are applicable methods for all study topics, but find a valuable pedagogical contribution from discussion and peer support in the education of climate change. The research adopts the theoretical position, meaning that knowledge is socially constructed; if supported by a more capable peer, a learner can be engaged in tasks and attain goals, which would have been out of reach without support (Davis & Miyake, 2004). This type of learner-support is called “scaffolding”, a metaphor which is referring to how scaffold is crucial at the first stages of a construction period, but that elements can be removed gradually, as the building gets independently robust. A theoretical model, explaining how social interactions shape and transform the way we think is explained as the Zone of Proximal Development. This model explains that there is one development level determined by independent problem solving and one extended development level, which could be reached in problem solving under guidance or collaboration. The distance between these levels is referred to as the “zone of proximal development” (Vygotskii & Cole, 1978). Wass et al. (2011) discovered an extended zone for critical thinking, as students were supported with verbal scaffolding and conversation with lecturers and peers, hence similar effects were anticipated for climate education with such support.

Using a board game as an active learning tool were thought to help increasing student knowledge and “translating” the results from climate science into a language easier understood by the students (outcomes suggested by Katsaliaki and Mustafee (2015) and Reckien and Eisenack (2013), respectively). The use of an educational game was furthermore desired to aid the communication of climate change by emphasising the “geeky”, complex matters of the topics, rather than conveying a “doomsday” threat, easily experienced when receiving climate change information.

Climate and climate change is a topic, dissimilar to many topics taught on a technical university. Hulme (2009, p.17) argues a need to understand the ways in which the idea of climate change action often is used to justify and convey ideology. Hulme points out science, economics and religion as some of the reasons to why we disagree about climate change (2009, p.xxxv). He points at climate as a highly charged topic, since changes in the climate have been used to tell stories about the rise and fall of human civilisations throughout history (2009, p.28). The choice of word when using “doomsday” in previous section works as an example of how language borrowed from religion, theology and morality often is used to discuss climate change (2009, p.173-174). The Encyclical letter “on Care for Our Common Home”, written by Pope Francis in the year 2015, is one example of how climate change is touching upon existential beliefs and religion. Pope Francis published the Encyclical with the stated aim of entering into dialogue “with all people about our common home”(Pope Francis, 2015, sec.3) and provides for scientific information about the state of the planet combined with religious motives for behaviour change:

“There is a nobility in the duty to care for creation through little daily actions, and it is wonderful how education can bring about real changes in lifestyle. Education in environmental responsibility can encourage ways of acting which directly and significantly affect the world around us, such as avoiding the use of plastic and paper, reducing water consumption, separating refuse, cooking only what can reasonably be consumed, showing care for other living beings, using public transport or car-pooling, planting trees, turning off unnecessary lights, or any number of other practices.” (Pope Francis, 2015, sec.211)

If returning to Hulme’s reflection about the various interpretations of climate change, he means that we do not disagree about climate change because we distrust the physical theories or methods used; we disagree because of our different understandings of science in relation to our risk perceptions and our views on the role of science in policy making. Disagreement, he says, is
an important form of learning (2009, p.xxxiv) and an underlying idea of this thesis is in accordance to Hulme’s view that science *thrive* on disagreement (2009, p.xxxv). In this thesis the complex art of the mere subject ‘climate change’ is argued to serve as one reason for careful attention in climate education; ensuring trust to scientific knowledge and inviting students to a scientific standpoint are thought to be important parts in climate education. Following quote formulates one further underlying thought on why and how climate education is addressed in this thesis: the relation people have to climate science must be of an art which makes the science valuable to use.

“In the production, or better still the co-production, of climate change knowledge for public policy, trust in the process of science and participation in the social processes of co-production are essential. Without trust and/or participation, scientific knowledge about climate change is unlikely to prove robust enough to be put to good use” (Hulme, 2009, p. 106-107).
3. Description of the Student Groups and the Active Climate Seminar

In this chapter the characters of the student groups, the parts of the seminar along with the context in which the seminars took place, are described.

3.1 Description of the Student Groups

Data for this study is collected from three student groups, with different fields of studies in higher education: the Graz-group, the CL-group and the Titeh-group, all described briefly in this section.

Group “Graz” consisted of students who electively had chosen to participate in the seminar course, after participating in the lectures of a 3 ECTS lecture course, but before being examined. The lecture course is called Earth’s Climate System and Climate Change and is provided by the Wegener Center for Climate and Global Change at the University of Graz, Austria. The seminar course was worth 1.5 ECTS and consisted of two occasions of playing a climate game (briefly explained in the Section 3.3.2). The students who took the seminar course came from various study fields, most of them were Industrial Ecology students. The majority of the 23 enrolled students were master students, but a few bachelor students participated as well.

The students in the so called “CL-group” were first-year students of a five year engineering program with pedagogy as a major field, provided by KTH in Stockholm, Sweden. A 90-minute online preparation (described in Section 3.2) followed by the interactive seminar formed an introduction to the topic of climate change, as part of a broad introduction course called Physics, Chemistry, Energy and the Environment, worth 15 ECTS which was examined by a written exam in the end of the semester.

The third group, called “Titeh”, were first-year students to a three year engineering program with technique and economics as major fields, also provided by KTH. For this group a 90-minute online preparation, followed by the interactive seminar, worked as an introduction to project group works in two different courses, linking the topic of climate change to business and investments.

3.2 Study Instructions for the CL- and Titeh-group

The two Swedish student groups (Titeh and CL) had no pre-education about Earth’s climate system and climate change in their university education. To provide the students with introductory knowledge a study instruction was developed in the form of a pdf-file. This study guide was designed to take 90 minutes to fulfil and contained directives to read certain pages in scientific papers on the one hand, and follow embedded Internet links on the other hand. The content of the study guide was inspired from the course content of the lecture course in Graz, Earth’s Climate System and Climate Change, with allowance from professor Gottfried Kirchengast who has developed the course. Thanks to the vast amount of available online material the study guide could be designed with the attempt to balance credible scientific sources with videos, interactive models, quizzes, images and personal attachment (e.g. by looking at local climate scenarios).

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3 Credits in the European Credit Transfer and Accumulation System.
4 The interactive seminar course was developed by the author of this thesis, with input and support from the professor of the lecture course, Gottfried Kirchengast.
The idea of moving the course content to online activities is in line with the flipped classroom approach described in Section 2.2. The CL-group were independently responsible to prepare for the seminar, whereas the Titeh-group had scheduled time to do the online pre-seminar preparations some days before the seminar took place. Valuable feedback from students in the interviews and focus groups was applied after the first session, hence the study-guide version used for the last group (Titeh) contained more “click-bating” links, less voluntary extra-material and emphasis was made on the more appropriate videos. See Appendix I for the complete study instruction (in Swedish).

3.3 The Interactive Seminar
The interactive seminars looked slightly different in the three cases, owing to the improvements from the iterative art of the process. Each seminar began with a warm-up discussions, which are briefly explained in Section 3.3.1. Thereafter the students were playing the board game “Clime-out” (described in Section 3.3.2). Debriefing is suggested to be a valuable part of gaming for educational purposes (Katsaliaki & Mustafee, 2015), hence all gaming sessions were ending with some sort of debriefing session and post-surveys.

3.3.1 Warm-up Discussions
The Graz students had a lot of pre-knowledge from visiting the lecture course, therefore the seminar worked as an opportunity for the students to deepen their existing knowledge as well as a help in further preparing for the exam. Before the gaming session took place, some time was allotted, in which the students were asked to freely discuss the course material in groups and help each other to fill knowledge gaps and misconceptions.

The pre-discussion in the CL-group involved dialogues of their two homework tasks: (1) discussing one identified part of the material, which they had not fully understood and (2) share one aspect they did not want to “lose”, due to a changing climate. The latter homework was inspired by the climate action campaign “For the love of” (The Climate Coalition, 2014) and from the psychological aspect that people have a tendency to rather avoid losses than to seek gains (e.g. negative feelings from losing an amount of money outweigh positive feelings associated with winning the same amount) (Center for Research on Environmental Decisions, 2009). The second homework was formulated as follows:

“Whether it is the possibility to go skiing in the winter time, or the knowledge that there are well-being orang-utans somewhere in the world; what consequences of the climate change do you want to avoid? Select one thing you want to maintain, that you can tell to your group on the seminar”.

The seminar for the Titeh-group started with an interactive mini-quiz contest, facilitated through the online tool Socrative (MasteryConnect, 2015). Students were using private cell-phones and computers to log in to a “virtual classroom”, via a link and an eight-digit-password, hence, the seminar leader could view the quiz process. The short quiz was desired to fill the function of rewarding the students who had prepared carefully with contentment, to work as a basis for full-class introduction and to gain student respect to the educational purpose of playing game in class. See Appendix II, for the design and content of the quiz questions. This group had only had one homework (the one described in the quote above), hence, a brief presentation on their thoughts worked as the bridge between warm-up discussion and gaming session.

3.3.2 The Game “Clime-out”
A climate board game called Clime-Out was used as an active learning tool, which means that discussions and interactivity were facilitated through gaming in groups of 6 students. The game was purposely designed, by the author of this thesis, with the aim to familiarize the players with
climate change science as well as with a scientific working procedure. One part of the game consists of explaining relevant vocabulary, another is focusing on scientific explanations of climate processes.

The idea on how vocabulary is exercised in Clime-Out comes from the party game “Med andra ord” (‘In other words’) (ALF, 2002): players explain vocabulary to one another under time pressure. Scientific explanation of climate processes is carried out as quiz-competitions with choices of answers on the one hand (this part was added to support the students who had only been prepared with the online studies) and is, on the other hand, carried out as the players, in turns, take roles as researchers, reviewers and “curious”. The roles have certain tasks so that they together interpret and digest selected parts from the IPCC reports. See Appendix III for the game rules.
4. Methodology

The study took place in Graz, Austria, as well as in Stockholm, Sweden, between January and March 2016. Throughout the study a combination of qualitative and quantitative methods were used to gather data from the three student groups’ climate education, namely: surveys, analysis of mind map reflections and interviews. The qualitative and quantitative methods were meant to complement each other – on the one hand surveys made a pre- and post-survey comparison possible, on the other interviews and the analysis of mind map reflections were giving a deeper insight of the students’ experiences and aided the interpretation of the quantitative results.

4.1 Surveys

Questionnaires were filled in by the students before as well as after the seminars. The surveys included space for free comments but were mainly designed with statements, to which the students were invited to respond their level of agreement on a scale (called Likert scale (O’Leary, 2004)) with points from e.g. “totally disagreeing” to “totally agreeing” (see Appendix X). Survey results were used to examine student attitudes towards learning about climate change (see Appendix IV for more detailed explanation), as well as measuring the effects that the active gaming seminars had on student confidence, in their own understanding as well as in their ability to explain climate change. The choice of using surveys as a method in this study, was made because it made it possible for the students to share their opinions in a more anonymous way, reducing the loyalty and censuring which could e.g. possibly have effects on the results of the interviews.

4.2 Analysis on Mind Map Reflections

With inspiration from concept mapping and the assessment methods used by Segalás Coral (2009) a mind map method was developed. Students in the Graz-group had five minutes to draw a mind-map before the first seminar began, likewise at the end of the second seminar. Student mind maps were collected immediately when drawn, and after the seminar course the student received their two scanned mind-maps as a pdf-file (see example in Appendix VIII). As part of the seminar course the students were asked to write a reflection on differences and similarities in the two mind-maps. The students’ texts were analysed to explore the effects of the proposed active gaming seminars on understanding: frequently mentioned observations were clustered into categories as part of the analysis (see Appendix XI for mind map reflection examples and more method description). The students’ mind map reflections were further used as a complement to the transcribed interviews, when analysing the effects on understanding and confidence.

4.3 Interviews

A selection criteria for which students to invite for interviews were decided before the seminar: students were asked to participate in interviews, based on where they were sitting in the classroom, in order to avoid a bias selection of students. Due to the students’ various schedules, three students were interviewed in a small focus group, whereas two students were interviewed individually in semi-structured interviews, see Appendix XII for interview guide. The transcriptions from each interview were iteratively analysed by linking the discussion parts to the objectives of the study. Quotes from group CL and Titeh were freely translated by the author from Swedish to English, whereas the quotes from group Graz originally were written in English.
5. Results

The results are presented with respect to the three objectives of this study: student’s attitudes towards learning about climate change, the effects of the active gaming seminar on students’ understanding as well as confidence in understanding and partaking in discussions.

5.1 Students’ Attitudes Towards Learning about Climate Change

Interview findings in this study suggest that the first question of a first year engineering student, with demand to learn about climate change, will be: “why should I learn this?”. Interviewees from the CL-group explain a constant challenge of prioritization between math courses and other courses; unless seeing a clear reason or profit to study something else, math will always be prioritized. Although the survey responds disclose that climate change is seen as an important topic, it is not seen as an equally obvious part of engineering education as e.g. math is. Moreover, the interviewed students suggest a distinction between the “common” engineering student and the “environment-interested” student. One interviewee means that students who have chosen an education program that is specialized on sustainability have an “inner motivation” to learn, whereas other engineering students may neither have the personal interest nor think of sustainability as something their future employees will demand.

One primary hypothesis of this study was that the students’ thoughts in how humanity will manage climate change would affect their will to work with something climate related in the future (e.g. only students believing in a successful management of climate change would want to work in the field). However, the survey answers (presented in Figure 1) suggest no correlation between how the student answered to the assertion “I think that humanity will succeed with handling the climate change in a good way” (x-axis) and “I want to (in one way or another) work with climate issues” (y-axis). The lack of correlation is shown by the linear trend line in Figure 1, which almost has no slope, and is further invalidated with a low coefficient of determination ($R^2=0.00125$). Markers for frequent answers are illustrated with a bigger circle, e.g. many students answered the combination (2,3), but no student answered (4,4).

![Figure 1. Will to work in the field plotted against the same student’s vision of successful management of climate change. The statements are answered on a four-point Likert scale, in which 1 means “totally disagree” and 4 means “totally agree”. Data is collected from a post-survey, answered by 52 students in the CL-group.](image-url)
Students who want to work with something climate related in the future are, according to interview discussions in this research, expected to find more motivation to learn about climate change, but since their vision of successful climate management could not easily explain the origin of that will, the various mind-sets were further explored. Based on responds to multiple contextualized statements, inspired from the temporal motivational theory (introduced in the introduction) the underlying ideas of the students were further analysed. Table 1 presents an attempt to cluster student attitudes into four groups, based on their responds on a four-point Likert scale. Although many respondents seem hopeless regarding the future quality of life, the underlying reasoning varies.

Table 1. Student mind-sets in believing humanity will manage climate change in a good way and their own involvement, clustered into four groups. Groups are formed based on survey responds to 5 assertions in the post-survey, which more or less directly address motivation towards working with climate. The statements are adapted to represent temporal motivation theory regarding: vision of overall success, will to contribute, confidence in improvement by personal contribution, delay of improvement and general tolerance for delays, see Appendix IV for further details. Data from 52 students, group CL.

<table>
<thead>
<tr>
<th>Mind-set</th>
<th>Reasoning</th>
<th>Percentages of students</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;It won’t work. I don’t want to try.&quot;</td>
<td>&quot;No use even in trying, what could I do anyway?&quot;</td>
<td>12 %</td>
</tr>
<tr>
<td></td>
<td>&quot;I could probably do a small change, but I’m not interested and it won’t work anyway.&quot;</td>
<td>19 %</td>
</tr>
<tr>
<td>&quot;It won’t work well, but we have to try.&quot;</td>
<td>&quot;I want to tell my grandchildren that I tried, but I won’t be able to change things.&quot;</td>
<td>13 %</td>
</tr>
<tr>
<td></td>
<td>&quot;We (and I) can make it less bad!&quot;</td>
<td>25 %</td>
</tr>
<tr>
<td>&quot;Others will manage it. I can focus on my other interests!&quot;</td>
<td>&quot;I can’t contribute, but humanity will manage it just fine.&quot;</td>
<td>4 %</td>
</tr>
<tr>
<td></td>
<td>&quot;Humanity will manage it, I could have been part of it but I have other plans.&quot;</td>
<td>10 %</td>
</tr>
<tr>
<td>&quot;We’ll manage it. Let’s begin!&quot;</td>
<td>&quot;We’ll make it eventually, let’s begin!&quot;</td>
<td>10 %</td>
</tr>
<tr>
<td></td>
<td>&quot;We’ll make it! It will work faster than we think, so let’s begin!&quot;</td>
<td>8 %</td>
</tr>
</tbody>
</table>

To add information to the data presented in Figure 1 and Table 1, students in group Titeh were asked if they were “feeling motivated” to (in one way or another) work with climate related matters, they were also asked to state main reasons to their answers in an open question. Students who did not feel motivated stated reasons such as not being passionate, lacking interest and that it would be too difficult to affect people to change. Students who felt motivated often mentioned the topic’s importance as one considered factor, other reasons were interests, that climate change have global impacts and that other people are too unconcerned (see Appendix V for student answers). Interview findings furthermore indicate that educators must bare in mind that first-year university students are young enough to have been brought up with awareness of global environmental problems; concern for the consequences of Antropocene is already part of those students’ lives.

One consequence of the awareness about global environment problems is that this pre-knowledge – from media and elsewhere – will affect the students’ attitudes towards learning about climate change at the university. One of the focus group discussions took departure in the view that media reporting on climate change at least not could harm people’s attitudes towards
climate change education. However, the discussion proceeded to the following conclusion: commands without sufficient explaining information get interpreted as “nag”. Too many commands, concerning what is good and bad for the environment, leads to a fatigue and “spammed” feeling. Another interviewee also reflected on the different emotions awoken by university versus media delivered information, the inference was that scientific explanations lead to understanding of why things are happening, whereas information in the media awakes feelings. Both types of communication were seen to be necessary to digest and accept the information.

Recurring in all interviews, as well as in post-surveys, is the experience that climate education, provided by school or university, can force students to deal with their “nagging pain”, caused by exposure to constant information flow about climate change but never seeking a trustworthy source. Three of the five interviewees stated to hear about climate change weekly, the other two on a monthly basis (see Appendix VI). Below follows two quotes from the Titeh-group, as they were asked to describe their emotions when climate change is brought up in the media as well as in the climate module in this study.

“Unaware or not, one tries to avoid it (due to the phycology since earlier on). Wish that I cared a bit more. Was more engaged during this seminar. Thank you.”

“It is easy to weed out information on the TV. ‘This does not concern me’. During a lecture like this it all becomes more personal and under-consciously you get more engaged.”

The quotes were chosen, since they contribute with interesting aspects to the study, namely that the first student says ‘thank you’, for getting engaged in the topic and that the latter reveals an escape from the topic, when exposed to information in the media. All other student answers can be found in Appendix VII. The interviewed students meant that climate information reaching them in everyday life is of a kind that they always take critical stance to. Hence, they experienced a relief by – more or less reluctantly – working with what they call “real” information before and during the seminar. As part of further discussion the interviewees brought up the important role of the communicator as a person. More than once An Inconvenient Truth was mentioned to have worked as a “wake-up call” – thanks to Al Gore’s authoritative voice and the accessibility of his film on the Internet. The interviewed students meant that less famous communicators need credibility and transparency; more specifically that would mean “practicing what they preach” and not risking losing trust of the students by trying to work around the psychology of the students.

### 5.2 The Effects of the Active Gaming Seminar on Students’ Understanding

The effects of the active gaming seminar was mainly tested on the Graz-group, who were given the task to write mind maps on five minutes before and after the seminars and later analyse differences and similarities in their mind maps. All 14 students drawing mind maps before and after participating in the interactive seminars, identified differences in their two mind maps (see Appendix VIII for one example of student mind map before and after). Student observations were clustered into subcategories and matched to three main categories, inspired by indexes used in concept map assessment by Segeläs Coral (2009): number of concepts, number of connections and relevance of concepts (Table 2).

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5 Documentary from 2006 with director Davis Guggenheim (IMDb, 2006).
Table 2. Categorization of students’ observed differences, when comparing their own mind map drawn before the interactive seminars (mind map 1) with that drawn after (mind map 2). Data from 14 students in group Graz.

<table>
<thead>
<tr>
<th>Main Categories</th>
<th>Frequently Identified Mind-Map Differences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of concepts</td>
<td>- Mind map 2 includes more words.</td>
</tr>
<tr>
<td></td>
<td>- Mind map 1 seems narrow compared to mind map 2.</td>
</tr>
<tr>
<td></td>
<td>- Mind map 2 has more number of concepts per category.</td>
</tr>
<tr>
<td>Number of connections</td>
<td>- More links and associations in mind map 2.</td>
</tr>
<tr>
<td>Relevance of concepts</td>
<td>- Mind map 2 gives a clearer and more accurate picture.</td>
</tr>
<tr>
<td></td>
<td>- Something is forgotten or avoided in mind map 1, that is mentioned in mind map 2.</td>
</tr>
</tbody>
</table>

All students identified improvements in their second mind map, but some weaknesses of the method were mentioned, e.g. that short time memory made it easier to draw the second mind map, since it was drawn straight after the gaming session, as well as that the five minute limit only was experienced to be limiting the drawing of the second mind map, since they knew more at that point. The following quote is picked as an example of the many similar student reflections, stating that the active way of learning was valuable as it transformed knowledge into communicable words and context:

“After hearing the lecture and before the first gaming session I thought I had an acceptable overview of the current climate system and its ongoing change. Sadly I was not able to create a proper mind map due to my lack of vocabulary and inability of linking the keywords. So I had a bit of a struggle with my first mind map which led to some doubts about my self assessment. After the second session and thanks to the “Activity” gaming style my vocabulary seems to have improved and linking the major keywords was easier thanks to the previous “scientific” questions. In our group, these questions tended to escalate into long lasting discussions.”

In order to explore which reasons the students pointed at, as lying behind the learning outcomes from the seminars, the interviews, open-answer questions and comment space in the post-surveys were helpful. As presented in Table 3 interactivity, discussions, learning-by-doing-effects and the “learner-friendliness” of the learning method were frequently mentioned as reasons to the increased knowledge and understanding.

Table 3. Frequently mentioned outcomes as well as students’ analysis of reasons behind the outcomes. Data is compiled from open questions and free comments in the post-surveys from all groups (Graz, CL and Titeh).

<table>
<thead>
<tr>
<th>Frequently mentioned outcomes</th>
<th>Frequently mentioned reasons to the outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Learning and gaining new insights</td>
<td>- Interactive activity</td>
</tr>
<tr>
<td>- Deeper understanding and practise knowledge</td>
<td>- Discussion with peers (additionally for Graz: positive that peers had various backgrounds)</td>
</tr>
<tr>
<td>- Understanding complexity better</td>
<td>- Learning by doing</td>
</tr>
<tr>
<td>- Clarify knowledge gaps</td>
<td>- Learning in a way that is not difficult</td>
</tr>
</tbody>
</table>

The interviews enabled increased comprehension of how the active learning impacted the learning process. The use of board game is mentioned to have created extra motivation and the interviewed students concluded two outcomes from not “thinking about that they were studying”: on the one hand it extended their attention span and on the other, it made them enjoy learning about climate change.
If negative aspects were raised, they were often followed by concrete improvement suggestions, e.g. that the vocabulary words could be written in Swedish and “Would be great with short explanations to the vocabulary (could be on a separate paper aside).” Complains about the teaching method were only found in the pre-survey. For example, one student in the CL-group commented: “For me, who is not so interested and conversant with the issue of climate change, I think it is better with lectures than having to actively participate in a seminar on the subject.”. One of the interviewees explained a positive change in attitude to the learning about climate change, thanks to the active learning method and one survey-respondent from Graz expressed the benefits of learning in a way that made the science seem easy:

“Well, we were not really having a positive attitude and thought it would be grey and boring. We did not really enter open-minded, that’s for sure. But instead we were allowed to sit freely and openly, we were allowed to discuss and laugh... and like - play game!”

“I really learnt a lot and realized a lot, and it was not so difficult. All the knowledge went smoothly in my mind.”

Throughout the interviews, the importance of explaining with own words, or listening to a course mate’s explanation, was highlighted. These activities was said to work around the situation when a lecturer tries to communicate something that the students anyway do not understand. The students meant that they felt more able to answer and, not the least, interpret questions since they were studying with peers, instead of approaching the topic of climate change alone. One informant expressed that the discussions about interpretations and various views felt utterly important, emphasising that awareness of others’ perspectives is crucial in order to proceed with eligible climate solutions. Moreover, interview results suggested that exploration of the topic’s complexity and participation in multifaceted discussions worked as an opposite pole to some encountered oversimplification experienced in media. This outcome is also encountered in the survey results, by quotes like:

“I expected to learn about the effects of climate change. Mostly [sic] I assumed I would hear a lot of man-made doomsday threats based on statistics. But I learned so much more than that! I learned the physics behind it all, which really helped me have a firmer grasp on the causes and effects of climate change in numerical terms. RF was a new (but very important!) concept for me. I learned the true complexity behind mitigating climate change and how much factors into it, not just driving less and eating less meat. Very difficult (in a good way), worthwhile course! Thank you”

Some interviewees had never heard of the IPCC before, and one student meant that there is an obvious need for pre-knowledge to be able to understand the information: “if you don’t have any pre-knowledge it’s like a stone wall”. This, in combination with the increased ability to express knowledge in words, being pushed to actively deal with learning about climate change and providing the students with a scientific knowledge basis suggests that climate education as part of the engineering education can increase something that could be called “climate literacy”. A “learner-friendly” climate education in the university may therefore reduce the risk of feeling as if hitting a wall of stone, next time the student is faced with climate science.

5.3 The Effects of the Active Gaming Seminar on Students’ Confidence

Data from the participators of this study suggests that active learning methods can facilitate a decoupled growth in the students’ perceived increase in understanding ($\Delta=0.29$) and confidence in explaining climate change ($\Delta=0.50$) (see Table 4).

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6 RF is referring to Radiative forcing, which is a measurement on affects on the global radiation balance.
Table 4. Total mean value of students’ perceived understanding of climate change as well as confidence in explaining climate change. The results are from surveys before and after the interactive seminars and are expressed with a number between 1-5. The standard deviations were analysed for the confidence interval of 5%. All groups (Graz, CL and Titeh).

<table>
<thead>
<tr>
<th></th>
<th>Mean Before (n=93)</th>
<th>Mean After (n=102)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perceived Understanding</td>
<td>3.12 ± 0.9</td>
<td>3.41 ± 0.82</td>
</tr>
<tr>
<td>Confidence</td>
<td>2.92 ± 0.95</td>
<td>3.42 ± 0.92</td>
</tr>
</tbody>
</table>

Figure 2 shows linear trend lines to how students judged their confidence and understanding before as well as after participating in the seminars. The differences in the linear fits gives a visual hint on a decoupled growth: after the seminar, students had a higher level in confidence to explain climate change, although the levels of understanding were the same as before the seminar. Learning about climate change in groups was generally appreciated by the students and survey answers suggest that it is not only students who usually study in groups, who are appreciating the cooperative learning during the seminar (see Appendix IX).

In the mind-map analysis, one student revealed the attempt of trying to avoid certain topics in the first mind map, since not being sure about them. The interviewees described similar experiences and explained a feeling of having been “pushed over a threshold” during the seminar; once they had been “forced” to discuss climate change they felt more confident in new discussions. Roles in the games seemed to have enabled a dynamic, the informants meant that it felt acceptable not to fully understand or be at the same knowledge level as your peers. For example, one student meant that the roles gave the players an ability to challenge the others’ knowledge by asking questions, which meant that they could be part of the discussion although they did not fully understand themselves. One interviewee witnessed a lot of discussions after the seminar: the students discussed different views, opinions and shared tips on climate related videos on the Internet. Evidently, they even started to discuss what they had learnt earlier on in the on-going introduction course, the interviewee expressed it: “It became more like: ‘this is perhaps not the world’s most boring topic, maybe it can even be a bit fun’”. The free space
during the game sessions was mentioned as a reason behind the changed perspective. The interviewee had a feeling that the gaming seminar was less “confined” and compared the experience to other seminars, in which a feeling of being “watched over” by the teacher was said to occur sometimes. Such an observed feeling was, understandably, also said to lead to less openness and the interviewee called it a fear towards saying “wrong things” and having “weird opinions”.
6. Discussion

6.1 Students’ Attitudes Towards Learning about Climate Change

The analysis of students’ attitudes toward learning about climate change is suggesting that university education about the topic involves emotions. The mind-sets of students, shown in Table 1, are in line with more extensive Swedish studies on young people’s emotions; one study is suggesting that 29% feel hopeless towards the global environment problems (Ask, 2016) and in another study 79% of 1000 respondents, reported to worry about how climate change will affect the world and their own future. Remarkably, one quarter of the respondents even stated stomach pain or unhappiness when thinking about climate change (WWF, 2013). As can be seen in Table 1 the majority of the students in this study are worrying about how humanity will manage the effects of climate change. These emotions and doubts in future success emphasize the challenging art of climate education, and can be understood as an importance to strive for student support in climate education.

Interestingly, a lot of students, in surveys as well as in interviews in this study, underline that the topic ‘climate change’ is of utmost importance. Still, some of the interviewed students do not appear to see climate change as an obvious part of engineering education (such as e.g. many math courses are seen as obvious parts). There seems to be a requirement to address the relevancy, by demonstrating how engineers can be part of climate change mitigation and adaptation; although the university sees a need for sustainability knowledge on the market, students might neither find it relevant to their future work, nor feel as if they could contribute to future improvements. If applying temporal motivation theory in this case (presented in the introduction), one learns that students would need to see some sort of future and/or immediate possibility of rewards, in order to be motivated to learn about climate change. The interviewees make a distinction between students who have chosen a sustainability profile and the “common” engineering student, meaning that “common” engineers may lack “inner motivation” to learn about sustainability and climate. This could either point towards a motivation stemming from anticipated future job opportunities/employer demands, or that the students who had a sustainability interest before choosing study program are motivated by some other reason.

One could think that the vision of a “success” in how humanity will manage climate change would influence students’ will to work in the field, working as a type of future “reward”. Figure 1 does, however, disprove this hypothesis for this study. Future studies with more students and a yet deeper analysis in the student mind-sets could probably contribute to better understanding on how climate education can meet the students’ needs. This study is only drawing the conclusion that some students’ attitudes leave space for them to imagine working with climate in the future, whereas others do not. Whether people with positive (or negative) reasons for engagement can influence their peers is left for future studies to discover. However, Vygotskii’s (1978) development model - suggesting that social interactions shape and transform the way we think - supports the idea that inspiration can occur from hearing other’s mind-sets. That would mean that the cherishing of the ability to tell future grandchildren that their granny is someone to be proud of (like some student in this study meant) or valuing the “nobility in the duty to care for creation” (as stated by Pope Francis in the Encyclical letter, Section 2.2) could inspire peers to find more meaning in climate action.
The “important but not for me”-phenomenon encountered in some of the survey answers is not unique for the topic of climate education. This attitude has e.g. also been found in a wider study about the perceived relevancy of science education in secondary school (Jenkins & Nelson, 2005), the “not for me”-attitude rather seems to relate to prejudices and the “status” of a topic. The interviewees mention math to be prioritized - a topic with long tradition and “high status” in the curriculum. Further attention on finding why students are motivated to prioritize e.g. math could probably contribute to the development of a suitable learning design for climate change. As discussed in Section 2.1, there are articles about suitable strategies to approach engineering students with the complex and diverse topic of sustainability, Keirstead (2013) suggests the use of mathematical models to be one possibility. The author of this thesis means that climate change education is one part of the education for sustainable development, which require re-imagination according to Jickling and Wals (2012, p.54) (see Section 2.2). If climate change education is presented in a suitable way for engineering students, it could probably become a natural topic for the students to prioritize.

Thus, the “important but not for me”-attitude do not seem to be a unique challenge for education addressing climate change, but rather for education in general. The defensive stance of the students, however, seems to be characteristic for climate education, due to the many emotions related to the topic. The interviewees mean that it is important for climate teachers to “practice what they preach” to remain credible - a phenomena which is also found in a study by Segalàs Coral (2009). The defensive attitude is understandable if agreeing with Hulme (2009, p.17), who means that the idea of climate change action often is used to justify and convey ideology (as discussed in Section 2.2), the students are critical to all type of messages which may have underlying ideologies. The choice of words when one of the interviewees describe less fear of saying “wrong things” and having “weird opinions” when playing the game, than if a teacher would constantly be around, highlights the difficulty of avoiding normativity when teaching about climate change. In other words, the student experience certain opinions to be “right” in the education for sustainable development, which creates a fear of discussing things which may lay outside the “correct” way of reasoning. The aspect of how to achieve pluralism, and avoid normativity, in education for sustainability is currently being discussed by practitioners (Ask, 2016). Freeman Herreid’s quote adds reflections on the teacher’s role in active learning: “When one gives up being ‘the sage on the stage’ to being a ‘guide on the side’, teaching will never again be the same.” (Freeman Herreid, 1998, p. 559). This study contribute to the understanding on how to avoid normative teaching, by suggesting that it is important for universities to be transparent with the reasons behind the chosen way of communicating climate science. The interviewees mean that it is important that any psychological “trick” used, should be clarified to the students to avoid distrust.

The several different mind-sets in Table 1 indicates a diversity in the classroom. Those differences in understandings of the topic ‘climate change’, as well as the various views on the role of science in the participating students’ future professions, can be seen as an asset in climate education. If the students get a space to discover the different views of their peers, the disagreements could contribute to the learning process, as Hulme argues (2009, p.xxxvi). The quote from the interviewee, explaining the changed atmosphere and discussions taking place after the interactive seminar (“It became more like: ‘this is perhaps not the world’s most boring topic, maybe it can even be a bit fun’”) reveals that the student attitudes towards learning about climate change easily can be influenced. This study further suggest that the reactive student feeling of being “nagged at”, when receiving information from a lecturer, could be worked around if creating space for peer-to-peer communication. As regards the importance of knowing
the audience in climate change communication, the facilitation of letting the audience communicate in the audience’s own language could be used as a short cut to ensure appropriate communication and avoid the feeling of normativity.

6.2 The Effects of the Active Gaming Seminar on Students’ Understanding

The categorization of students’ observed mind map differences (see Table 2) shows the effects that the active gaming seminar had on students’ understanding. Although the mind map method has its weaknesses (few partaking students, not excluding the aspect of short time memory contribution, etc.) the students’ observed mind map changes are similar with previously used concept map assessment indexes such as number of concept, number of connections and relevancy of concepts (Segalàs Coral, 2009). The increase in number of concepts both means that the perspective on climate change was widened and deepened, whereas the increased number of links and associations points on a better capability on putting the knowledge into context. That the concepts were more relevant in the second mind map suggests an improved comprehension of the holistic picture of climate change and the fact that students tactically avoided certain areas in the first – but not the second – mind map shows an increased “ownership” of the topic. The student quote: “Sadly I was not able to create a proper mind map due to my lack of vocabulary and inability of linking the keywords” (see Section 4.2) brings attention to the valuable effects that the active gaming seminars had on students’ understanding. After participating in discussions, using climate vocabulary in a context and digesting the science with peers, the student became more capable to organise and communicate knowledge. The student quote confirms Keyser’s (2000) distinction between active learning and traditional learning – the student talks about the development of skills, which was added when learning occurred in an active way, rather than through mere “information transmittance”.

The most frequently mentioned reasons to the learning outcomes were emphasising the value of interactivity, discussions and the practical, easy way of learning (Table 3). All those reasons are being closely linked to how “active learning” normally is distinguished from traditional learning, e.g. by Freeman Herreid (1998). If recalling the more negative comment about the learning method: “For me, who is not so interested and conversant with the issue of climate change, I think it is better with lectures than having to actively participate in a seminar on the subject.”, the quote can be compared to a study by Mok (2014), who found similar attitudes in his study about active learning in programming. Mok means that the “forcing” of students to be engaged in programming activities in class benefited students who would otherwise not attempt to do the task. If a basic understanding of climate change is seen to be important for all professions (as claimed by the ordinances on an international and national level), active climate learning at the university is an opportunity to reach out. The positive changes in attitudes (e.g. “Well, we were not really having a positive attitude and thought it would be grey and boring. [...] But instead we were allowed to sit freely and openly, we were allowed to discuss and laugh” and “I assumed I would hear a lot of man-made doomsday threats based on statistics. But I learned so much more than that! [...]”, see Section 4.2) show that the active seminar enabled affections on students who otherwise might have passed the course with an “least-amount-of-effort”-attitude. Possible to think is that those students’ original attitudes would have been blocking their learning and increased understanding if the learning method did not demand an active participation.

6.3 The Effects of the Active Gaming Seminar on Students’ Confidence

Pushing the students over the threshold to discuss climate change – as well as providing for increased ability to discuss – are in this study suggested to be strategies to involve when aiming at enhancing student confidence. The active gaming seminar had the effect to increase student
confident in explaining the topic, a growth which is suggested to not even be limited by the increase in understanding. Fautch (2015) argue it being important that students exercise in taking ownership of their learning, and means that the flipped classroom approach encourage such a process. This is in line with the results in this study, suggesting that an active and supportive climate education will increase “climate literacy”. The meaning of “literacy” in this case, is that this study suggests that engineers who have undertaken supportive climate education, as part of their engineering education, will be more able to receive and understand climate information in the future – avoiding the feeling of hitting a “stone wall” if faced with scientific climate information for the first time in their professional roles.

Wass et al. (2011) discuss how critical thinking can be encouraged through different types of scaffolding techniques, and brings up the challenging balance of not stripping away complexity, yet avoiding overwhelming difficulties. One result in this study, presented in Section 4.2, is that the exploration of complexity and participation in multifaceted discussions about climate change worked as an appreciated opposite pole to oversimplifications encountered in the media. This indicates that students lack contact with first hand scientific communication of climate change. Once they have been introduced to the existence of the IPCC, useful websites on the internet as well as the scientific and political working procedures behind climate reports, though, they may not only increase their present confidence and knowledge level, but might also be more capable of processing a yet deeper understanding in the future. This illuminate one important role universities can play in climate communication. Whether the university is being a third-party communicator of the compiled research results in the IPCC reports, or also presenting its own climate research, the future professionals might feel empowered to utilize the Summary for Policymakers, if climate change education is being wisely integrated in the curriculums.

6.4 Discussion about the Methods Used
The methods were generally complementing each other in a valuable way to cover the objectives of this study. Strengths and weaknesses of the methods are discussed in the sections below, along with a description of the sample.

6.4.1 Choice of student groups
The choice of student groups were a sort of “convenience sample”, determined by which lecturers who were open-minded to the idea of implementing the seminar in their courses, as well as time restrictions demanding courses on the spring semester. The reason to why one part of the study was conducted in Graz and two groups in Stockholm, had to do with the thesis author’s contacts, from studying at KTH and doing an exchange year at the Technical University of Graz.

6.4.2 Surveys
The surveys gave the possibility to analyse quantitative data in this study. Open answers were useful for the iterative improvements of the seminar parts, but also when analysing student mind-sets and attitudes (e.g. for the questions in Appendix IV). The usefulness of Likert scales can be slightly questioned, as students perhaps remembered their answers from before the seminar, which might have had affects on their post-survey answers in one way or the other, e.g. one student expressed “But! Now I know what I don’t know”, as he were asked to rate his understanding the second time. Other impacts on the self-rating may also be the general self-confidence in the classes, due to three-year alternatively five-year engineering program, gender or other circumstances such as one student who transparently wrote “I think it is boring + am sick at the moment, so my motivation is low for everything”.

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A five-graded Likert scale was used for the first student group, when asked about self-rated understanding and convenience in explaining climate change. Later in the study, students were wished to be “forced” to show their standpoints, hence a four-point Likert scale were used for these questions. This choice resulted in questionnaires with two five-graded scales (for the questions on understanding and confidence) and that remaining questions only had four grades to choose between. The mix of Likert-scales could either have been confusing for the students, or beneficial to make them not answer questions per routine. Other efforts in order to avoid routine answers in the survey, was that assertions were formulated so that some of them were calling on affirmative and others disagreeing answers in order to discourage result influence.

Figure 1 and Figure 2 are presented with a linear fit, although the Likert scale was not continuous. The lines are meant to assist the reader when interpreting the changes and correlations, hence this way of presenting the data is seen to add value, although the scales optimally should have been continuous for such data presentation.

6.4.3 Mind Map Analysis
Using mind maps to analyse the students’ level of understanding was reckoned to be one of the better method alternatives, within the time- and resource access in this study. However, the applied mind map analysis had strengths as well as weaknesses. High response rate and consistent 5-minute limit was prioritized, hence the exercise was done in-class instead of afterwards, through the Internet or such. As student mind maps were collected immediately after they were drawn, the students did most likely not remember all concepts from their first mind map, by the time drawing their second mind map a couple of days later. Short time memory from the gaming session, and the discussions from the seminar must however have had impacts on the second mind-maps, just as some students were addressing in their analysis. The capacity of linking the concepts to one-another, however, are seen to be less affected by the short-time memory.

In the dissertation written by Segalàs Coral (2009) the impediment with impacts from the analyser and the applied method is mentioned. The method used in this thesis was designed with attempts to bypass this problem – by letting the students compare and analyse their mind maps themselves, and then analyse their reflections. The student analyses indeed had similar conclusions as the “professional analysers” in Segaàs Coral’s dissertation, this similarity is seen to increase the reliability of the findings from the mind map-metod.

6.4.4 Interviews
Interviews gave the opportunity to follow up the students’ ideas and encourage the students to develop their reasoning. Although the interviewees were selected with an unbiased criteria (they were asked to participate, based on where they sat in the classroom), a possibly biased selection occurred anyways, due to which students who actually took the time to participate in the study. The focus group contributed with a relaxed discussion amongst the peers, and gave the participants a chance to build on each others’ ideas. In the transcribed version of the focus group, it became clear to notice the different roles taken by the students: sometimes a student tried to be “cool” and another student were cautious to be gentle when asked to criticize the seminar, which points at the weakness of having the seminar leader to conduct the research. In order to diminish this impact, the interviewer actively tried to encourage openness towards negative critique as well as positive. Conducting the interviews with students from the CL-group was thought to enrich the study, since those students have interest of and knowledge in pedagogy. Nevertheless, this could be a wrong assumption, since those students may be more (or less) open-minded towards new pedagogical methods.
7. Conclusion

This study suggests that active learning through gaming is a supportive teaching method, when addressing climate change in higher technical education. Climate change is a sensible topic and students, who have grown up with awareness of global environment problems, have many emotions related to the subject. These emotions are affecting students’ attitudes towards learning about climate change. A lot of students in this study are believing that humanity will not manage climate change in a good way, there are also students who neither think it is worth trying to do climate change mitigation and adaptation, nor see the relevancy of this work for their future work as engineers. However, there does not seem to be a correlation between a student’s belief in successful management of climate change and the will to work in the field, according to this study. Nevertheless, consideration of various attitudes towards the learning of climate change seem important and a mind-set analysis can advise educators on how to address ‘climate change’ in a way that is relevant to the students.

An active learning method containing student discussions can contribute to improved understanding of climate processes, partly since the peer-to-peer communication moves away from the idea of one single communicator, explaining something that students may interpret as normative commands. Survey answers in this study show a decoupled growth in a student’s self-rated level of understanding and the student’s confidence in explaining climate change. Interview findings also shows that encouraged in-class discussions, on the topic of climate change and sustainability, led to further discussions outside of the classroom. These results do indicate that universities could play an important role in climate communication, since an introduction to climate change can “push the students over a threshold”, so that participation in future discussions on the topic become less distant. Using games as an active learning method has the potential to increase student understanding and confidence in the topic of climate change – and doing so in a supportive and enjoyable manner.
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Appendix I [Study Instructions for the Climate Module]

Instuderingsinstruktioner till klimatmodul för TITEH

Välkommen till klimatmodulen för TITEH! Modulen är designad enligt the flipped classroom approach, vilket innebär att du kommer:

1. **förbereda dig under minst 90 minuter på egen hand,** med hjälp av den litteratur och multimedia som presenteras i den här instuderingsinstruktionen,
2. **delta i ett 90 minuters interaktivt seminarium den 5 april. Ta med dina anteckningar från förberedelserna!**

ReadMe!
Den här instuderingsinstruktionen kommer guida dig i ditt lärande med 9 steg bestående av en mix utav litteratur, online-föreläsningar och quiz.


Efter varje video finns frågor att svara på, frågorna är ett bra sätt att kolla av att du förstått viktiga delar av videon. Det krävs att du loggar in på TED för att svara - registreringen sker enkelt via facebook eller en mejladdrss.

Materialet nås via hyperlänkar i detta dokument samt specifika sidor av de tre PDF-filerna (som även ligger i KTH social):

1. **IPCC:s sammanfattning för beslutsfattare**
   (välj mellan svenska och engelsk version)
2. **Stocker**
3. **Ruddiman**

Läxa
Du har **en läxa** inför seminariet den 5 april. Vare sig det är att kunna åka skidor på vintern eller vetskapan om att det finns välmående orangutanger någonstans i världen; Vilka följder av klimatförändringarna vill du undvika? Välj ut något du vill bevara, som du kan berätta för din grupp på seminariet.

Kursmodulen utvärderas som del av ett masterarbete. Eventuella frågor och kommentarer skickas till saratr@kth.se.
I. Klimatförändringarna och vår hjärna

1. Ofta när vi pratar om ett förändrat klimat tänker vi på något som sker långt bort och långt fram i tiden. **Men hur ser egentligen klimatscenerierna ut för din hemregion?** Ta en titt på hur prognoserna för klimatindexen temperatur, nederbörd och vind ser ut i din hemregion.
   - Vilka förändringar förväntas ske i din hemregion?
   - Vad är en RCP (Representative Concentration Pathway)?
   - Vad är IPCC (Intergovernmental Panel on Climate Change)?

2. **Så funkar våra hjärtor för att slipa tänka på klimatförändringarna.**
   - Vad tror du skulle kunna få en företagsledning/privatperson att förändra något för att minska klimatpåverkan?

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**Ofta tror vi att vi kan mer om klimatförändringarna än vi faktiskt kan!**
Vi hör så ofta om diverse klimat- och miljökatastrofer att vi blandar ihop dem och inte riktigt orkar lyssna på fler anledningar till dåligt samvete för att finnas till...

I följande steg kommer du guidas till grundläggande kunskap om jordens fascinerande klimatsystem och de komplexa processer som gör systemet så intressant att försöka förstå. Ta nu på dig dina nördigaste ingenjörsglänsögon och lycka till!

---

II. Klimatsystemet: komponenter & energiflöden

3. **Nu är det du som är klimatforskare!** Följ de fyra stegen i energibalansmodellen. Läs texten och förklaringen till de understrukna begreppen så noga att du skulle kunna förklara modellen för någon annan.

   - I modellen går solkonstanten, $S_0$, att ändra. Hur ser det ut i verkligheten, är värdena konstant eller föränderligt?
   - Den så kallade albedoefekten reflektar ca 30% av solens strålar vid jordens yta. I dagsläget minskar albedoefekten succisivt – vet du varför? (OBS: vanligtvis betecknas albedo "$\alpha$").
   - I modellen visas atmosfären som en röd ring. Var befinner sig växthusgaserna i verkligheten? (OBS: vanligt är att bli förvirrad av "ozonlagret" – se till att förstå skillnaden på uttuningen av ozonlagret och klimatförändringarna).
     - Fuskhjälp 1: Läs Box 2-1 "The Structure of Earth’s Atmosphere" (s.5) i PDF-filen *Ruddiman*.
     - Fuskhjälp 2: *SMHI förklarar* ozonskiktet och klimatet.
4. Titta på lektionen "Hur kvantummekanik kan förklara växthuseffekten".
   - Varför absorberar växthusgaserna främst energi från jordens strålning och inte solens strålning? (Du behöver ej förstå i detalj, bara känna till anledningen).

5. Läs kapitel 1.2 "The climate system" (s. 4-7) i PDF-filen Stocker. Titta närmre på figur 1.1 och figur 1.2, som visas i miniatyrer nedan.

- Vilka 6 komponenter utgör klimatsystemet?
- I punkt 3 utforskade vi en väldigt förenklad klimatmodell, men i texten beskrivs att en bra klimatmodell tar hänsyn till klimatkomponenternas "couplings". Vad innebär "coupling" och varför är det så viktigt att känna till komponenternas respektive tids- och rumskalor?
- Vad betyder det egentligen att 0.9 W/m² absorberas?
- Notera uttrycket 'atmosfäriskt fönster'. "Fönster" används som beskrivning för att strålning med viss våglängd ej abсорberas av växthusgaser, utan fritt går genom atmosfären.

III. Återkopplingsmekanismer (‘feedbacks’)

6. Varför liknas Arktis vid en kanariefågel i en gruva?
   - Vad karakteriseras en positiv respektive negativ återkopplingsmekanism?
   - Kan du ge exempel på två återkopplingsmekanismer i klimatsystemet?
     - Fuskhälp 3: Läs Box 2-2 "Albedo-temperature feedback" (s.8) samt Box 2-4 "Water Vapour feedback" (s.14) i PDF-filen Ruddiman.

IV. Förändringar inom klimatsystemet

7. Världens mest "creddiga" klimatrapport. Kolla på några grafer och läs igenom några av textutorna i PDF-filen IPCC's sammanfattning för beslutsfattare.
   - Vad tycker du om språket och sannolikhets-termerna (t.ex. "praktiskt taget säkert" som betyder 99 %-100 % sannolikhet)?
8. **Dags för ett Quiz!**
   - Vad orsakar havsnivåhöjningen? Vad är skillnaden mellan småttande havsisc och is på land?

9. **Navigera dig på NASA:s sammanställning** av förändringar som sker inom klimatsystemet. Genom att klicka på ”Expand” under följande huvudrubriker kan du lära dig mer om förändringarna via quiz, texter och videos.
   - Havsnivåhöjning
   - Global temperaturökning
   - Uppvärmdning av världshavet
   - Krympande isutbredning
   - Minskning av den arktiska havsiscen
   - Smältande glaciarer
   - Mer extrema väderevent
   - Havsförservering
   - Minskning av snötäcket.

**Vidare allmänbildning**

★ **WWF:s sammanställning** av hur klimatförändringarna påverkar några djurarter (gäller på några av de arterna: orangutang, elefant, havsskölpadda och ...humla).
★ Pampig presentation av de **möjligheter** som öppnas när Arktis is smälter.
★ Professor **Johan Rockströms sommarrapport 2015**.
★ Ett känt tal med frågan: "If not us, then who? If not now, then when?" från Filipinernas förhandlare under klimatkonferensen i Doha 2012.
★ Bra **guide** kring klimatkommunikation
Appendix II [Quiz Questions for the Warm-up Activity in Socrative]

Question 1:

Här har mer än 90 % av den ackumulerade energin från den globala uppvärmningen sen 1970-talet lagrats.

A: i hydrosfären
B: i atmosfären
C: i antroposfären

Correct Answer:
i hydrosfären

Explanation:
Question 2:

Exemplet: "Jag sover dåligt en natt --> dricker kaffe --> sover sämre nästa natt"

A  beskriver en POSITIV återkopplingsmekanism (feedback mechanism)

B  beskriver en NEGATIV återkopplingsmekanism (feedback mechanism)

Correct!

Question:
Exemplet: "Jag sover dåligt en natt --> dricker kaffe --> sover sämre nästa natt"

Correct Answer:
beskriver en POSITIV återkopplingsmekanism (feedback mechanism)

Explanation:
- Positiva återkopplingsmekanismer ökar magnituden av en förändring i samma riktning som den ursprungliga förändringen.
- Negativa återkopplingsmekanismer stabiliserar ett system genom att motverka ursprunglig förändring.
Appendix III [Game Rules to the Climate Game “Clime-Out”]

CLIME-OUT

Spelet i korthet
Lagen tävlar om att lyckas fånga flest gigaton koldioxid [GtCO₂] från atmosfären, genom att förklara klimatvetenskap under utmanande omständigheter. Det finns tre spelmoment genom vilka GtCO₂ kan vinna:

2. "Forskaren förklarar": Ditt lag ska förklara klimatvetenskap på ett korrekt och pedagogiskt vis, de andra lagen grillar dig med frågor.
3. "Duell": Tävling i vem som kommer ihåg mest från förberedelsematerialet.

Vem vinner?
Vinner gör det lag som lagrat flest GtCO₂ i sin ask när tiden är ute! (Seminarieledaren har en timer och kommer att annonsera när tiden är ute).

Dela i spelet
1 spelplan, "Forskaren förklarar"-kort, Duell-kort, ordpolletter, 1 tygpaše till ordpolletterna, 1 tämlas (30 sekunder), 1 täning, 3 spelpjäser, 3 askar för 'carbon capture and storage', 1 glasburk med GtCO₂ (a.k.a. bönor).

Antal spelare
6 spelare i lag om två.

Innan spelet börjar
1. Delta in gruppen i tre lag. År ni fler än 6 spelare får ni vara 3 personer i något lag.
2. Varje lag väljer en spelpjäs.
3. De 3 spelpjäserna placeras ut med jämst mellanrum på de svarta rutorna.
4. Laget med den yngsta lagmedlemmen börjar.

Så här spelar ni
• Kasta täningen och flytta spelpjäsen medurs runt jordgloben. Tre saker kan hända; du kan landa på en tom svart ruta [Med andra ord], en tom rosa ruta [Forskaren förklarar] eller landa på samma ruta som ett motståndslag [Duell].
• Turen går vidare medurs.
Med andra ord [när ni landat på tom svart ruta]
Ditt lag försöker vinna så många ordpolletter som möjligt under 1,5 minuter. Då ni samlat ihop till 5 ordpolletter kan ni växla in dem mot en GtCO₂.
1. Sätt igång en mobiltimer på 1,5 minuter eller utse en ansvarig för att vända 30 sekunders-timglaset.
2. En spelare börjar genom att dra en ordpollett från tygpansen och förklarar ordet som står på polletten – utan att säga hela eller delar av ordet.
   - Spelaren får ej använda ord som står på polletten, t.ex. ge ledträdets "en molekyl som innehåller syre och två kol".
   - Om spelaren verkligen inte vet ordets mening läggs polletten åt sidan. Detta får max. ske 2 gånger per tillfälle.
   - Förkortningar accepteras endast om det fullständiga uttrycket ej finns skrivet på polletten.
   - Håller till ämnet! Försök att beskriva vad ordet faktiskt betyder snarare än genom att ta genvägar med andra associationer.
   - Inom tidsbegränsningen får ni gissa och ge många ledträdar tills rätt ord gissats.
   - En och samma lagmedlem fortsätter att ta upp och förklara ordpolletter tills tiden går ut.
3. När laget samlat ihop 5 ordpolletter växlas dessa in mot en GtCO₂ som tryggt kan förvaras i er ask.
   - Om laget ej får ihop till 5 polletter under de 60 sekunderna förvarar de polletterna på bordet framför sig tills fler är vunnna.

Forskaren förklarar [när ni landat på tom rosa ruta]
Ditt lag besvarar frågan på ett "Forskaren förklarar"- kort tills motståndarlaget "de nyfikna" (till vänster) förstå och "granskarna" (till höger) är nöjda med kvaliteten på din förklaring.

Vi ställer frågor för att förstå!
De nyfikna
Vi håller koll på tid och faktakvalitet
Vi förklarar vetenskap på ett begripligt vis
Forskarna
Granskarna

2. En granskare sätter igång timern/vänder timglastet och ansvarar för att ge uppgiften 2 x 1,5 minuter.

3. Forskare 1 får en 1,5 minuters chans att förklara frågan utan förberedelse. Under tiden läser forskare 2 in sig på ledtrådar som finns skrivna i punktform inuti "forskarförlagring"-kortet – allt för att vara förberedd för att efteråt få 1,5 minuters "time to shine" för att fördjupa förklaringen.
   - "De nyfikna" ställer frågor till forskaren för att förstå ordentligt / se till att forskaren förklarar på ett pedagogiskt vis.
   - "Gransknarna" får ställa frågor om forskarens förklaring inte är tydlig eller korrekt. Gransknarna får även vika upp sina kort för ledtrådar, samt använda sina anteckningar och internet för att se till att förklaringarna verkar korrekt.

4. När 2 x 1,5 minuter har gått avgör "de nyfikna" tillsammans med "gransknarna" om forskarna gjort sig förtjänst av en GtCO₂. Beslutet grundas på om faktan var: korrekt, tydligt förklarad och på en tillräckligt avancerad nivå för en högskoleutbildning. Var noga med att motivera era beslut!

---

Duell [när ni landat på samma ruta som ett motståndarlag]

Då två lag hamnar på samma ruta utlyses en duell om vem som minst mest från förberedelserna! Det tredje laget kommer att grilla er på fakta från förberedelsematerialen, genom att ställa detaljfrågor tills endast ett av lagen kan frågan. Det lag som vinner får stjälka det andra lagets ordpolletter som ännu ej växlat in till GtCO₂.
   - Frågor från ett duell-kort läses högt. De tävlade lagen skriver ner sitt svar på en lapp och svaret gävs igenom kontinuerligt.
   - Om båda lagen klarar av alla frågor avgörs duellen med "sten, sax, päse".

---

Om CLIME-OUT

Spelet utvecklades i februari 2015 för kursen Earth’s Climate System and Climate Change på University of Graz i Österrike. Påhittat och utvecklat av KTH-student Sara Trulsson med inspiration från ALFs brädspel "Med andra ord", ovan nämnda kurs med klimatprofessor Gottfried Kirchengast och Jon-Erik Dahlins arbete med att använda spel i undervisning. Utvegalet av grafer och ekvationer är anpassade till att passa klimatmodulen, fackligt "Forskarförlagring"-korten är kopierade från IPCC:s publiceringar.

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Tack till Gottfried Kirchengast, som genom var positiv till idén kring ett interaktivt seminarium. Tack till min systers och farfars för hjälp att tillverka spelutrustning och till mina föräldrar, vänner och studenter för förbättringsförslag till reglerna.

Jag tar tacksamt emot fler idéer till förbättring och utveckling av klimatmodulen, så tveka inte att prata med mig om kommentarer och idéer, eller skicka mig ett mejl: saratr@kth.se
Appendix IV [Student Mind-sets]

The method used to cluster the answers from the 52 CL-students into various “mind-sets” were based on five statements on Likert-scales from 1-4, so that students were forced to choose if they rather agreed or disagreed to the statements. The statements were adapted from Temporal Motivation Theory to suit the context of climate and serve as a basis for the analysis of student attitudes. The assertions were formulated so that some of them were calling on affirmative and others disagreeing answers in order to discourage result influence. The five statements were formulated as follows:

1. Vision – “Jag tror att människan kommer lyckas hantera klimatförändringarna på ett bra sätt”
2. Will – “Jag vill (på ett eller annat sätt) jobba med klimatfrågor.”
3. Reliance – “Jag tror inte att jag skulle kunna bidra till en nämnvärd positiv förändring genom att jobba med klimatfrågor.”
4. Delay – “Även om jag jobbar med klimatfrågor när jag är färdigutbildad, tror jag att en positiv förändring först skulle märkas av långt i framtiden.”
5. Patience to delay – “Jag vill jobba med något där man omedelbart kan se ett resultat av det jag gör.”

To aid the analysis a colour-code was developed with red and green cells, respectively. The “custom sort”-function in Excel enabled a convenient sorting and clustering of the students.

Quotes from the interviews and open questions in the surveys were inspirational for the “attitude quote” for the main- and subgroups in the mind-sets, as seen in Appendix IV.

Table 5 Clustering of Student Mind-sets (52 students from the CL-group)

<table>
<thead>
<tr>
<th>Vision</th>
<th>Will</th>
<th>Reliance</th>
<th>Delay</th>
<th>Patience to Delay</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>4</td>
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</table>

"No use even in trying, what could I do anyway?"

<table>
<thead>
<tr>
<th>Vision</th>
<th>Will</th>
<th>Reliance</th>
<th>Delay</th>
<th>Patience to Delay</th>
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<tbody>
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"Won't work, I don't want to try"

"I could probably do a small change, but I'm not interested and it won't work anyway."
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</table>

"I want to tell my grandchildren that I tried, but I won't be able to change"

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</tr>
</tbody>
</table>

"Won't work well, but we have to try"

<p>| | | | | |</p>
<table>
<thead>
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</table>

"We (and I) can make it less bad!"

<p>| | | | | |</p>
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"Humanity will manage it, I could have been part of it but I have other plans"

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</table>

"We'll make it eventually, let's begin!"

<p>| | | | | |</p>
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</table>

"We'll make it! It will work faster than we think so let's begin!"
Appendix V [Reasons for motivation and demotivation]

The responds in the table below concerns if the students feel motivated to (in one way or another) work with climate-related matters. Their motivation was graded on a 4 pointed Likert scale and they were asked to give a short reason to their given answer in an open follow-up question.

<table>
<thead>
<tr>
<th>Antal</th>
<th>&quot;Motiveringsgrad&quot; 1-2</th>
<th>&quot;Motiveringsgrad&quot; 3-4</th>
<th>Antal</th>
</tr>
</thead>
<tbody>
<tr>
<td>III</td>
<td>Vet ej</td>
<td>Viktig</td>
<td>VIII</td>
</tr>
<tr>
<td>II</td>
<td>Brinner ej för</td>
<td>Intressant</td>
<td>IIIII</td>
</tr>
<tr>
<td>II</td>
<td>Tyvärr inte intresserad av</td>
<td>Andra är för obrydda</td>
<td>II</td>
</tr>
<tr>
<td>I</td>
<td>Tråkigt</td>
<td>Gillar att läsa på om miljön</td>
<td>II</td>
</tr>
<tr>
<td>I</td>
<td>(men viktigt)</td>
<td>Påverkar alla</td>
<td>II</td>
</tr>
<tr>
<td>I</td>
<td>Redan andra planer</td>
<td>Alla har ett ansvar</td>
<td>I</td>
</tr>
<tr>
<td>I</td>
<td>Viktigt att alltid tänka på klimat</td>
<td>Allvarligt</td>
<td>I</td>
</tr>
<tr>
<td>I</td>
<td>För svårt att göra intryck på folk</td>
<td>Måste stoppa innan positiva feedbackmekanismer sker</td>
<td>I</td>
</tr>
<tr>
<td>I</td>
<td>(men nu har jag blivit mer medveten i mitt tänkande)</td>
<td>Roligt med energiforskning</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Aktuellt ämne</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gott &amp; självklart syfte</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ofräknligt</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Roligt att påverka til positiv utveckling</td>
<td>I</td>
</tr>
</tbody>
</table>
Appendix VI [Information about the Interviewees]

The Questionnaire below was filled in by the 5 interviewees individually before the interview, for
the interviewer to get to know a bit more about the students and take stance from the answers.
Answers are displayed in brackets after the question.

<table>
<thead>
<tr>
<th>Question</th>
<th>Answers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ålder:</td>
<td>[19, 20, 20, 21, 23]</td>
</tr>
<tr>
<td>Vilken stad är du uppvuxen i?</td>
<td>Tumba, Stockholm x 3, Mellbystrand</td>
</tr>
<tr>
<td>Hur ofta spelar du spel?</td>
<td>Varje vecka [3*], Varje månad [1], Ett par ggr/år [1], Nästan aldrig</td>
</tr>
<tr>
<td>Hur lång tid lade du på seminarie-förberedelserna?</td>
<td>&lt;30 min [1], 30-60 min [3], 60-90 min [1], &gt;90 min</td>
</tr>
<tr>
<td>Hur ofta spelar du?</td>
<td>o Varje vecka [3*]</td>
</tr>
<tr>
<td>Vilken tid lade du på seminarieförberedelserna?</td>
<td>o &lt;30 min [1]</td>
</tr>
<tr>
<td>Hur ofta tittar du på onlineföreläsningar (t.ex. Khan academy, TEDtalks)?</td>
<td>Varje dag, Varje vecka [3], Varje månad [2], Nästan aldrig</td>
</tr>
<tr>
<td>Hur brukar du lära dig på bästa sätt?**</td>
<td>o Genom att läsa själv[1], Lyssna på föreläsningar [2], Plugga i grupp [1]</td>
</tr>
<tr>
<td>Vilken av beskrivningarna tycker du passar bäst in på dig?***</td>
<td>o “Extrovert” [3], “Introvert” [2], Ingen av dem [1]</td>
</tr>
<tr>
<td>Hur ofta hör du något som rör klimatförändringarna?</td>
<td>o Varje dag, Varje vecka [3], Varje månad [2], Nästan aldrig</td>
</tr>
<tr>
<td>1 student: “5 dagar/veckan”, 1 student “3-4 dagar i veckan”</td>
<td></td>
</tr>
<tr>
<td>** 1 student kryssade i alla tre val.</td>
<td></td>
</tr>
<tr>
<td>*** 1 student beskrev sig som både extrovert och introvert</td>
<td></td>
</tr>
</tbody>
</table>
Appendix VII [Emotions when Hearing about Climate Change]

The Table below shows all answers from the group Titeh, when they were asked to describe emotions connected with receiving information about climate change in the media as well as in the climate module, as part of this study.

<table>
<thead>
<tr>
<th>Starkare känslor nu</th>
<th>Är själv skeptiskt till vad media säger. En svår fråga som måste lösas.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Det här var mer personligt och intressant!</td>
</tr>
<tr>
<td></td>
<td>Mycket i media är väldigt ytligt och dumt för det får folk att tro på halva sanningen</td>
</tr>
<tr>
<td></td>
<td>Samma, en känsla av att det spelar inte roll vad jag som privatperson gör i slutändan</td>
</tr>
<tr>
<td></td>
<td>Det känns alltid jobbigt att inte fler kan ta till sig och att det är svårt själv också</td>
</tr>
<tr>
<td></td>
<td>Man, omedvetet eller ej, försöker ignora det (pga psykologin sedan tidigare)</td>
</tr>
<tr>
<td></td>
<td>Önskade att man brydde sig lite mer.</td>
</tr>
<tr>
<td></td>
<td>Var mer engagerad under den här ovningen. Tack</td>
</tr>
<tr>
<td></td>
<td>Mer specifikt och insiktsfullt i denna klimatmodul. Till vardags tänker jag på det ofta, men mer övergripande.</td>
</tr>
<tr>
<td></td>
<td>Mina känslor är starkare när jag träffar på begreppet i media. här idag var det tråkigt.</td>
</tr>
<tr>
<td></td>
<td>Dem är nog snarlika. Kanske att denna övnning gav ett positivare intryck än vad nyheterna brukar ge.</td>
</tr>
<tr>
<td></td>
<td>På TV är det lätt att man sällar bort informationen. &quot;Det berör inte mig&quot;. Under en sån här föreläsning blir det mer personligt och man engagerar sig undermedvetet mer.</td>
</tr>
<tr>
<td></td>
<td>Jag tycker att det är enviktig fråga och jag försöker tänka på detta genom att äta mindre kött och källsortera.</td>
</tr>
<tr>
<td></td>
<td>Känslorna är lika vid båda. Jag tror inte vi kan göra så västligt mycket för att förbättra läget, jag tror rent av att vi är ***ed vet inte</td>
</tr>
<tr>
<td></td>
<td>Det är intressant för mig alltid. Det är bra att man kan hitta enkla informationer om det lika jobbiga. frsmtiden känns jobbig tack vare alla hemskheter i världen</td>
</tr>
<tr>
<td></td>
<td>Jag blir mestadels irrerad på att vi inte tar miljöfrågorna på större allvar bara för att det inte säkert kommer att drabba oss märkbart, under tiden som vi lever här på jorden.</td>
</tr>
<tr>
<td></td>
<td>Jag har kanske inte haft så stort intresse, inte varit så insatt.</td>
</tr>
<tr>
<td></td>
<td>fick mer information nu och förstår det mycket bättre</td>
</tr>
<tr>
<td></td>
<td>Jag brukar inte lägga någon vikt vid denna typ av fråga så jag är relativt likgiltig till båda typerna.</td>
</tr>
<tr>
<td></td>
<td>Idag har jag haft en tävlande inställning. Det brukar oftast bara vara ett langt konstaterande när man pratar om klimat, eller om man pratar om nagan ny handelse som har hant till följd av detta.</td>
</tr>
<tr>
<td></td>
<td>Känns mer &quot;hopplöst&quot; i media, vilket gör att man ignorerar problemet ännu mer.</td>
</tr>
<tr>
<td></td>
<td>Känslorna har var blivit mer påtagliga, intresset har ökat.</td>
</tr>
</tbody>
</table>
Appendix VIII [Example on Mind Maps, Graz]

The mind maps below serve as an example of the Graz-students’ mind maps before, as well as after the seminars.
### Appendix IX [Studying Together with Classmates]

The responds in the table below concerns if the students normally study together with classmates and if they liked that KTH arranged an occasion for students to study together. The level of agreement was shown on a Likert scale from 1-4, n=30, group Titeh.

<table>
<thead>
<tr>
<th>Studerar du vanligtvis ihop med dina kurskamrater?</th>
<th>Tyckte du om att KTH ordnade ett tillfälle för er studenter att plugga tillsammans?</th>
<th>Kommentarer:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>ämnet var intressant, man kan snvända metoden för andra ämne också</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>trevligt</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>Bra med multimediaförberedelser och spel för att fånga upp och repetera den kunskap man lärt sig. Bra arbete som lyfter den viktiga klimatfrågan. Detta har ökat intresset för klimatfrågan!</td>
</tr>
<tr>
<td>1</td>
<td>4</td>
<td>Jättebra, men jag själv är inte intresserad</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>skulle nog föredra ett vanligt lektionstilfälle för att man går igenom alla viktiga begrepp osv innan en lektion där man spelar. dock var det kul att göra något annat för en gångs skull</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>väldigt bra lektion</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>Det var roligt att få göra något annorlunda och inte bara ha en vanlig föreläsning och jag har nu fått en lite bättre koll på klimatförändringarna i vården :)</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>&quot;applåder&quot;*</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>Save earth pls</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>Inom spelet vi spelade så tycker jag det borde funnits ett start och ett mål.</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>Lektionen var ett bra sätt att lära känna nya personer i klassen och för att få en aningen bättre bild över klimatförändringarna.</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>....</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>Bra tillfälle att diskutera tillsammans på ett roligt men lärorikt sätt</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>..</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>det var kul att man fick öära känna nya kamrater. men spelet var trålig.</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>det var trevligt</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>Bra upplägg, bra spel även igall det tog lite tid att förstå</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>Kul övning!</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>Roligt sätt att lära sig nya saker på. Och en skönt temploväxling från vanliga föreläsningar</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>Det var väldigt kul med de här korten man skulle beskriva! Gillar att det var en tävling!</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>inget speciellt</td>
</tr>
</tbody>
</table>

XX
<table>
<thead>
<tr>
<th>Rating</th>
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<th>3</th>
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<tbody>
<tr>
<td>Comment</td>
<td>tycker det var en aning för mycket fakta för att ta in på en dag, annars ett roligt upplägg.</td>
<td></td>
</tr>
<tr>
<td>Rating</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Comment</td>
<td>Kreativt lärande genom annorlunda föreläsningsmetodik.</td>
<td></td>
</tr>
<tr>
<td>Rating</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Comment</td>
<td>Trevligt och interaktivt sätt att lära sig om ett ämne som kan vara ganska svårt och &quot;tråkigt&quot;. Jag kände mig mer motiverad att förbereda mig inför detta än en vanlig föreläsning.</td>
<td></td>
</tr>
<tr>
<td>Rating</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Comment</td>
<td>Det var annorlunda men väldigt roligt.</td>
<td></td>
</tr>
<tr>
<td>Rating</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Comment</td>
<td>Det var bra! Jag skulle vilja kalla mig själv en vinnarskalle, sa när det blir tavling sa forser man lite extra.</td>
<td></td>
</tr>
<tr>
<td>Rating</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Comment</td>
<td>Trevligt roligt upplägg, annorlunda mot traditionell undervisning ja. Men mycket var svårt</td>
<td></td>
</tr>
</tbody>
</table>
Appendix X [Surveys]

Example on a pre-survey from Group Graz (note that that 1 is the confirmative option in Austrian surveys, hence this survey was written in the local way):

Make a circle around the number that expresses your answer on the scale.

1. How confident are you to explain climate change?

   1  2  3  4  5

   Very confident  not confident at all

2. How well do you understand the content of the course Earths climate system and climate change?

   1  2  3  4  5

   Very well  not well at all

3. What are your expectations from this seminar?

   - to get more confident in explaining things about climate change
   - to get to know other participants
   - get more confident about knowledge
   - learn more (also from other students)
Example on a post-survey from **Group Graz** (note that that 1 is the confirmative option in Austrian surveys, hence this survey was written in the local way):

1. How confident are you to explain climate change?

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very confident</td>
<td>not confident at all</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. How well do you understand the content of the course *Earth’s climate system and climate change*?

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very well</td>
<td>not well at all</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. Did the seminar part fulfill your expectations?

   | Yes |
   | No |

Comments: I really learned a lot! It was great to discuss with people from other background studies!
Pre-survey from Group CL:

**Inför klimatmodul, MJ1530**

Hur bekväm/själväsäker är du med att förklara klimatförändringarna?

<table>
<thead>
<tr>
<th>inte alls bekväm/själväsäker</th>
<th>mycket bekväm/själväsäker</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

Hur väl förstår du klimatförändringarna?

<table>
<thead>
<tr>
<th>inte alls</th>
<th>mycket väl</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

Känner du dig motiverad till att jobba med klimatbegränsning / klimatanpassning?

*Your answer*

Tycker du om idén om att ha kursmaterialet tillgängligt som online-föreläsningar, och att studenterna endast deltar i interaktiva seminarium (istället för traditionella föreläsningar)?

*Your answer*

Eventuella kommentarer:

*Your answer*

Skriv 5 ord som du förknippar med "klimatförändringar".

*Your answer*
Post-survey from **Group CL:**

### Klimatmodul i MJ1530

**Hur bekväm/självständig är du med att förklara klimatförändringarna?**

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>inte alls bekväm/självständig</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>

**Hur väl förstår du klimatförändringarna?**

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>inte alls</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>

**Skriv 5 ord som du förknippar med "klimatförändringar".**

```

```

**Jag tror att människan kommer lyckas hantera klimatförändringarna på ett bra sätt.**

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Håller inte alls med</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>

**Jag vill (på ett eller annat sätt) jobba med klimatfrågor.**

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Håller inte alls med</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>

XXV
Jag tror inte att jag skulle kunna bidra till en nämnvärd positiv förändring genom att jobba med klimatfrågor.

1 2 3 4

Håller inte alls med  o  o  o  o  Håller absolut med

Även om jag jobbar med klimatfrågor när jag är färdigutbildad, tror jag att en positiv förändring först skulle märkas av långt i framtiden.

1 2 3 4

Håller inte alls med  o  o  o  o  Håller absolut med

Jag vill jobba med något där man omedelbart kan se ett resultat av det jag gör.

1 2 3 4

Håller inte alls med  o  o  o  o  Håller absolut med

Efter klimatmodulen är jag mer motiverad att jobba med klimatfrågor.

1 2 3 4

Håller inte alls med  o  o  o  o  Håller absolut med

Klimatmodulen ökade mitt intresse för klimatbegränsning / klimatanpassning.

1 2 3 4

Håller inte alls med  o  o  o  o  Håller absolut med
Jag tycker klimatfrågan känns övermäktig och tung och vill därför inte fördjupa mig mer inom ämnet.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Håller inte alls med</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

Jag tyckte det var ansträngande att delta i det interaktiva seminariumet.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Håller inte alls med</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

Jag tyckte det var givande att delta i det interaktiva seminariumet.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Håller inte alls med</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

Jag brukar lära mig mer genom traditionell undervisning än genom det här kursupplägget.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Håller inte alls med</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

Jag tycker om idén om att ha kursmaterialet tillgängligt som online-föreläsningar istället för traditionella föreläsningar.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Håller inte alls med</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>
Jag föredrar att läsa i kursbok/kompendium, framför PDF:er.

1 2 3 4

Håller inte alls med ○ ○ ○ ○ Håller absolut med

Jag kommer bättre ihåg saker som jag diskuterat med andra.

1 2 3 4

Håller inte alls med ○ ○ ○ ○ Håller absolut med

Vilken del i klimatmodulen tyckte du bäst om?
(svara gärna med en kort förklaring varför)

Vilken del av klimatmodulen behöver förbättras?
(svara gärna med ett kort förbättringsförslag)

Eventuella kommentarer:
Pre-survey from **Group Titeh:**

<table>
<thead>
<tr>
<th><strong>Hur väl förstår du klimatförändringarna?</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A</strong> 1 (inte alls)</td>
</tr>
<tr>
<td><strong>B</strong> 2</td>
</tr>
<tr>
<td><strong>C</strong> 3</td>
</tr>
<tr>
<td><strong>D</strong> 4</td>
</tr>
<tr>
<td><strong>E</strong> 5 (mycket väl)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Hur bekväm/självsäker är du med att förklara klimatförändringarna?</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A</strong> 1 (inte alls bekväm/självsäker)</td>
</tr>
<tr>
<td><strong>B</strong> 2</td>
</tr>
<tr>
<td><strong>C</strong> 3</td>
</tr>
<tr>
<td><strong>D</strong> 4</td>
</tr>
<tr>
<td><strong>E</strong> 5 (mycket bekväm/självsäker)</td>
</tr>
</tbody>
</table>
Post-survey from **Group Titeh:**

**Utvärdering - klimatmodul**

*Form description*

**Hur bekväm/självsäker är du med att förklara klimatförändringarna?**

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>inte alls bekväm/självsäker</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

**Hur väl förstår du**

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>inte alls</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

**Håller du med påståendet: "Jag brukar lära mig mer genom traditionell undervisning än genom det här kursupplägget". (Att förbereda via multimedia och göra något aktivt under seminariumet).**

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Håller inte alls med</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

**Studerar du vanligen ihop med dina**

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Väldigt sällan</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>
Tyckte du om att KTH ordnade ett tillfälle för er studenter att plugga tillsammans?

Tyckte inte alls om det

Tyckte mycket om det

Kommentarer

Short-answer text

Vad ledde diskussioner med dina kurskamrater

Short-answer text

Anser du att spelet hjälpte dig att förstå vetenskapen bakom klimatsystemet bättre?

Hjälpte inte alls

Hjälpte mycket

Vilken är huvudanledningen till ditt

Short-answer text

Känner du dig motiverad att (på ett eller annat sätt) jobba med klimatrelaterade frågor?

Inte alls

Vidligt

Vilken är huvudanledningen till ditt

Short-answer text
Kan du kort jämföra de känslor du brukar ha när det talas om klimatförändringar i media med de känslor du haft under den här klimatmodulen. Är känslorna lika vid båda tillfällena får du gärna beskriva dem kort.

---

Long-answer text

---
Appendix XI [Mind Map Reflections]

Below 3 examples on student reflections on their mind maps are given. Key words were marked and clustered into categories and sorted by most frequently mentioned areas. Figure 3 shows a simplified table of the analysis process, in which highlighted student quotes were sorted and categories were selected, based on the most frequently mentioned mind map reflections.

Example 1
My first mind map dealt only with modelling methods and also my second mind map had its main point on modelling but in a slightly different way. The second mind map dealt more with the themes that have to be modelled such as clouds, or seas, where the first mind map only or nearly only was about mathematical ways to solve the problems in climate modelling. One other main point in the second mind map is that I mentioned the EBE (energy balance equation), which is in my point of view the most important idea or equation to understand climate changes. For me the modelling aspect of climate-studies and climate change is the most interesting thing, so it is easy to understand, that my mind maps are focused on this topic. In retrospective I also should have mentioned CO₂ IPCC and trace gases as other important headlines for climate-change but at the two days I did not think about these thinks so much because I was interested in how to compute and to model such a complex system as climate. If we handle the modelling of climate I think we would also understand what and how different cycles are working. Even after ten years IPCC we are quite unsure about some aspects and how they work exactly, a good example for this is how the cloud do their part. In the cloud feedback or aerosols lies as the IPCC protocol shows a very high uncertainty, they could have a small warming effect or up to the strongest cool-down effect. It has much happened in the last years in the field of modelling but in my point of view there will soon be a increase of knowledge that will go hand in hand with an increase in the computing power. So maybe it will be possible in an other ten years to get a global resolution even below 1km, so that we can study the exact impact of a global warming. If I would do the mind-map again it would look different but at these two day my thoughts travelled around the mathematics.

Example 2
My knowledge about climate change coming into this seminar was very surface-level. I knew about greenhouse gases and their warming effect, of course, but I did not really know how the system worked on a physical level. Now I know many details about how the sun emits short-wave radiation to the earth, which the earth absorbs and reflects as long-wave radiation. It is this radiation that is then trapped by the greenhouse gases (the most potent being carbon dioxide for its enormous lifespan, and methane for its high potency). A certain degree of this
trapping is good, because otherwise our planet would be quite cold, but too much of it creates this blanketing, warming effect. Although the temperature has only risen one degree Celsius, this still has quite an impact on the cryosphere, especially the polar ice caps, which melt more and more because of this heat and rising ocean temperatures. This in turn creates a positive feedback loop, because the melting of this ice because of heat leaves dark spots in the ocean, reducing the earth’s albedo, which then causes more radiation absorption, which then heats the earth’s oceans and atmosphere, and so on in such a cycle. Unless we have substantial and sustained reductions in carbon emissions, we will not achieve a significant reduction of emissions. Based on many examples just like this one, I can rate my associations of and knowledge about climate change to be much, much higher than before the course. When I started the seminar, my thoughts were scattered and knowledge superficial. Afterwards, however, I gained a deeper understanding and a clear picture as to what primarily causes climate change, as well as its largest direct and indirect impacts. Thanks for a great course!

**Example 3**

After looking at my mind-maps and comparing the one before the course and the one after the course I would say that my overall knowledge hasn't change this much, but I wrote down deeper and more accurate information about some fields. For example, at first I only wrote about greenhouse gases as one big topic, but at the second one, I was thinking about a categorization of all this gases and wrote down specific information about the different kinds of traces gases. The biggest mistake I made at the first mind-map was that I forgot to mention H2O, which is, as we all know, the most important greenhouse gas. In the first mind-map I was more influenced by other lectures I attended before like climate history and Paleoceanography and the documentary “Years of Living Dangerously”. At the second mind-map I was more thinking about the different spheres and the interaction between these spheres or the energy transport to these spheres which were more mention in this lecture and course. I would also say that part of the second mind-map bubbles were influenced by the last “The scientist explains” cards we discussed before in my group. At last I have to say that on both mind maps I would have needed more time to write down everything I know, and sometimes I was longer thinking about the right English explanation for a word than for the topic itself. All in all I enjoyed the course very much. It was a nice opportunity to meet new people which were interested in the same topics as I, talk to them and sometimes find a different way to look at things. Climate is a system with so many parameters and feedbacks and it influences so many things in our world that people would never think about. I hope that the other students learned as much as I did form the lecture and the course and I hope there will be more events like this in the future.
Appendix XII [Interview Guide]

Välkomna

1. Tack
2. Presentation av mig själv
   ○

Praktisk info

3. Syfte med fokusgruppen är att komma fram till förbättringsförslag för klimatmodulen / “mini-kursen”.
   - Online-förberedelserna
   - De interaktiva seminarierna
     i. Kunskapshöjning
     ii. Läroprocess
     iii. Motivation

5. Jag vill att ni pratar och kommer att be om era åsikter om ni inte sagt något på ett tag.
6. Ni kommer vara anonyma i största möjliga mån. (Examinator etc.)
7. Jag kommer använda datan till mitt masterarbete som ni kommer få tillgång till om ni vill.
8. Jag spelar in och transkriberar, kommer att använda andra arbetsnamn.
10. Demografi m.m. (siffror 1,2,3,...)
11. Skriva namnspel.

”Experience criteria”

1. Bästa kurs ni någonsin tagit. [skriv ned]
   ○
2. Varför var den så bra? Vilka kriterier? [Skriv ned]
   ○
3. Baserat på dessa kriterier, vad tyckte ni om den här ”mini-klimat-kursen”?
   ○

Attityd och erfarenhet klimatförändringar

4. När var första gången ni verkligen förstod att klimatet förändras?
   - Varför tror du det var just då?
   ○
5. Finns det någon person som särskilt påverkat er attityd till klimatförändringarna?
   - Vad gjorde personen?
   ○
6. Skiljde sig informationen kring klimatförändringar under klimatmodulen från hur ni är vana att höra om klimatförändringar?
   - Känslor till respektive?
   ○
Instuderingsinstruktionen
7. Vad tänkte ni när ni fick mejlet med instuderingsinstruktionerna?
   • Hur många gjorde hela förberedelsen?
     i. Hur kan man göra för att alla ska göra det? Prov i början av seminariet?
   • Hur många gjorde något av extramaterialet?
     i. Hur locka till att vilja lära mer? Det finns yttre och inre:
        1. I undersökning med studenter som fått jobb efter KTH-utbildning
           sägs att mer kunskap om HU efterfrågas från arbetsgivarna.
        2. Tro på att kunna bidra till positiv förändring?
   • Bra eller ej med cirka tidsåtgång i PDF:en?
   • Tydlig nog, mer specifikt än “utforska”...
   • Övrigt om upplägget?

Innehållet: videos, texter
• Vilken video var bra / dålig?
  i. Vad gjorde att ni tyckte om de videos ni tyckte om?
  ii. Resultaten från enkäten visar på positiva tankar kring att ha föreläsningar
   online. Varför tror ni att era klasskompisar är så positiva till det?
• Cirka hälften föredrar att läsa i kursbok/kompendium framför olika PDF:er.
  i. Er upplevelse av att klicka er fram m.h.a. länkar?
• Lagom utmanande?

Seminariet
1. Hur upplevde ni seminariet?
   • Fyllde läxorna någon funktion?
   • Vad är era tankar kring uppvärmningsdiskussionen?
   • Spelet
     i. Förbättras: svenskt språk, tydlig förklaring, mer guidning till de rosa
        rutorna. Vad mer?

2. Både hur bekväm man känner sig att prata om klimat och hur bra man förstår ökade
   enligt enkäten. Kände ni skillnad efter att ha deltagit?
   • Mer motiverade att jobba med klimatfrågor ca 50-50.

Avsluta
3. Finns det något ni vill tillägga hur ...
   • ni upplevde den här klimatmodulen?
   • den skulle kunna förbättras?

Berätta lite grand hur du upplevde ...
Kan du berätta mer om...
Förstår jag det rätt om...
Kan du ge ett exempel...

SAMMANFATTA OCH FÅ BEKRÄFTAT UNDER INTERVJUNS GÅNG!