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Sustainability Aspects in ICT Engineering Thesis Works

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Abstract

An evaluation of thesis reports performed by students from the degree programme Computer Engineering, TIDAB, that was made by UKÄ, The Swedish Higher Education Authority, showed that there was a lack of consideration of environmental and sustainability aspects in the thesis reports, leading to many students not meeting the criteria in the degree objectives regarding this aspect. The purpose of this bachelor thesis is to improve students' ability in considering the important aspects of sustainability in their thesis works, by providing them with guidelines which they can follow and implement during their thesis work that will enable them to reach the level 'Very High Quality'.

A literature study was performed thoroughly in conjunction with reviewing previous thesis reports and conducting expert interviews as an approach to find a solution to the problem.

The outcome of the analysis was three methods that was developed, which the students can use as guidelines in their thesis work. A set of guidelines, a table with skill sets and the SEMAT Essence Kernel card for sustainable development was the resulting methods that will help the students to at minimum accomplish the criteria for 'High Quality' on the objective "Demonstrate an understanding of technology capabilities and limitations, its role in society and people's responsibility for its use, including social and economic aspects, environmental and safety aspects" when the methods are followed.

Keywords: sustainable development, sustainability, ICT, environment, UKÄ, thesis work, SEMAT Essence, software engineering

Abstract

En utvärdering av examensarbeten utförda av studenter från utbildningsprogrammet Datateknik, TIDAB, gjort av UKÄ, Universitetskanslersämbetet, visade att det fanns en brist på hänsynstagande till miljö- och hållbarhetsaspekter i rapporterna, vilket ledde till att flera studenter inte uppfyllde kriterierna i examensmålen gällande denna aspekt. Syftet med detta examensarbete är att förbättra elevernas förmåga att ta hänsyn till de viktiga aspekterna av hållbarhet i sina examensarbeten genom att ge dem riktlinjer som de kan följa och genomföra under sina examensarbeten, som gör det möjligt för dem att uppnå nivån 'Mycket Hög Kvalité'.

En litteraturstudie genomfördes noggrant i samband med genomgång av tidigare examensarbeten, och intervjuer med ledande experter gjordes, som en metod för att hitta en lösning på problemet.

Utfallet av den utförda analysen var tre metoder som har utvecklats, vilket studenterna kan använda som riktlinjer i sina examensarbeten. En uppsättning av riktlinjer, en tabell med kompetenser och SEMAT Essence Kernel kort för hållbar utveckling var de resulterande metoder, som ska hjälpa studenterna att åtminstone uppnå kriterierna för 'Hög Kvalité' på målet "Visa förståelse för tekniska möjligheter och begränsningar, dess roll i samhället och människors ansvar för dess användning, inklusive sociala och ekonomiska aspekter, miljö- och hållbarhetsaspekter" när metoderna följs.

Nyckelord: hållbar utveckling, hållbarhet, ICT, miljö, UKÄ, examensarbete, SEMAT Essence, mjukvaruutveckling

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1 Introduction

In this chapter the subject-matter 'Consideration of sustainability aspects in thesis work' is described. The background, purpose, goals, delimitations and overall methodologies are presented here.

1.1 Background

Bachelor thesis reports that are written today in the ICT area should be improved regarding consideration of environmental and sustainability aspects. A need of improvement in this area is required based on the criteria KTH (The Royal Institute of Technology) has for students in order for them to graduate with a degree on undergraduate level [1].

UKÄ, Universitetskanslersämbetet [2], is the Swedish Higher Education Authority, whose task is to evaluate all higher education. For each degree offered by universities and colleges, the Government has developed qualification descriptions which are nationally valid. UKÄ did a research on reports written by students in three undergraduate programs offered by The Royal Institute of Technology, to see if the degree objectives were met in the thesis reports performed by students on undergraduate level. One of the graduate programs that were evaluated was the graduate program in Computer engineering, TIDAB, at the ICT School in Kista. The evaluation showed that the objective for consideration of environmental and sustainability aspects in the reports could be improved.

1.2 Problem

The problem that arises when not considering environmental and sustainable development thoroughly in education is that when students enter the labour market, they will not consider it there either [3]. Production, transportation and use of ICT (Information and Communication Technology) products entail various environmental effects. Use of ICT products can provide indirect impact on the environment, including changes through consumption and transport patterns [4].

A broad part of the society's energy consumption or spreading of pollutants is not directly contributed by ICT. It is primarily the application of ICT products that enable the environmental load to either increase or decrease. The quantities of these products are growing rapidly and are integrated into more and more products. The ICT products play an increasingly important role seen from a life cycle perspective. The direct environmental and sustainability

issues become significant if not taking account of the energy and environmental impacts of ICT products and applications and sustainability [5].

The main ambition of this thesis work is to find solutions to how students at an undergraduate level can take environmental and sustainability aspects into consideration in their thesis works, comprising of both the outcome of the project, i.e. the system, the report, adapting an environmental and a sustainable approach in the project work itself, but also how the future engineers can adapt an environmental and sustainable way of working at their future workplaces.

Today, students usually approach the application of environmental and sustainability aspects in their degree work in two different ways. Some students tackle the problem after finishing writing the report, and this way of working is known as taking a *'reactive'* approach towards implementing environmental and sustainability aspects. However, other students take a *'proactive'* approach in both planning and applying these aspects into their thesis work right from the beginning. According to Anders Sjögren [3], Head of the Degree Programme in Computer Engineering at KTH, many students take a reactive approach regarding consideration of environmental and sustainability aspects because they are "forced to do so" meaning, it has to be included in their reports and therefore they do it at the end, resulting in a non proactive approach.

1.3 Purpose

The main purpose is to improve students' ability in considering environmental and sustainability aspects in their thesis works and reports. With the guidelines that will be developed in this report, students will be able to at least achieve what today is called 'approved quality' meaning 'High Quality', but the goal with the guidelines is however to enable students achieve 'Very High Quality'[1].

The aim is to improve students' way of working with and managing environmental and sustainability aspects in their thesis works. With this report, which will be the resulting product of the project, future bachelor

[1] There is no such thing as 'approved quality', in order to be 'approved' on the criterion for sustainability aspects, the students must achieve 'High quality'.

students will be given tools, such as guidelines and ideas for how they can take sustainability aspects into account in both their thesis work reports, but also how the future engineers can adapt an environmental and sustainable way of working at their future workplaces.

Out of Sweden's 11 national 'degree objectives', see Appendix A, three of them discusses environmental sustainability, ethics and ergonomics, which an engineering student must show in the thesis work in order to receive an bachelor degree [6].

The graduate program in Computer Engineering at the ICT School in Kista wants to improve the management of these issues in thesis works and thesis's on bachelor level after an evaluation made by UKÄ, The Swedish Higher Education Authority, to demonstrate compliance with these degree goals. The evaluation which was done on all of Sweden's engineering educations showed that most of the programs had too many technology-related courses or projects, but too little emphasis was put on the interplay between technology, humans and society, which engineering students must consider in their thesis work according to Anders Sjögren [3].

1.4 Goal

The principal goal is to do a thesis work and develop a bachelor thesis on how students can manage to consider the environmental and sustainable aspects in their thesis work and reports on bachelor level in the ICT area. Future students can then read and refer to this report and thus fulfill the purpose described in chapter 1.5 when this goal is met.
The ambition is that once students have followed the guidelines developed in this report, the quantitative and qualitative target should consist of at least half of the thesis working students achieving the criterion 'High Quality' and the other half 'Very High Quality'. This would lead to the whole programme achieving 'Very High Quality'.
According to Sven Eklund, the author of 'Arbeta i Projekt' [7] there are three types of goals that are the stakeholders' goal with the project:

Effect goal; due to the lack of consideration of environmental and sustainability aspects in thesis reports, a need for guidelines have been developed. Thus, the effect goal is to improve the quality of future thesis works regarding sustainability.

Result goal; the result of this thesis work is to write a well approved report. The guidelines in the report should be used by the students to implement and referred to in their reports, in order for them to improve their thesis work.

Project goal; the project goal is to implement a successful thesis work and report which the target groups will find useful. The stakeholders of this thesis work include the task provider and future bachelor students. The task provider will use the report in a project-related course, where the enrolled students will read and undertake the corresponding work during their projects (non-related to thesis works in this case). Future bachelor students will benefit from this report during their thesis work by reading or referring and undertaking the corresponding work which is/which will be presented in this report. The project goal for the project members is to meet the objectives defined in the assessment template for thesis works.

The expectations for this thesis work are to highlight how environments and sustainable aspects can be considered in a thesis work done by bachelors in the ICT area.
The goal is to do a thesis work and report which suggests references that can be used for future student's bachelor theses or reports regarding the methods and aspects to take into account. The specific goal is thus the report describing the work. The thesis work will be done by doing the thesis report. If students read or refer to this report and undertake the corresponding work, they will accomplish the goals surrounding consideration of environmental and sustainability aspects.

1.4.1 Benefits

There are different target groups who will benefit from the resulting product of this thesis work, which is the thesis report, whereof one of them is the task provider, Royal Institute of Technology. This stakeholder will provide future bachelor students with the thesis report who will use it as a guideline when performing their own thesis works.

As mentioned above, under chapter 1.4, the main goal is to upgrade from an 'Accepted level' which means 'High Quality' to the highest level which is a 'Very High Quality' in the criterion listed for thesis works regarding environmental and sustainability aspects according to the evaluation template developed by UKÄ, The Swedish Higher Education Authority [2]. This will in turn lead to awareness around these vital aspects surrounding the interplay between society and technology among students, which are future engineers and who will with great possibility be decision makers when developing systems used in people's' everyday life.

1.5 Methodology

The overall approach to meet the desired effect and result goal is through a theoretical feasibility study, interviews of people working with this subject and then summarizing the material in the report into formulated guidelines among other.
To find a solution to this issue, the following questions will be evaluated during this thesis work:

1. How can the transition from a reactive approach to a proactive approach be implemented?
2. What skill set is demanded for graduate education at a basic level to incorporate sustainability aspects in thesis work? How can one reach the criteria Very High Quality in thesis reports?
3. What methods can be used in a proactive way of working?

1.6 Delimitations

One of the methods in this paper which will be used to gather data is by conducting expert interviews. The focus in this paper is on the ICT (Information and Communication Technology) area and a delimitation is choosing the participants for the interviews, since the interviewees have to be skilled in either project management and/or environmental and sustainability issues.

Another delimitation is that no/little research has been done in this area earlier, which can be perceived as a pro or con;

- Pro: if the research idea has not been explored earlier, the paper will be a good contribution to the field since it is a necessary subject which needs to be highlighted.
- Con: due to the lack of any previous research surrounding this subject-matter we acknowledge the difficulty of drawing any empirical parallels or conclusions based on (previous) empirical framework

An analysis on earlier thesis work will be performed, also described in chapter 3, to see if the findings in this thesis will apply on thesis reports. The reason behind this is that this thesis, containing guidelines, will help future students to conduct an environmental and sustainable way of working in their thesis works. However, this analysis cannot be done on reports which is outside the scope, i.e. which is not in the ICT (Information and Communication Technology) area.

The focus of this report has been delimited to only researching on environmental and sustainability aspects, and therefore ethical aspects are not covered in this report.

1.7 Outline

This paper discusses how future ICT (Information and Communication Technology) students can with the help of guidelines apply different methods, adapted to the type of thesis works which they are performing, to establish environmental and sustainability aspects to their projects. The paper contains six different parts: introduction, theoretical background, methodologies, and process of the methodologies, results, and conclusion.

The second chapter of the paper discusses all relevant theory on the subject. Chapter 3 comprises the methods which have been chosen for the project. The reasoning behind the chosen target groups for the various methods is also presented here. The methods for the research phase, work planning, technology and lastly methods for documentation of solution proposals are included in this chapter. Chapter 4 discusses the approach which was made to implement the chosen methods described in chapter 3. This chapter describes thoroughly how the project group carried through to implement the different methods, how the preparations and planning for the interviews was made. In chapter 5 the results from the methods will be presented. All data will be gathered and presented in the form of figures and text. The last chapter of the thesis, chapter 6, will be comprised of an analysis which is done of the gathered data. A discussion about the results/analysis will be done in order to draw conclusions based on the gathered material.

2 Theoretic Background

This chapter covers the theoretical areas that are considered in this study. It introduces and explains the concepts of what this report encounters with and gives a thorough description of environmental and sustainable development and its different aspects. This chapter also presents the ICT area in which the problem of environmental and sustainable development is sustained and how the ICT sector is growing rapidly worldwide.

In this chapter, The Swedish Higher Education Authority (UKÄ) is also presented and how they evaluate and examine different universities, programmes, institutions etc. in different styles.

2.1 Environmental and Sustainable development

The subject of sustainable development contains taking actions and making decision that consider protecting the natural world, with a distinct significance in protecting the capability of the environment to support human life. Today, it is an important issue because it has come to further realisation for us humans that businesses and individuals have a great impact on the environment.

To make wise and responsible decisions, which will reduce the businesses negative impact on the environment, is what environmental and sustainability is about. It's not only concerned with reducing the amount of production of waste or using less energy, but to develop processes which will lead to a business becoming completely sustainable subsequently [8].

It is emphasized that sustainable development is an interaction of ecological, economic and social sustainability. But it is also accentuated that growth and social development must take place within the limits of the planet's ability to recover and therefore the ecological sustainability weighs the heaviest [9].

Thus, there are three dimensions of sustainable development; environmental, economic and social sustainability, which mutually creates a long-term and sustainable society, see Figure 2.1.1.

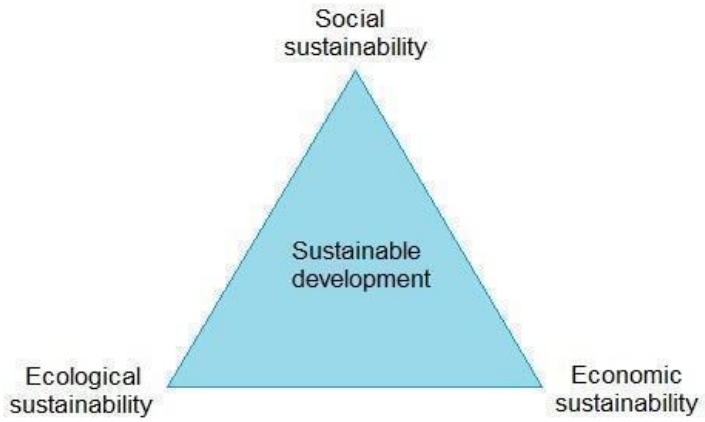

Figure 2.1.1: The three dimensions of sustainable development.

2.1.1 Environmental sustainability

The government of Sweden has set up goals for the environmental sustainability [10]. The environment must be protected, which, among other things means that emissions should not harm humans and the natural cycle should be protected.

Furthermore, unnatural substances should not appear in the environment and the biodiversity must be preserved. The second goal is to create an efficient use of energy and natural resources. This means that the use of energy and materials should be limited. Community planning should strive for being more economical on resource products and processes [11].

2.1.2 Economic sustainability

Economic sustainability is simply about getting the economy manageable and convenient, and the counties have different strategic approaches to this. An endeavor for economic development is a common long-term goal. It is about meeting the demand with an appropriate range. It is also about making use of the local products and services to protect the local economy [11].

2.1.3 Social sustainability

Social sustainability is generally the dimension of sustainable development which is perceived as the most difficult to define and there is also no general definition of the term. However, social sustainability focuses on people and other subjects such as democracy, justice, human rights and lifestyles. Public health, culture, security, drugs, quality of life and equality are a few topics that are discussed in the different counties of Sweden, in their ambition for social sustainability and social habitat [11].

2.2 ICT (Information and Communication Technology)

ICT indicates to technologies which contribute access to information using telecommunications. It is comparable to information technology or IT, but is broader and targets mainly on the communication technologies that include wireless networks, Internet, and other communication mediums.

In the past few years, information and communication technologies have contributed society with a large range of new communication competencies. People can, for instance, communicate in real-time with others in different countries using technologies like instant messaging, voice over IP or VoIP, as well as video conferencing, e.g. using an application like Skype. Social networking websites such as Facebook allow users globally to remain in contact and communicate on a daily basis [12].

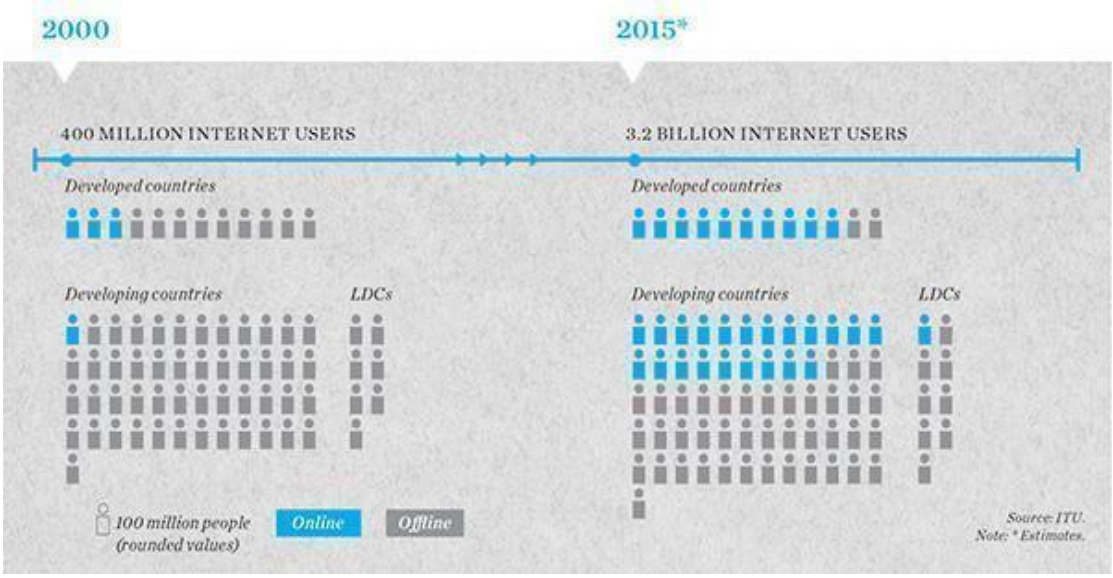

Figure 2.2.1: The global estimates of 2000 till the end of 2025 [13].
LCD = Least Developed Countries. Source: The ITU ICT Facts and Figure.

Access to ICT is steadily growing, see figure 2.2.1. The global cell phone impact is at 96%, which is marginally lower in developing countries, sitting at 89%. Broadband internet has become more approachable globally because the cost has decreased by 82%. Even the computer's processing capability is increasing and expanding exponentially [14].

2.3 UKÄ (The Swedish Higher Education Authority)

The Swedish Higher Education Authority, UKÄ, was founded in 2013, as a result of merging three authorities from the higher education area into two. The main purpose of UKÄ is to deal with questions regarding universities and

university colleges. As stated on their webpage, their work comprises of three different areas being:

- *Quality assurance of higher education and appraisal of the degree-awarding powers of public-sector higher education institutions.*
- *Legal supervision of higher education.*
- *Monitoring efficiency, follow-up and horizon scanning as well as responsibility for statistics in the higher education sector.*

**The italic text above has been cited from UKÄ* [15].

Being a government agency, all operations which are executed are regulated by the government through an instruction which defines the responsibility areas and also what tasks that should be performed [16].

UKÄ performs evaluations of all the first and second-cycles in different programmes offered by universities and university colleges in order to control the level of quality in the education. This work also covers examining the degree-awarding powers of the institutions in which the evaluation is being performed. Besides the work mentioned above, UKÄ also examines applications for degree-awarding powers by judging whether the programmes meet the required quality or not.

Each programme is evaluated with the help of a panel consisting of subject experts, labour market representatives and also students. The panel performs the evaluation using a three-level scale, which is the following:

- Very High Quality
- High Quality
- Inadequate quality

The levels listed above holds different criteria, and depending on how the programme attains the criteria it will receive one of the quality levels. If a programme is assessed as having 'inadequate quality' it needs to be reviewed within a year. When the review is completed, UKÄ will decide if the programmes entitlement to award a qualification will be revoked or not.

Below is the table from The Higher Education Board containing the objectives holding the three quality levels 'Very High Quality', 'High Quality' and 'Inadequate Quality'. As shown in the table, there are six objectives and they are grouped into the three categories Kunskap och förståelse (eng. Knowledge and understanding), Färdighet och förmåga (eng. Skills and abilities) and

lastly Värderingsförmåga och förhållningssätt (eng. Ability to judgements and adopt a standpoint). The area of concern, i.e. objective number six, see Table 2.3.1, which is being regarded from the table in this thesis work, is below the category *Ability to judgments and adopt a standpoint* says "*Demonstrate an understanding of technology capabilities and limitations, its role in society and people's responsibility for its use, including social and economic aspects, environmental and safety aspects".*

Table 2.3.1: Assessment template from UKÄ, The Swedish Higher Education Authority [17].

Kunskapsform: Kunskap och förståelse	**Kriterier för mycket hög måluppfyllelse**	**Kriterier för hög måluppfyllelse**	**Kriterier för bristande måluppfyllelse**	
Mål 1: För högskoleingenjörsexamen skall studenten visa kunskap om det valda teknikområdets vetenskapliga grund och dess beprövade erfarenhet samt kännedom om aktuellt forsknings- och utvecklingsarbete	Underlagen indikerar att studenten visar ● god kunskap om det valda teknikområdets vetenskapliga grund och god kännedom om aktuellt forsknings- och utvecklingsarbete ● god kunskap om det valda teknikområdets beprövade erfarenhet	Underlagen indikerar att studenten visar ● kunskap om det valda teknikområdets vetenskapliga grund och kännedom om aktuellt forsknings- och utvecklingsarbete ● kunskap om det valda teknikområdets beprövade erfarenhet	Underlagen indikerar att studenten visar ● bristande kunskap om det valda teknikområdets vetenskapliga grund samt aktuellt forsknings- och utvecklingsarbete ● bristande kunskap om det valda teknikområdets beprövade erfarenhet	”Vetenskaplig grund” bedöms genom användande av relevant litteratur samt förmåga att värdera källor. Bedömning av målet kompletteras mha information ur SV.
Mål 2: För högskoleingenjörs-examen skall studenten visa brett kunnande inom det valda teknikområdet och relevant kunskap i matematik och naturvetenskap	Underlagen indikerar att studenten visar ● mycket brett kunnande inom det valda teknikområdet och mycket god kunskap inom relevanta områden i matematik och naturvetenskap	Underlagen indikerar att studenten visar ● brett kunnande inom det valda teknikområdet och relevant kunskap i matematik och naturvetenskap	Underlagen indikerar att studenten visar ● bristande kunnande inom det valda teknikområdet och bristande kunskap inom relevanta områden i matematik	”Kunskaper i matematik” bedöms mha information ur SV. Naturvetenskap tolkas brett. Särskilt viktigt inom data-it-medieteknikklustret då naturvetenskap ej är relevant för många delar inom detta område. Bedömning av brett kunnande kompletteras mha information ur SV.

			och naturvetenskap	

Kunskapsform: Färdighet och förmåga	**Kriterier för mycket hög måluppfyllelse**	**Kriterier för hög måluppfyllelse**	**Kriterier för bristande måluppfyllelse**	
Mål 3: För högskoleingenjörs-examen skall studenten visa förmåga att kritiskt och systematiskt använda kunskap samt att modellera, simulera[2], förutsäga och utvärdera skeenden med utgångspunkt i relevant information	Underlagen indikerar att studenten med utgångspunkt i relevant information visar ● god förmåga att kritiskt och systematiskt använda kunskap ● god förmåga att modellera, simulera, förutsäga och utvärdera skeenden	Underlagen indikerar att studenten med utgångspunkt i relevant information visar ● förmåga att kritiskt och systematiskt använda kunskap ● förmåga att modellera, simulera, förutsäga och utvärdera skeenden	Underlagen indikerar att studenten med utgångspunkt i relevant information visar ● bristande förmåga att kritiskt och systematiskt använda kunskap ● bristande förmåga att modellera, simulera, förutsäga och utvärdera skeenden	”Modellera” och ”simulera” tolkas brett. Vid bedömning ska det räcka att antingen visa förmåga att ”modellera” *eller* ”simulera”.
Mål 4: För högskoleingenjörs-examen skall studenten visa förmåga att utforma och hantera produkter, processer och system[3] med hänsyn till människors förutsättningar och behov och samhällets mål för ekonomiskt, socialt och ekologiskt hållbar utveckling	Underlagen indikerar att studenten visar ● god förmåga utforma och hantera produkter/processer/system ● god förmåga att ta hänsyn till människors förutsättningar och behov samt till samhällets mål för ekonomiskt, socialt och ekologiskt hållbar utveckling	Underlagen indikerar att studenten visar ● förmåga att utforma och hantera produkter/processer/system ● förmåga att ta hänsyn till människors förutsättningar och behov samt till samhällets mål för ekonomiskt, socialt och ekologiskt hållbar utveckling	Underlagen indikerar att studenten visar ● bristande förmåga att utforma och hantera produkter/processer/system ● bristande förmåga att ta hänsyn till människors förutsättningar och behov samt till samhällets mål för ekonomiskt, socialt och ekologiskt hållbar utveckling	Produkter, processer och system tolkas brett. Te x kan en teori i vissa fall ses som en produkt Vid bedömning ska det räcka att visa förmåga att utveckla och utforma produkter, processer *eller* system Bedömning av det andra kriteriet (hänsyn till människors förutsättningar…) kompletteras mha information från SV.

[2] Vid bedömningen är förmågan att simulera är inte nödvändig för att målet ska anses uppfyllt

[3] Vid bedömningen läggs tyngdpunkten på det första delmålet. ”förmåga att utforma och hantera produkter, processer och system.”

Mål 5: För högskoleingenjörs-examen skall studenten visa förmåga att muntligt och skriftligt redogöra för och diskutera information, problem och lösningar i dialog med olika grupper	Underlagen indikerar att studenten visar ● god förmåga att muntligt redogöra för och diskutera information, problem och lösningar ● god förmåga att skriftligt redogöra för och diskutera information, problem och lösningar ● god förmåga till dialog med olika grupper	Underlagen indikerar att studenten visar ● förmåga att muntligt redogöra för och diskutera information, problem och lösningar ● förmåga att skriftligt redogöra för och diskutera information, problem och lösningar ● förmåga till dialog med olika grupper	Underlagen indikerar att studenten visar ● bristande förmåga att muntligt redogöra för och diskutera information, problem och lösningar ● bristande förmåga att skriftligt redogöra för och diskutera information, problem och lösningar ● bristande förmåga till dialog med olika grupper	”Skriftlig förmåga” bedöms ur SA. ”Muntlig förmåga” bedöms mha information ur SV. ”Dialog med olika grupper” bedöms mha information ur SV.

Kunskapsform: Värderingsförmåga och förhållningssätt	**Kriterier för mycket hög måluppfyllelse**	**Kriterier för hög måluppfyllelse**	**Kriterier för bristande måluppfyllelse**	
Mål 6: För högskoleingenjörs-examen skall studenten visa insikt i teknikens möjligheter och begränsningar, dess roll i samhället och människors ansvar för dess nyttjande, inbegripet sociala och ekonomiska aspekter samt miljö- och arbetsmiljöaspekter	Underlagen indikerar att studenten visar ● god insikt i teknikens möjligheter och begränsningar, inbegripet sociala och ekonomiska aspekter samt miljö- och arbetsmiljöaspekter ● god insikt i teknikens roll i samhället och människors ansvar för teknikens nyttjande, inbegripet sociala och ekonomiska aspekter samt miljö- och arbetsmiljöaspekter	Underlagen indikerar att studenten visar ● insikt i teknikens möjligheter och begränsningar inbegripet sociala och ekonomiska aspekter samt miljö- och arbetsmiljöaspekter ● insikt i teknikens roll i samhället och människors ansvar för teknikens nyttjande, inbegripet sociala och ekonomiska aspekter samt miljö- och arbetsmiljöaspekter	Underlagen indikerar att studenten visar ● bristande insikt i teknikens möjligheter och begränsningar inbegripet sociala och ekonomiska aspekter samt miljö- och arbetsmiljöaspekter ● bristande insikt i teknikens roll i samhället och människors ansvar för teknikens nyttjande, inbegripet sociala och ekonomiska aspekter samt miljö- och arbetsmiljöaspekter	Bedömning av målet kompletteras mha information från SV.

2.4 Bloom’s Taxonomy

Bloom’s Taxonomy devised by Benjamin Bloom is a framework consisting of three models for classifying educational learning goals. The three models cover different domains of the learning objectives and these are the cognitive,

affective and sensory domains and they are knowledge-based, affective-based and skill-based, respectively, see Appendix D for a more detailed description of the different domains. However, the only list which will be presented in this section is the first one, the cognitive domain, which is commonly used for educational purposes [18]. As depicted in figure 2.4.1 below, the taxonomy is constructed in a hierarchical model, consisting of six categories, each of the major categories consists of subcategories, but the focus will only be on the major ones.

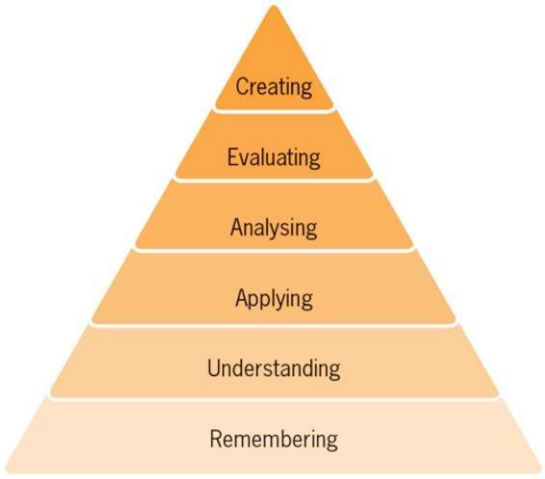

Figure 2.4.1: Bloom's Taxonomy [19].

Starting from the bottom layer of the pyramid, the first category *Remembering* is the first level and here the student is able to recall facts and basics concepts, meaning the students can define, duplicate and state different facts. The next level is *Understanding,* meaning the student is able to explain ideas or concepts and not only remembering the facts. On third level ”Applying” the student now knows how to use and as the name says, apply, information in new situations, not only understanding the facts but also implementing it. Reaching the fourth level ”Analyzing” the student is now thinking and operating on a more advanced level in a sense of connecting different ideas. Level five of Bloom's taxonomy *Evaluating* discusses the student's ability of justifying a stand or decision and making judgments. On the final level of the taxonomy ”Creating”, the student has the ability of putting elements together with purpose of forming a functional whole and creating a new product or maybe perspective.

2.5 SEMAT Essence

The Essence Kernel contains some slight definitions that take on the essence of innovative and effective software engineering in a practical self-reliant way. It has several assets which are:

- *Allowing you to apply as few or as many practices as you like.*
- *Allowing you to easily capture your current practices in a reusable and extendable way.*
- *Allowing you to evaluate your current practices against a technique neutral control framework.*
- *Allowing you to align and compare your on-going work and methods to a common, technique neutral framework, and then to complement it with any missing critical practices or process elements.*
- *Allowing you to start with a minimal method adding practices as the endeavor progresses and when you need them*

**The italic text above has been cited from* [20].

The Essence Kernel currently has suggested three concerns which are Customer, Endeavor and Solution and each concern has different Kernel alphas, which are mandatory in a software engineering project. A software engineering project can contain as many alphas as the project considers appropriate. There are currently seven alphas, these alphas belong to *'Essential things to work with',* which describes what type of stuff the team will produce and use in the development of a great software. In each area of concerns there are also *'Essential things to do',* a definition of challenges the team faces and the things the team will do to prevent them, and in *'Essential competencies'* the skills are defined that the team requires to then be able to perform the activities [20].

Let's look at the first area of concern which is *Customer*, this area of concerns includes everything that has to do with the absolute use and exploitation of the software system to be developed. In software engineering there is always one customer for whom the software is developed for. The perspective of the customer has to be combined with the periodic work of the team in order to avoid producing an incorrect solution. The customer area of concerns accommodates of the alphas *Stakeholders* and *Opportunity,* where the team needs to master the stakeholders and the opportunity be addressed.
1. Stakeholders - The groups, people or organizations that are affected or affect the software system.
2. Opportunity - All of the circumstances which make it applicable to produce or change a software system [21].

The *Solution* area of concern has to do with the development and specification of the software system. The purpose of software engineer is to produce working software as part of a solution to a problem. Any method used must explain a set of practices to benefit the team to develop High Quality software

in a collaborative and productive way. Thus, in this concern the team has to establish a mutual understanding of the requirements, and implement, build, deploy and support a software system which achieves them:
3. *Requirements* - Is what the software has to do to address the opportunity and appease the stakeholders.
4. *Software System* - A system developed with data, hardware and software which maintain its essential value by the execution of the software [21].

Endeavor is the area of concern where everything has to do with the team and the way they access their work. Software engineering is an important endeavor that normally takes several weeks to complete; it affects a lot of people (stakeholders) and concerns a whole development team and not one developer. Whatever practical method must define a set of practices to adequately plan, lead and monitor the achievements of the team, see figure 2.5.1, for the different alphas and concerns relation with one another. The endeavor area of concern is the concern where the team and its way-of-working have to be organized and the work has to be done. The alphas of this concern are:
5. *Work* - Activity that includes physical or mental effort to achieve a result.
6. *Team* - A group actively involved in the development, maintenance, support or delivery of a certain software system.
7. *Way of working*- The customized set of tools and practices used by a team to support and guide their work [21].

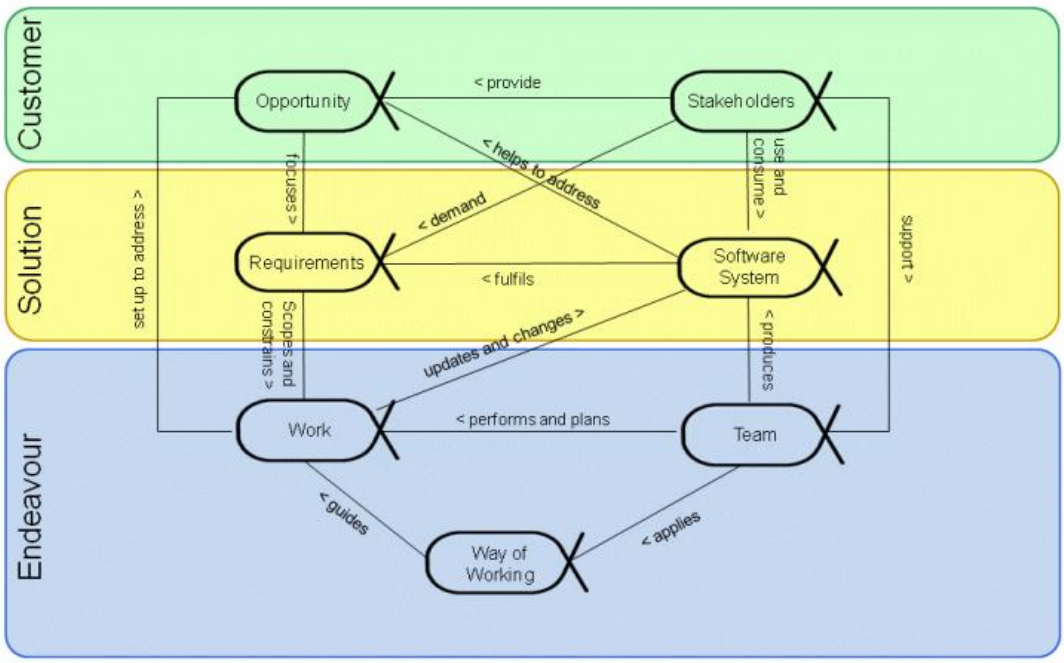

Figure 2.5.1: Alphas: The things to work with [21].

The alpha cards (1-7) also have different states and each state has checklists which the team has to go through and tick in order to get to the next state. The cards are absolute, meaning that all of them have to be considered once this method is applied; none of the seven cards can be ignored or replaced by another.

3 Methods

This chapter describes the methodologies used for gathering information.

3.1 Research Method

Chapter 3.1 presents the method which was developed specifically for this project in order to reach the desired end-result. The methods involves a literature study, and conducting expert interviews, and depending on the information gathered from this activity, which is activity two of the project, methods for considering and handling environmental and sustainability aspects in engineering projects was developed.

As mentioned in chapter 1, to obtain the result of this project degree the following questions will be answered, using the methods described below:

1. How can the transition from a reactive approach to a proactive approach be implemented?
2. What skill set are demanded for graduate education at a basic level to incorporate sustainability aspects in thesis work? How can one reach the criteria Very High Quality in thesis reports
3. What methods can be used in a proactive way of working?

Literature search, expert interviews and analyzing of previous thesis works are some of the various methods which the research includes. These methods are used for qualitative analysis to investigate and acquire the answer to the subject issue through interviews of experts who have expertise in environment and sustainability. Additionally, previously submitted thesis work reports are analyzed to examine how these reports take environmental and sustainability into account.

Although it is believed that one understands what the problem formulation is, people often misunderstand the task provider or do not understand the problem fully, means Sven Eklund in the book 'Arbeta i Projekt' [7]. He gives an example of how one completely focuses on the simple, concrete result goals and forgets the effect goals. This is why clarifying and understanding the research question is important in the earliest stage. The second activity is to achieve the background information of the research questions that are to be answered in this report and get an insight of what exactly the subject is about. The next step is to develop something good based on the material gathered in the previous activity. Here developing the methods of how to answer the research question will be done. When testing the methods we will take several of the previously submitted thesis works and test the methods we have established reactively. We will also evaluate with some of the experts to get

better feedback. After testing the methods, they will get adjusted in the manner of what the methods lacked and when modified the test will be redone until the methods get qualified in order to move forward towards documenting, see Figure 3.1.1.

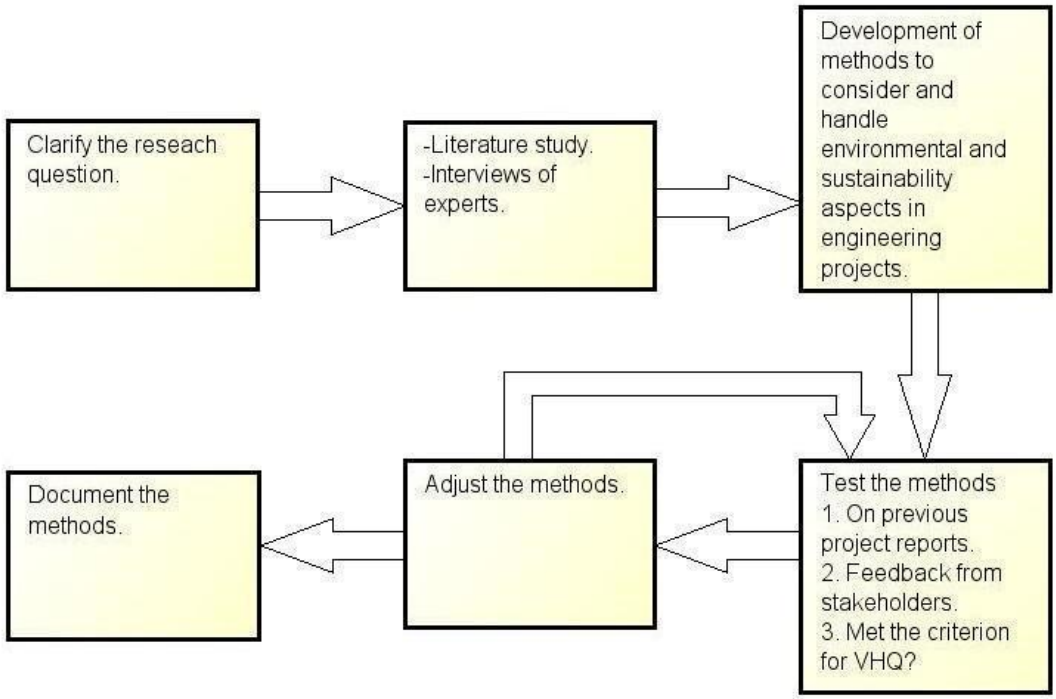

Figure 3.1.1: The different activities.

The considerations to environment and sustainability which will be made within the project (i.e. the work itself), is that the work can be done remotely. The project members do not have to commute/use transport to attend meetings, instead they can be done through Skype when necessary.

A scientific method is about how to set and answer questions and how to acquire knowledge, see the following steps 1-10. Various sciences take advantage of different methods and social sciences are distinguished by not being limited to a method set. In social sciences, there has only been under limited periods found unity in what methods are appropriate. Gradually the unity seems to dissolve through one either gets tired of the available methods or want to free themselves from the constraints the unity tends to lead to. Some methodological positions are based on philosophical discussions about what knowledge is and how it can be available. Others may base their methodology on conceptions of human beings or society's nature and still others are based on an ideal image of what science is [22].

To follow a good research method we have tried our best to follow the scientific research process which focuses on technology research given by Bunge (1983) in the following 10 steps:

1. *How can the current problem formulation be solved?*
2. *How can a technology/product develop to solve the problem in an effective way?*
3. *Which data/information exists and is required to develop technology/product?*
4. *Develop technology/product based on data/information in step 3. if the technology/product proves satisfactory, go to step 6.*
5. *Try with new technology/product.*
6. *Create a model/simulation of the proposed technology/product.*
7. *What are the consequences of the model/simulation in step 6?*
8. *Test the application of the model/simulation. If the outcome is not satisfactory, go to step 9 otherwise go to step 10.*
9. *Identify and correct the flaws in the model/simulation.*
10. *Evaluate the result in relation to the existing knowledge and practices, and identify new problem areas for further research.*

**The italic text above has been cited from* [23].

The research method that is developed in this thesis is a reflection of some of these ten general steps shown above.
The first step for a method to be considered as scientific is to identify the problem within the area of the subject-matter. The question to be asked is *How can the current problem formulation be solved?* In order for the problem to be solved, which is how students shall consider sustainability aspects in ICT engineering thesis works, three questions, as presented both in chapter 1.5 and chapter 3.1, have been developed to obtain the desired results. The second question in Bunge's list asks *How can a technology/product be developed to solve the problem in an effective way?* It is during the research phase where a project group can find out what needs to be developed to help solve the issue of the subject-matter, meaning a technique or a product. When research phase was completed, the technique which the research showed there was a need for was guidelines for students to follow and implement/undertake in their thesis works to achieve *'Very High Quality'* as a minimum grade for the criteria surrounding consideration of sustainability aspects.

As of now, there has been little to no research done in the subject area covered in this thesis work. Since the problem to be solved only covers thesis works within the area of ICT, there is not enough information to develop the

guidelines. However, for projects in other areas such as Construction Engineering, guidelines have been developed intended to be undertaken in order for the project to take sustainability aspects into account. These guidelines can be considered as a basis where inspiration can be taken to develop guidelines for ICT thesis works.

If information is found during step three in Bunge's ten step list, the required technique can be developed. Since an insignificant amount of research has been done regarding the subject area, other approaches have to be taken. Step four in Bunge's list says *"Develop technology/product based on data/information in step 3. If the technology/product proves satisfactory, go to step 6."* In order for the guidelines to be developed, the problem formulation which was formulated during the first step needs to be answered and since there is little information available to help solve the problem other methods have to be used. A part of the research method includes conducting expert interviews with the purpose to help develop the guidelines.

In this thesis work, step five in Bunge's list "*Try with new technology/product"* will not be considered. When the technique has been developed, a reactive approach will be taken regarding taking sustainability aspects into account in thesis works. This will be done by implementing the guidelines on previous thesis works. Step five can be regarded in future works, where the provided guidelines can be undertaken from the beginning, a proactive approach, of a thesis work in order to prove its validity.

As shown in figure 3.1.1, the third box from the lower left, describes the testing-activity, i.e., once the guidelines have been developed they will be tested on previous thesis works. This step of the development method corresponds to step eight in Bunge's list *"Test the application of the model/simulation. If the outcome is not satisfactory, go to step 9 otherwise go to step 10."* The development method model in figure 3.1.1 also covers step nine in Bunge's list, which says *"Identify and correct the flaws in the model/simulation"*. This step corresponds to the second box from the lower left, where the activity 'Adjust the methods' is taking place. If flaws are shown in the guidelines during the previous activity 'Test the methods' corrections of them has to be made in order to develop suitable guidelines for the purpose.
The last step in Bunge's definition to follow a scientific method tells us to "*Evaluate the result in relation to the existing knowledge and practices, and identify new problem areas for further research."*

3.2 Method for Work Planning

Chapter 3.2 describes the methods used for work planning in the thesis work, consisting of implementing the MOSCOW method and dividing the thesis work into different phases. The five phases which the project was divided into leads back to the developed model in figure 3.1.1.

3.2.1 GANTT chart

The GANTT chart, see Appendix C, was used in the project to describe the different phases, see Appendix E. It also contains checklists, activities, milestones, etc. We have used the GANTT chart to get a clearer image of how the phases are visualized and in that way it becomes easier because we will become more prepared of what is in store for the next phase, and so on.

3.2.2 Project Triangle

The first thing to be done when planning a project is to view a Project Triangle (or Iron Triangle) [7], see fig 3.2.1. The Project Triangle contains three corners. They comprise of the project being finished in the right amount of time and cope within the budget. The larger a budget a project has, the more people can service the project, which leads to the project having more time on it and functionality (delivering the right elements).

However, all of the corners of the Project Triangle cannot be 'fixed'. It is not possible to determine exactly how much each corner will contain about, some of it must be flexible.
For this specific project we have agreed upon the following:

Duration: This corner of the triangle can partially be changed because our mentor, Anders is fine with it only to a certain limit. Thus, this is slightly flexible and if we are not finished our mentor can move the deadline forward. But the project should at least be finished within a year, because a thesis work that is not finished in a year gets deregistered from the course and one has to start all over again.
Resources: There are two people in this project and we have 400 hours individually, that is 2x400h. That is fixed and nothing can change that because it is a part of the thesis work thesis to be able to dimension the work in this direction.
Scope: There is an opportunity to be able to change this corner, if we do not have time to do what we had planned.

To solve this with these conditions, mentioned above, about the functionality that varies we will work with MOSCOW.

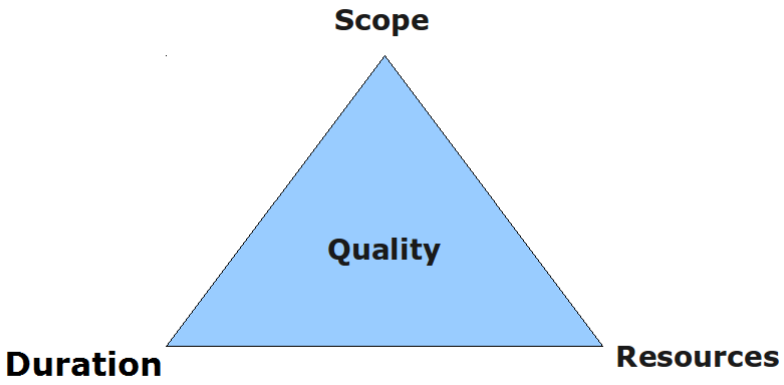

Figure 3.2.2: The Project Triangle.

3.2.3 MoSCoW

The MoSCoW method, abbreviated for ‘Must Have, Should Have, Could Have, Won't have’ will be used. MOSCOW is a commonly used method in many fields including software development and project management and is a technique for prioritizing requirements in a project. [ref] According to the method, the ‘Must Haves’ are the requirements that have to be completed in time. The 'Must Have' of this thesis work which needs to be completed is the thesis report, with the guidelines included, for future students to use when dealing with methods for implementing environmental and sustainability aspects into their thesis works [7].

After completing the requirements listed as ‘Must Have’ there are other important requirements remaining which need to be completed, these can however be completed later on during the project, i.e. if time allows. These requirements are categorized as ‘Should Have’ and will cover consideration of ethics in thesis work, which can be regarded the same way as the methods for implementing environmental and sustainability aspects, adapted to this specific area.

The ethical and sustainability aspects are however parallel, since the latter also contains ethical aspects because it deals with social sustainability, i.e. that a system/product/service should not violate or offend anyone.
Requirements that are considered to be good if they are met, but not vital for the project are listed as ‘Could have’. The ‘Could Have’ of this thesis work discusses how students can consider work-environment and ergonomical aspects in their thesis works. The former discusses how people are using their computers/systems while the latter touches the subject of constructing systems which are human-friendly [7].

3.3 Working Phases

In this chapter the process of the thesis work is described. The various parts of the work, including different phases are presented.

The implementation of the thesis work was done in the several phases listed below:

- Preparation phase
- Definition phase
- Research phase
- Implementation phase
- Testing phase
- Final phase

3.3.1 Preparation and Definition Phase

During the preparation phase the subject matter was presented and agreed upon between the project members and the stakeholders, being the mentor and the examiner. The preparation phase was followed by the definition phase where a document called Project Definition was created and in which the whole project was planned out, i.e. the research method was decided, the stakeholders were addressed, a timetable was developed for the number of hours to be spent during the thesis work just to mention a few of the different aspects considered in the document. When these two phases were completed a transition was made to the Research phase in which the research method developed earlier was about to be implemented.
The chosen research method is divided into a scientific implementation where a literature study was conducted and an engineering related implementation where interviews were conducted.

3.3.2 Research Phase

The scientific implementation and engineering related implementation of the research phase is presented here.

3.3.2.1 Scientific Implementation

The literature study was conducted with the aim to gather information regarding the subject-matter. Since sustainability is a minor subject in the area of ICT (Information and Communication Technology) compared to other areas where it is a much discussed topic finding information was a bit difficult. The main database which was used was KTHB Primo due to the sources being carefully reviewed and the quality of them being high [24]. During this phase many articles and papers were read however, the amount of information found was small but since there had been similar work done on other areas,

such as in construction, information from these sources was used. Besides a literature study, a careful research on earlier thesis reports was done with the aim of getting an insight of how students have considered sustainability in their work.

3.3.2.2 Engineering Related Implementation

The other approach for gathering information besides the literature study and reviewing old thesis reports was to conduct interviews. The interviews was done with the aim of getting information directly from sources who were people that either works with environmental and sustainability topics or project-related topics. The interviews were divided into two categories; expert interviews and industry expert interviews. All of the participants were chosen carefully, meaning, all of them have expertise in certain areas in which their knowledge would benefit the thesis work. Our first interviewee Anna Björklund, associate professor, has expertise in strategic environmental assessment (SEA), energy planning and transport infrastructure and vehicle design just to mention a few areas. [https://www.kth.se/profile/annab/]. The second participant, Anne Håkansson, also associate professor, has research which lies within Computer Science and Data Science with the focus on Artificial Intelligence for different application areas, environmental impact assessment among others. Lastly, Mira Kajko-Mattsson, associate professor at KTH in software engineering has expertise in industrial lifecycle software processes. For the industry expert interview, Madeleine Bergrahm, a sustainability manager at HP (Hewlett-Packard) was chosen.
As mentioned previously all of the participants were chosen with great consideration with the aim of gathering information from the questions that were developed specifically based on their knowledge area.

3.3.3 Implementation Phase

When information had been gathered from the literature study, the review of previous thesis reports and the interviews the project transitioned to the implementation phase. During the implementation phase the focus was on answering the research questions, hence developing the result of the thesis work, i.e. the guidelines, the skill set, SEMAT Essence Kernel card.

3.3.4 Testing Phase

3.3.4.1 Limitations

When developing the research method, it was planned that once the results were completed, the product would also be tested on previous thesis work reports. Initially it was planned that the methods would be tested on three old reports to see how they could possibly be constructed if these methods were applied; if they (the methods, i.e. guidelines, skill set among others) would be

usable, bad or not usable at all. However, due the time limit, there was no time for testing the methods on previous reports.

3.3.5 Final Phase

During the final phase an opposition on another thesis work will be conducted, the final report will be handed in and preparations for the project presentation will be done.

3.4 Technology

The different technology applications used when developing this report are represented here.

3.4.1 Google Document

Google Document or Google Doc is used jointly among the project members to write this rapport. With only access to a computer one can write the data that needs to be written anytime and anywhere. Google doc saves the content on their server so till next time one can continue where they last were.

3.4.2 Microsoft Word

The application Word will be used for the final touches of the document. Google Doc does not consist of all features a proper document should have considering KTH's template for a thesis report.

3.4.3 Astah

To make certain diagrams which are more text based, Astah has been used.

4 Results

In this part of the report there will be the presentation of the results from the different methods that have been used to develop guidelines which the students will utilize. The first thing that has been done to enable the research was to do a literature study.

When this part was thoroughly completed, questions for the expert interviews were made where there were 4 participators from different areas with 7-9 disparate questions. The questions consisted of discussive sustainability related questions. In order to create the greatest possible level of knowledge in the subject area, we included experts from both the university (KTH) and also we wanted someone from outside the actual education range and searched for the sustainability manager at HP.

4.1 How can the transition from a reactive approach to a proactive approach be implemented?

There are pros and cons in both proactive and reactive approaches, which one has to consider while and when starting the project. In a reactive approach one has to solve matters as they emerge. This can invite creativity and the focus becomes mainly on the progress, but when issues do arise you are expected to work on them until they are not solved. In a proactive approach one solves the matters before they become an issue. Spending more time on optimizations is normal and the development or approach is more durable. However, one can assume the wrong future and consume time on unimportant tasks [25].

To obtain the answer for this research question we have done interviews, literature studies etc., in different ways and it has been a little inductive because the answers have been unknown. So, within the framework of this project we can't claim we have all the answers or have collected all the ideas. Anders Sjögren [3] says that the need has to be there in the mere beginning of the project *"something that triggers the work on sustainability also something that forces the reflections on the subject or forces standpoint around environmental and sustainable development early in the graduate thesis process"*.

4.1.1 Interviews

In the expert interviews there were only a few that were asked the question about transitioning from reactive to proactive approach considering that not

all of the experts could take upon and answer this question because of their profession not being in that particular area.

One of the interviewees that were asked the question was Anna Björklund, who is course responsible and examiner of the course Sustainable Development, ICT and Innovation. The course which is mandatory for the Degree Programme in Information and Communication Technology but only conditionally elective for Degree Programme in Computer Engineering [26].

When asked Anna the question about how the implementation can be done to transition from a reactive to a proactive approach she answered, see Appendix D for interviews, that a lot of students will have it difficult to know exactly what to write about in the subject of environmental and sustainable development, but to give the students leading questions early in the project plan regarding this subject will make it easier for them. She continued saying *"Maybe giving a number of key concepts to get started in this way of thinking, because if it just says 'what does this have to do with sustainable development?' the answer will most likely be 'I don't know'"*. She also mentions in the interview that there should be a checkpoint, *"so that the students can't move on until they've talked about it, commented on it and written a motivation on how they will handle it when working with problem solution or will I not handle it, describe why"*. See figure 5.1.1 for another quote by Anna.

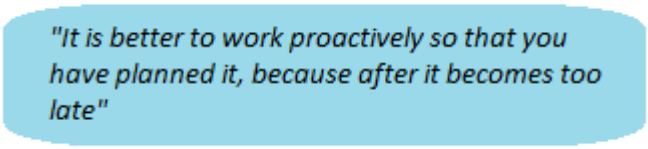

Figure 5.1.1: A quote from Anna Björklund's interview.

We asked another expert Anne Håkansson, who is an examiner for thesis works on bachelor level, the same question and she replied shortly by saying that *"Generally, people are more reactive than proactive. It is not easy to be proactive if you do not know what problems you may encounter"*.

4.1.2 Guidelines

Here the guidelines developed are presented. The guidelines are divided into four different aspects; *Development Process, Maintenance Process, System Production and System Usage*. In every aspect the three dimensions of sustainable development were considered, which are environmental (ecological) sustainability, economic sustainability and social sustainability.

The guidelines were made to benefit ICT projects and students to list what they need to realize to be sustainable in the mere beginning to the very end when taking upon a project.

The development process aspect is sustainability in the introductory software development process [27].

Development Process Aspect

Social Sustainability

- **Security:**
  - Changes in the system should only be made by authorized members.
  - Unauthenticated users should not be able to access the developing system
- **Privacy:**
  - Data privacy of team-members, which includes:
    - Social security number
    - Phone number
    - Address
  - But also:
    - Data use
    - Data access
    - Data integrity
- **Interaction**
  - Good working environment for the team-members, meaning mutual respect
- **Fair employment**
  - Gender-equality
  - Sexual orientation
  - Race
  - Ethnicity
  - Religion
  - National origin
  - Age
- **Fair Working Conditions**
  - Healthy and safe working environment

Economic Sustainability

- **Safety:**
  - Unsafe products will not lead a company to reach long-term economic terms
- **Capital budget**
  - Define capital budget for planning and controlling project cost
- **Finance plan**
  - Define and plan in detail when and how the budget will be used

Environmental Sustainability

- **Safety:**

    - No chemical or other hazardous accidents
- **Place of work:**
    - Smart communications, i.e. choosing the train rather than choosing the car.
    - Team-members should have the possibility to work remotely instead of coming to the work
- **Energy consumption**
    - Taking energy consumption into account and not overusing more than needed

Maintenance process aspect focuses on the sustainability of the software system amid its maintenance period until it is replaced by a new system. This means ongoing monitoring of quality and expertise in management [27].

Maintenance Process Aspect
Social Sustainability
- **Safety** - **Security** (Authentication, authorization, integrity):
Economic Sustainability
- **Safety** - **Cost**   - A system which costs more to maintain should be taken down.
Environmental Sustainability
- **Safety:** - **Energy efficiency:** - **Reduction and disposal of waste** - **Conserving, reusing and recycling**

System Production aspect is the sustainability of the software system as product with regard to its use of resources or components for production, for example by using sustainability in ICT principles and sustainably produced hardware components [27].

System Production Aspect
Social Sustainability

- **Safety**:
- **Security**(Authentication, authorization):
- **Integrity**:
- **Privacy**:
- **Modifiability**: Ability to introduce changes quickly and cost effectively
    - Enables system to be continuously adapted to meet societal demands
- **Reusability**: Level in which system components can be reused in other systems
    - Enables the production of new products with less effort

- **Portability**: Ability of the system to run under different computing environments.
    - Reduced cost for technology adoption, by minimizing user's dependency on latest technology.
- **Supportability**: System's ability to be easily configured and maintained after deployment.
    - Vendor's independence increases the product usability and thus accessible to a larger population.

Economic Sustainability

- **Safety**:
    - if the product is not safe, there will not be an economic success.
- **Modifiability**
    - Minimizes development and support costs
- **Reusability**
    - Accelerates time-to-market
- **Portability**
    - Increases potential market and system's lifetime.
- **Supportability**
    - Increased customer base due to reduced support costs.

Environmental Sustainability

- **Safety**:
- **Components** (Reuse and recycle)
- **Algorithmic efficiency**: (Minimize energy consumption)
- **Modifiability**
    - Minimizes environmental waste through less effort in producing and maintaining existing system
- **Reusability**
    - Minimizes environmental impact through less effort in producing system
- **Portability**
    - Minimizes e-waste by extending the lifetime of old hardware.
- **Supportability**
    - Indirect benefits are minimisers of

System usage aspect is the sustainability in the usage process in the application domain triggered by the software system. This considers responsibility in the impact on the environment and using sustainable business processes [27].

System Usage Aspect

Social Sustainability

- **Safety**:
- **Security** (Authentication, authorization):
    - the user must be protected, i.e. user information
    - unauthorized access

- **Integrity** Corporate ethics, human rights, government relations)
- **Privacy**:
    - for instance, privacy breaches in online banking
- **Human Computer Interaction:**
    - Support for disabled persons (address societal and economic issues, such as digital inclusion and disability inclusion).
- **Performance**: The time required by the system to respond to user request
    - Minimizes dependency on latest technology
- **Dependability**: The ability of a system to function as expected at any given time
    - Increases societal
- **Usability**: Features that enable a system to be user friendly.
    - Contributes to the digital inclusion, by eliminating barriers (learning curve) and making a system more accessible to a broader number of users.
- **Accessibility**: The system's to serve people regardless of location, experience, background, or the type of computer technology used
    - Enables technology to minorities, elderly, people with disabilities, non-English communities, and illiterate population

Economic Sustainability

- **Security** (Authentication, authorization, integrity):
    - insecure systems results in no market success
- **Performance**
    - Improves productivity
- **Dependability**
    - Minimizes support and maintenance cost
- **Usability**
    - Increases customer satisfaction. Minimizes support costs.
- **Accessibility**
    - Increases potential market and/or audience

Environmental Sustainability

- **Safety**:
- **Energy efficiency**:
- **Performance**
    - Minimizes e-waste by extending hardware lifetime
    - Minimizes energy consumption through less computer time
- **Dependability**
    - Indirect benefit
        - Minimizes energy waste
- **Usability**
    - Indirect benefit is less waste of resources used in training (books, training rooms, energy, etc.)
- **Accessibility**
    - Indirect benefit
        - Increases multicultural awareness and provides equal opportunities.

**Some of the guidelines listed above have been directly taken from the references* [28] [29] [30].

4.2 What skill set are demanded for graduate education at a basic level to incorporate sustainability aspects in thesis work? How can one reach the criteria Very High Quality in thesis reports?

As a result from an evaluation made by The Swedish Higher Education Authority, a need for improvement regarding consideration of environmental and sustainability aspects in thesis works arose. The evaluation showed that there was a lack of consideration regarding the aspects mentioned previously leading us to the goal of this report which has been to find guidelines regarding sustainability for students to incorporate in their ICT engineering thesis works.

In order to find a solution for the poor performance surrounding these aspects and help students to not only achieving the criterion for 'High Quality', meaning approved quality, but also 'Very High Quality' the ambition has been to develop guidelines to make this possible. As mentioned previously in chapter 1.4, the ambition of this thesis work has been to help half of the students to at minimum achieve the degree 'High Quality' and the other half or more to achieve 'Very High Quality' resulting in the whole education programme achieving the quality 'Very High Quality'.

The graduation objectives which concerns engineering degrees on bachelor level has been developed by The Swedish Council for Higher Education. As mentioned in previous sections, there are 11 degree objectives, shown in Appendix A and all of these goals are presented in the assessment template for thesis works performed in the bachelor computer engineering programme TIDAB. The programme objectives are sectioned into the areas *Knowledge and understanding*, *Skills and abilities* and *Ability to judgements and adopt a standpoint*. Objective number 10, the objective which will be discussed in this section in order to answer our second question 'What skill set are demanded for graduate education at a basic level to incorporate sustainability aspects in thesis work? How can one reach the criteria Very High Quality in thesis reports' falls under the latter one (third area). For each goal there is three levels corresponding to a quality for which the student has to fulfill specific criteria to achieve a certain level of quality. As shown in the table below, *Lack of Quality*, *High Quality* and *Very High Quality* are the different levels of quality a student can receive depending on how well/poor they fulfill the criterion.

For each objective concerning the education programme, UKÄ, The Swedish Higher Education Authority, has criterion which the students' work will be assessed on. However, students might find these criterion complicated and hard to understand and accomplish, leading to them (the criterion) being neglected or considered poorly. The solution for this is to develop sub-objectives to the main objective, and present the students with skills to perform in order to meet the criterion and finally achieving the desired quality. This skill set is aimed to offer the students the possibility to at least achieve the approved level of quality, 'High Quality', once applied in their work. Moreover, students who wish to achieve the highest level of quality, 'Very High Quality', this skill set enable that also.

Table 5.2.1: The assessment template from UKÄ with the skill set and references to them included.

Level of Quality	**Assessment criteria from The Swedish Higher Education Authority**	**Skills**	**Footnote to the given skill**
High Quality	- *insikt i teknikens möjligheter och begränsningar inbegripet sociala och ekonomiska aspekter samt miljö- och arbetsmiljöaspekter* - *insikt i teknikens roll i samhället och människors ansvar för teknikens nyttjande, inbegripet sociala och ekonomiska aspekter samt miljö- och arbetsmiljöaspekter*	**Bloom nivå 1 – Fakta** ● Känna till detta examensmål i utbildningen och kunna ange dess ungefärliga lydelse. ● Kunna referera till bakomliggande idé och syfte med detta examensmål. ● Känna till arbetsmiljölagstiftningen och översiktligt ange dess innehåll. ● Kunna lista faktorer och åtgärder som berör arbetsergonomi i det egna och andras arbete. ● Känna till globala och nationella miljömål. ● Kunna ange några tekniska och forskningsmässiga tillkortakommanden ur ett tillämpningsperspektiv och samhällsperspektiv. ● Kunna ange teknik och forskning, inom det egna teknikområdet, som förändrat samhället socialt, ekonomiskt och miljömässigt samt ändrat människors ansvar och arbetsmiljö. **Bloom nivå 2 – Förståelse** ● Förstå och redogöra för hur egna och andras teknikkonstruktioner ger samhället och människor möjligheter till förändringar (både positiva och negativa) ur aspekterna socialt, ekonomiskt, miljö och arbetsmiljö. ● Förstå och redogöra för hur egna och andras tekniklösningar kan nyttjas ur önskade och oönskade aspekter och var ansvar finns.	**See Apendix A** **Read** [31]

Very High Quality	• *god insikt i teknikens möjligheter och begränsningar, inbegripet sociala och ekonomiska aspekter samt miljö- och arbetsmiljöaspekter* • *god insikt i teknikens roll i samhället och människors ansvar för teknikens nyttjande, inbegripet sociala och ekonomiska aspekter samt miljö- och arbetsmiljöaspekter*	**Bloom nivå 3 – Tillämpning** ● Kunna förstå och tillämpa de givna riktlinjer som finns i syfte att genomföra ett projektarbete ur aspekterna socialt, ekonomiskt, miljö och arbetsmiljö ● Kunna förstå och tillämpa de givna riktlinjer som finns i syfte för att utveckla system ur aspekterna socialt, ekonomiskt, miljö och arbetsmiljö och/eller kunna förstå och tillämpa kunskaper och metoder från MHU kurser för att utveckla system ur aspekterna socialt, ekonomiskt, miljö och arbetsmiljö. ● Kunna applicera och genomföra vald metod för hänsynstagande till MHU från början och konsekvent genom projektets gång.	**See Appendix B** **See Appendix B** **See Chapter 5·3**

In chapter 2.4, Bloom's Taxonomy was presented, which discusses how a student handles information, by first *remembering* the facts, and once the fact is memorized being able to *understand* it etc. As shown in figure 2.4.1 the two levels which were just described are the first and second levels of the hierarchical model read from bottom. The other levels of Bloom's taxonomy are *Applying*, *Analyzing*, *Evaluating* and *Creating*, in that order from bottom to top. Bloom's taxonomy is a crucial way of handling information because it is not enough for students to only remember the criteria needed for a certain degree; they also have to understand the criteria thoroughly in order to know how to implement it in their work.

Bloom's Taxonomy, presented in chapter 2.4 discusses the different levels of learning. The levels have a hierarchical structure where the process begins by first *remembering* the facts, and once the fact is memorized being able to *understand* it. As shown in figure 2.4.1 the two levels described previously are the first and second levels of the model, read from bottom. The other levels of Bloom's Taxonomy are Applying, Analyzing, Evaluating and Creating, in that order from bottom to top. Bloom's Taxonomy is a crucial way of learning knowledge because it is not enough for students to only remember the criteria needed for a certain degree; they also have to understand the criteria thoroughly in order to know how to implement it in their work. Bloom's Taxonomy increases the quality of knowledge, from it being basic to more advance.

Objective number 10, says that the student has to "*Demonstrate an understanding of technology capabilities and limitations, its role in society*

and people's responsibility for its use, including social and economic aspects, environmental and safety aspects".
In order for students to fulfill this criterion a skill set mentioned previously was developed. The idea behind this skill set is that once the skills are undertaken, the student will achieve the level of quality corresponding to that work. The skill set was developed based on Bloom's Taxonomy and after research a decision was made that for attaining the highest level of quality students have to reach the third level of the Taxonomy which corresponds to *Applying*. The two levels previous to this one will only help the student to achieve the approved level of quality and not higher than that. 'Very High Quality' will however only be attained if the previous skills are undertaken, since the levels of Bloom's Taxonomy are build on top of each other and a higher level cannot be reached without completing the previous, called progression.

A continuation of a specific area in the document 'Course objectives and progression towards education objectives' developed by Anders Sjögren, Head of Degree Programme in Computer Engineering at KTH, was done. In this document, see the first part of Table 5.2.1, i.e. the criterion and skill set for 'High Quality'. Sjögren has listed all the programme objectives and has suggested some sub-objectives which have to be accomplished by the students in order for them to meet the objectives. Throughout this list of objectives, it has been described which progression of Bloom's levels that has to be reached at minimum in order to achieve the specific objective. As of today, the progression regarding objective number 10, is Understanding however this is not enough for students to reach the level 'Very High Quality', they can 'only' attain 'High Quality' resulting in that the education programme also only receives this quality.

As presented in the table, the progression is changed to Applying, with sub-objectives developed for the purpose of giving the students the opportunity to achieve the highest level of quality. Five sub-objectives are developed and each one of them describes the specific skill which has to be undertaken to meet the main objective. The different sub-objectives are described in more detail below:

Each sub-objective described below refers to the corresponding objectives in the order they are presented in Table 5.2.1.

Sub-objective 1
The first sub-objective discusses the students' ability to understand and apply the given guidelines to implement a thesis work by considering the aspects;

social-, economic and environmental sustainability. In order to achieve this sub-objective the student can choose to undertake and consider the content of the guidelines, presented in chapter 5.2, which is aimed to help students to consider the different aspects of sustainability in their thesis works.

Sub-objective 2

Also for this sub-objective students can choose to implement the given guidelines, however; only the content concerning sustainability in software-development (i.e. when developing a system) has to be regarded. The guidelines touching these aspects are for instance discussing the use of energy effective algorithms or using components which have little impact on the environment when used in hardware-systems.

Besides the guidelines, in order for the student's to know how to implement sustainability in their work or product it is necessary for them to have the basic knowledge regarding sustainability in conjunction with software-development/software-development-projects. However, since sustainability is not a major topic in IT as in other areas it might not be perceived as straightforward and clear as in what to consider regarding this aspect. To solve this, students have to be exposed to the idea of sustainable development early on in the education, for instance during an introductory course or by establishing a mandatory course in the education programme. Therefore, for achieving this sub-goal a student can choose to both implement the guidelines and/or using the knowledge learned from previous courses.

Sub-objective 3

As mentioned below research question 1 and research question 3, a mechanism is needed to trigger the idea of applying and implementing a method for sustainability throughout the thesis work. The proposed mechanism needed for this aim is the SEMAT Essence Kernel cards used in software engineering projects to help discipline projects. By applying this method from beginning to the end of the project it will help the students to consider the different three main aspects regarding sustainability. A concern card presented below research question 3 discusses Sustainable Development, and the purpose of this card is for it to be used consistently during the thesis work to prevent the important issue of sustainability of sustainability being disregarded. Using this card will initiate a proactive way of working right from the beginning of the project.

4.3 What methods can be used in a proactive way of working?

Students can implement the Alpha State Cards used for agile software development provided by the SEMAT organization so that the sustainability aspects are taken into account early on in the thesis work, leading to a proactive approach rather than a reactive approach which is the most common approach among students today.
In chapter 2.5 where the SEMAT Essence is presented; besides the three absolute concerns that are already described in chapter 2.5, other concerns which might also be appropriate to a project can be developed. For this research question we have put out an idea out for future works, we have started to implement an Alpha State Card of Sustainable Development.

A starting idea of Anders Sjögren that we have begun to develop, see figure 5.3.1. We have concluded to four states: *Objectives Defined, Agreement with Stakeholder, Strategy* and *Quality Analyzed*. With Objectives Defined the thought is to set the goal for the considering aspects of sustainable development, what policies the team is following in order to create a system that is sustainable. In Agreement with Stakeholder the team has to for instance address the environmental and sustainable policy with the stakeholders. The Strategy state is intended for a team to go through the checklists made for sustainable development, see Appendix C, meet the criteria The Swedish Higher Education has established for environmental and sustainability aspects in thesis works as well as the reference list should be followed, see chapter 5.4. Quality Analyzed is intended to be the last state and should contain checklists of how a team should review the quality sustainability, how they have taken it into account.

Figure 5.3.1: A sketch of the Sustainable Development alpha card.

5 Discussion

In this chapter an analysis of the literature study and the interviews which were conducted has been done.

5.1 Discussion of Literature Study

The literature study was started from the beginning and continued on for a longer time than predicted. We first achieved physical help from the KTH Library; an appointment was booked with a librarian who guided through the different appliances available like Primo, Libris, etc. for searching different articles available.

Considering sustainability in ICT or in software engineering isn't so common today as hoped, it was a bit difficult to treasure literature on this subject. However, there is a lot of literature in other technology based industries (i.e. construction) in the subject of environmental and sustainable development, where an assemblage of literature already exists. Some aspects of sustainable and environmental in construction meet with ICT/Software Engineering such as the aspect taken into account with the development team as one example.

Our mentor, Anders Sjögren, gave us a review article written by Birgit Penzenstadler which is called Sustainability in Software Engineering. Automatically after reading the review, the thought about there being more than just a review by this author arose. Because it was a well written literature review about in what different aspects one can take sustainability into account in software engineering, a research on the articles by this author was done and the research gave us the key article reference for the guidelines that were made.

Other advantageous literature found in discussion with the mentor was the SEMAT Essence, which gave the idea of developing an alpha card called Sustainable Development. Since the SEMAT Essence is a large method and theory initiative with different disciplines, there was not enough time to develop a whole alpha card. Nonetheless, an idea of what the alpha Sustainable Development card visually could look like (or a draft) was done in reference to the other literature study done, and not just the research on SEMAT organization. SEMAT was profitable when it came to the manner on how the alpha card should be inclined.

To create an alpha card one must do a prolonged in-depth research on this subject to analyze how to the different checklists, things to work with, competencies etc. are/were developed, see chapter 6.1 for Future works.

5.2 Discussion of Interviews

As mentioned in previous chapters, the research method contained conducting interviews with different participants from various areas of expertise, with the aim of gathering information to help answering the research questions. Four interviews were conducted, whereof two of them was face-to-face with the interviewees and the two others were digital, meaning the interview questions was sent to them via e-mail and the answers were also sent back through email.

The interview questions were specifically constructed for each of the participants, and adapted for them based on their expertise area. Some of the questions were however similar for all of them, as shown in Appendix D where the interviews have been compiled.

The main focus with the interviews was to gather information, which would guide us to develop the method for considering environmental and sustainability aspects in thesis works. Therefore, it was important that the questions were formulated in such way it would contribute to the guidelines, skill set and the SEMAT Essence Kernel card.

The amount of information we initially thought that we would gather after conducting the interviews was less than what we actually hoped. Even though the participants are involved in the subject-area, it was difficult for them to give us the exact answers on what was missing today, or what could possibly be done in the future, in order to find a solution for the subject-matter. However, the answers differed from the various interviewees, and we got an interesting insight in how each of them had similar, yet different, thoughts on the topic and questions.

Anna Björklund, one of our three participants for the expert interviews said, as mentioned in previous chapters, that a mechanism is needed right from the beginning of the thesis work in order for the students to be engaged in the subject-matter early on. The mechanism Björklund was referring to was to incorporate the topic of sustainability during the project definition phase and making sure that the students really considers this aspect before being allowed to move on to the next phase of the project. The topic of sustainability is already discussed in the mandatory document Project Definition which every

students have to write before beginning with the thesis work, however, Björklund was saying that the students could be offered sub-questions or key concepts to guide them in the right direction when it comes to a sustainable way of thinking. This idea was also shared by our other participant Anne Håkansson, who also pointed out that in addition to this, sustainability regarding the ICT-area can be exemplified.

For the last expert interview the focus was on trying to find out if there existed any framework for specifying how environmental and sustainability aspects can be regarded in Software development projects. Mira Kajko-Mattson, associate professor in Software Engineering at KTH, the participant for this interview, said that she was not familiar with any specific framework for that purpose and that the term sustainability can be complex with many different meanings. Kajko-Mattson was describing that sustainability for a system can be that the system is easily maintained and therefore it can automatically be considered as sustainable. When asked about what is needed for students to consider sustainability in their thesis works, the answer was that the term sustainability can have different meanings, depending on if it is the working environment or if it is the system environment that is being referred to. If the concern is about being environmental-friendly then students have to regard being energy-efficient or not overusing paper for instance, or that perhaps the project members could decide to meet virtually instead of taking public transportation with the aim of not contributing to pollution. An interesting insight which Kajko-Mattson shared was that she could agree that outsourcing can have benefits for economic sustainability, but it could at the same time be disadvantageous for the system since communication between project members would not be as immediate as if it would be if they worked together in an office where exchanging thoughts and ideas can take place immediately, leading to better quality in the system they are developing.

The fourth interview, which was an industry expert interview, was conducted with Madeleine Bergrahm, a sustainability manager at HP (Hewlett-Packard). The aim of this interview was to get an insight into how sustainability aspects are regarded in the industry. When asked about what methods students could use for incorporation of sustainability aspects in their thesis works, Bergrahm explained that it is important for students to see the whole picture. For instance, if their task is to optimize a way of calculating material consumption and they only choose to analyze the weight of the material without considering the energy consumption, then it can lead to a sub-optimization. She suggested that it is important to see whether the product that is being developed will have a positive effect in society or not. One of the questions asked was if there were any guidelines for sustainability which projects have to follow, and it

turned out that HP did have guidelines for the own work, the supply chain and for how they communicate with customers. Information regarding the guidelines was provided in the policies HP have for the different areas of concern. The policies that was provided as a part of the answer to the question described earlier also helped to developed the guidelines for this thesis work, since similar aspects as the ones which students in ICT thesis works have to consider was discussed in the different policies.

5.3 Discussion of the Results

The three research questions that were developed with the aim of solving the current issue, being that students are considering environmental and sustainability aspects poorly in their thesis works, has been answered throughout this work. Our research questions resulted in some guidelines for the students to incorporate in their thesis work, helping them to consider the aspects mentioned previously.

How can the transition from a reactive approach to a proactive approach be implemented?

Chapter 5 begins with answering our first research question, which was 'How can the transition from a reactive approach to a proactive approach be implemented'. After conducting both a meticulous literature study, reviewing of old thesis reports and expert interviews we concluded the fact that there was a need for a mechanism that would trigger the idea of implementing a thesis work by considering sustainability aspect right from the beginning of the work and consistently throughout the work. We found that even though sustainability was a topic in both the Project Definition document and the report template, students were still not considering it in proper manner and that something else had to be developed to help them.

After careful research we decided that a mechanism for adopting a sustainable way of thinking in a thesis work, consequently from beginning to end, could be implemented by using the Alpha State Cards which are used for software development, developed by the SEMAT organization. Since these cards are constructed in such way that the project has to follow and measure different phases during the work it "forces" them to execute a sustainable project (since the group has to follow through with each of the states for it to be considered that the alpha has been accomplished).

Another mechanism for a proactive approach is that each group can choose to write a policy in which it is stated how sustainability aspects will be regarded during the thesis work. The group can either decide that sustainability will be

considered throughout the thesis work by for instance using the Alpha State Cards mentioned above, or they can write that no consideration will be regarded in a proactive way, but a reactive approach will rather be taken towards the end of the project. If the group chooses not to be proactive, they can conduct an impact assessment after finishing the project and discuss the different consequences their work may have in regards to sustainability. This approach would be similar to the one that is commonly used today, however, they could choose to follow the guidelines in chapter 5.2 to assess their own work, or to see if their system or development process can be considered as sustainable or not.

What skill set are demanded for graduate education at a basic level to incorporate sustainability aspects in thesis work? How can one reach the criteria Very High Quality in thesis reports?

As the result suggests in chapter 5.2, a skill set is demanded for the students to follow during their thesis work with the aim of reaching all the criteria needed for Very High Quality in the assessment template regarding the objective *"Demonstrate an understanding of technology capabilities and limitations, its role in society and people's responsibility for its use, including social and economic aspects, environmental and safety aspects"*. During the literature study we recognized that the objectives for the quality levels 'High Quality' and 'Very High Quality' can be difficult for students to understand since they are not formulated in such way that it is clear as what needs to be performed to fulfill certain criteria. Our mentor, Anders Sjögren, provided us with a document where an attempt to clarify these criterions has been made. For each objective regarding the quality 'High Quality' Sjögren had developed sub-objectives, which can be seen as skills that are necessary for students to perform in order to achieve the desired level of quality. However, as mentioned in the result chapter, a set of skills had not been developed for 'Very High Quality' and we concluded the fact that there was a need for it since the objectives for this level could also be hard to perceive leading to not considering them at all.

If we reconnect this issue to the main issue that developed the idea for this thesis, it was that the Degree Programme in Computer Engineering at KTH, among others, had been reviewed by UKÄ, The Swedish Higher Education Authority, and the result of the review was that there was a lack of quality regarding the objective previously mentioned. Half of the thesis works performed by the students have to achieve at minimum 'High Quality' and the other half or more have to achieve 'Very High Quality' in order for the whole education programme to achieve 'Very High Quality' resulting in an improvement.

The literature study showed that the demanded skill set should be comprised of the other methods that were developed to answer research question one and three. Meaning, in order for the students to reach the criteria Very High Quality in their thesis reports they have to implement the methods presented to them as *Skills* in Table 5.2.1. If and when these skills are performed, the students should receive the highest level of quality.

What methods can be used in a proactive way of working?
By using the method of following an Alpha card for Sustainable Development, which has yet not been implemented completely, the way of working automatically turns proactive because of the different states the card has for the working team and product.

At the beginning of the thesis project it was not meant to create an alpha card. But because of the literature treasured in the literature study phase and a discussion with our mentor, Anders Sjögren, we thought about somewhat kicking off with the idea. We were aware of the comprehensive study it was going to take and we were skeptical with the time span which was already outlined and decided to leave the excess for other future works.

With a complete alpha card for sustainable development, the students will efficiently become proactive in their sense of working in whether it be a regular ICT thesis report or thesis work.

Method and Delimitations
Our approach for developing some guidelines for students to use in their thesis work was to conduct expert interviews and a literature study. We developed a model of the method which was divided into different activities, see Figure 3.1.1., these activities were however overlapping, meaning that one activity did not have to be fully accomplished to move on to the next one, leading us to performing the literature study and interviews simultaneously as we were developing the methods for consideration of sustainability aspects.
As described in chapter 3 we chose various methods for work planning, the Project Triangle being one. The Project Triangle suggests that there are three variables which have to be considered during a project and these are *Duration*, *Resources* and *Scope*. All of the corners are dependent on each other and changes in one corner might affect another corner.

During this thesis work we also chose to work with the MoSCoW method which is a technique for prioritization used in projects. We listed everything that was necessary to include in the project as Must Have, which was methods

for implementing a sustainable way of working in thesis projects, and Should Have was consideration of the aspects ethics. Other aspects, such as how students can consider work-environment and ergonomical aspects were listed as Could have. Due to the time limit, we mainly prioritized the Must have and Should have so that we would stay within the frame of the Project Triangle, however, the corner "duration" was still expanded as a consequence of the literature study and interviews lasting longer than expected.

In chapter 1.6 where the delimitations were discussed, we described that the work would be limited to only the area of ICT. During the literature study this was an obstacle, since the amount of previous research surrounding this area was very limited and it was hard to find information that would help us progress and develop the desired guidelines. This resulted in that we had to search for studies done within the similar area, but in other fields, such as construction and also that we had to depend on the information that was going to be gathered from the expert interviews. Another delimitation was the participators of the interviews, since it was important to gather valuable information we had to ensure that the interviewees chosen would provide us with the information we were searching for. Even though the participants were chosen carefully to fulfill this task, we did not receive as much information as we initially had thought we would.

Future Works

Most of the methods for this thesis have been fulfilled. However, there is one prime method that had not been done for this report, as planned, which was testing of the methods on other previously submitted ICT thesis work. To which the report authors would get feedback from the stakeholder and then see if the criterion for Very High Quality was met, if not the test would've been done again till it is met. This would be great to refine, as it is important to acknowledge if the methods would actually work on project reports that have had a reactive approach.

Other possible future work on this platform can include:

- A complete SEMAT Alpha card on Sustainable Development, as mentioned in chapter 6.1, one must do a detailed study on this subject to meet the standard that Ivar Jacobson has developed. On this report only a sketch has been developed of what the Alpha card on Sustainable Development could include, it is not in-depth but an overall idea, see chapter 5.3.

- The Table 2.3.1 can by future workers is translated in English since the report in general is in English. Nonetheless, the reason why we have not compassed this is because the time does not allow and it is produced by a high authority so the translation considering that needs to be accurate.

5.4 Conclusion

The overall research presented showed that to accomplish high criteria in students thesis work in the subject of sustainability, something had to be provided to the students for them to easily bargain references to use. During the thesis work, which included a literature study and interviews, methods were developed to decrease the issue of students not incorporating sustainability aspects into their work. The methods that were developed were: Guidelines for the students to follow and take into account during their project in different aspects of Development, Maintenance, Production and Usage considering the three dimensions of sustainability: economic, environmental and social sustainability

For reaching the highest level of quality to when not only memorizing and understanding but also applying the methods, Bloom's Taxonomy was used as a basis for measuring the level of knowledge quality. A skill set for 'Very High Quality' regarding the criteria of objective number 10 was developed for the students to identify how they can achieve that certain level of quality in the subject of sustainability.

Also an idea of the Alpha State Cards by the SEMAT organization was presented with the aim of enabling consistent implementation of sustainability from beginning to end in thesis projects. The card contained states such as Objectives Defined, Strategy, Agreement with Stakeholder and Quality Analyzed, and can further be implemented and adjusted.

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Appendix A – Degree goals

Study Programme

Degree Programme in Computer Engineering Högskoleingenjörsutbildning i datateknik, Kista
180.0 credits

Valid for students admitted to the education from Autumn 16 (HT - Autumn term; VT - Spring term).

Programme objectives

The purpose of the Degree program in engineering at KTH is to train students for computer engineering of high international standard to meet society's needs for competence for the use and development of technology. Training must be balanced so that the engineer students are well prepared to begin practice in their profession, but also have a good basis for continuing self-development and learning.

For engineering programs, in particular, it is necessary to provide knowledge and skills in applied mathematics, basic and applied technical subjects, computer systems and its use and the knowledge and understanding of technology and engineering work, general conditions.

Especially for this Degree program is the focusing on information technology that builds up and allows for the modern Internet. This is done in several aspects which are matched by education specializations, see appendix.

The purpose of the different orientations is to meet society's need for complementary areas of expertise in these areas with sufficient skills and knowledge depth.

Knowledge and understanding

For Bachelor of Science in Engineering, shall the student

- Demonstrate knowledge of the scientific basis for computer technology and its proven experience and knowledge of current research and development work.
- Demonstrate broad knowledge in the chosen technology and relevant skills in mathematics and science.

Skills and abilities

For Bachelor of Science in engineering, the student

- Demonstrate ability to holistic independently and creatively identify, formulate and manage issues and analyze and evaluate various technologies related to information technology.
- Demonstrate an ability to plan and using appropriate methods carry out tasks within a given framework.
- Demonstrate an ability to critically and systematically use knowledge and to model, simulate, predict and evaluate events based on relevant information;
- Demonstrate an ability to design and manage products, processes and systems with regard to human conditions and needs and society's objectives for economically, socially and ecologically sustainable development,
- Demonstrate ability for teamwork and collaboration in groups with different composition.
- Demonstrate ability to verbally and in writing, explain and discuss information, problems and solutions in dialogue with different groups.

Ability to judgements and adopt a standpoint

For Bachelor of Science in Engineering, the student shall

- Demonstrate an ability to make judgments in the light of relevant scientific, social and ethical aspects;.
- Demonstrate an understanding of technology capabilities and limitations, its role in society and people's responsibility for its use, including social and economic aspects, environmental and safety aspects, and
- Demonstrate an ability to identify their needs for additional knowledge and to continuously develop their skills.

Appendix B – Guidelines

Development Process Aspect

Social Sustainability

- Security:
  - Changes in the system should only be made by authorized members.
  - Unauthenticated users should not be able to access the developing system
- Privacy:
  - Data privacy of team-members, which includes:
    - Social security number
    - Phone number
    - Address
  - But also:
    - Data use
    - Data access
    - Data integrity
- Interaction
  - Good working environment for the team-members, meaning mutual respect
- Fair employment
  - Gender-equality
  - Sexual orientation
  - Race
  - Ethnicity
  - Religion
  - National origin
  - Age
- Fair Working Conditions
  - Healthy and safe working environment

Economic Sustainability

- Safety:
  - Unsafe products will not lead a company to reach long-term economic terms (ref s.24)
- Capital budget
  - Define capital budget for planning and controlling project cost
- Finance plan
  - Define and plan in detail when and how the budget will be used

Environmental Sustainability

- Safety:
  - No chemical or other hazardous accidents
- Place of work:
  - Smart communications, i.e. choosing the train rather than choosing the car.
  - Team-members should have the possibility to work remotely instead of coming to the work
- Energy consumption

- Taking energy consumption into account and not overusing more than needed

Maintenance Process Aspect

Social Sustainability

- Safety
- Security (Authentication, authorization, integrity):

Economic Sustainability

- Safety
- Cost
  - Ett system som kostar mer att underhålla är bättre att ta ur drift

Environmental Sustainability

- Safety:
- Energy efficiency:
- Reduction and disposal of waste
- Conserving, reusing and recycling

System Production Aspect

Social Sustainability

- Safety:
- Security(Authentication, authorization):
- Integrity:
- Privacy:
- Modifiability: Ability to introduce changes quickly and cost effectively
  - Enables system to be continuously adapted to meet societal demands
- Reusability: Level in which system components can be reused in other systems
  - Enables the production of new products with less effort
- Portability: Ability of the system to run under different computing environments.
  - Reduced cost for technology adoption, by minimizing user's dependency on latest technology.
- Supportability: System's ability to be easily configured and maintained after deployment.
  - Vendor's independence increases the product usability and thus accessible to a larger population.

Economic Sustainability

- Safety:
  - If the product is not safe, there will not be an economic success.
- Modifiability
  - Minimizes development and support costs
- Reusability
  - Accelerates time-to-market
- Portability

    - Increases potential market and system's lifetime.
- Supportability
    - Increased customer base due to reduced support costs.

Environmental Sustainability

- Safety:
- Components (Reuse and recycle)
- Algorithmic efficiency: (Minimize energy consumption)
- Modifiability
    - Minimizes environmental waste through less effort in producing and maintaining existing system
- Reusability
    - Minimizes environmental impact through less effort in producing system
- Portability
    - Minimizes e-waste by extending the lifetime of old hardware.
- Supportability
    - Indirect benefits are minimizers of

System Usage Aspect

Social Sustainability

- Safety:
- Security (Authentication, authorization):
    - the user must be protected, i.e. user information
    - unauthorized access
- Integrity (Corporate ethics, human rights, government relations)
- Privacy:
    - for instance, privacy breaches in online banking
- Human Computer Interaction:
    - support for disabled persons (address societal and economic issues, such as digital inclusion and disability inclusion).
- Performance: The time required by the system to respond to user request
    - Minimizes dependency on latest technology
- Dependability: The ability of a system to function as expected at any given time
    - Increases societal
- Usability: Features that enable a system to be user friendly.
    - Contributes to the digital inclusion, by eliminating barriers (learning curve) and making a system more accessible to a broader number of users.
- Accessibility: The system's to serve people regardless of location, experience, background, or the type of computer technology used
    - Enables technology to minorities, elderly, people with disabilities, non-English communities, and illiterate population

Economic Sustainability

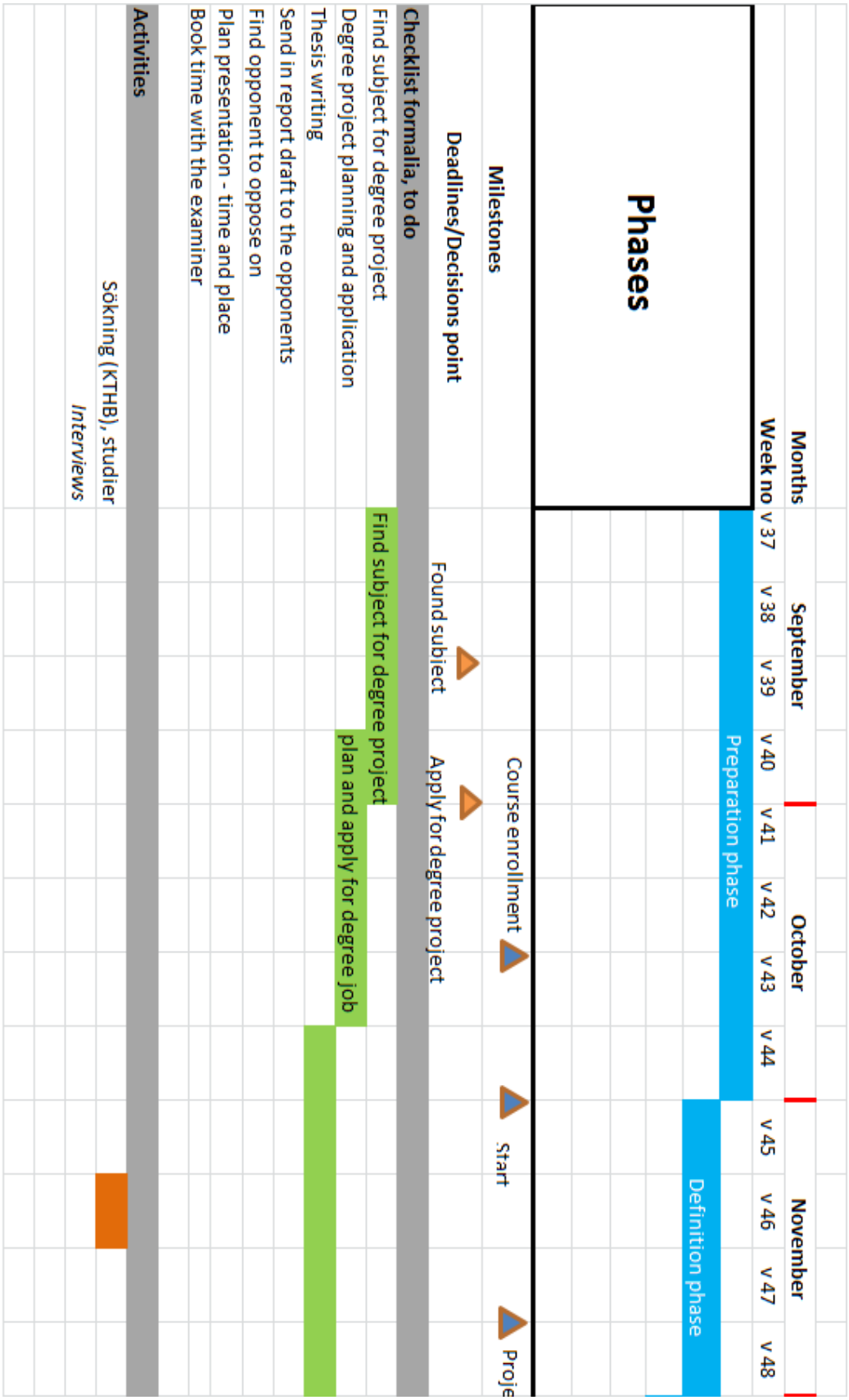
- Security (Authentication, authorization, integrity):
    - insecure systems results in no market success

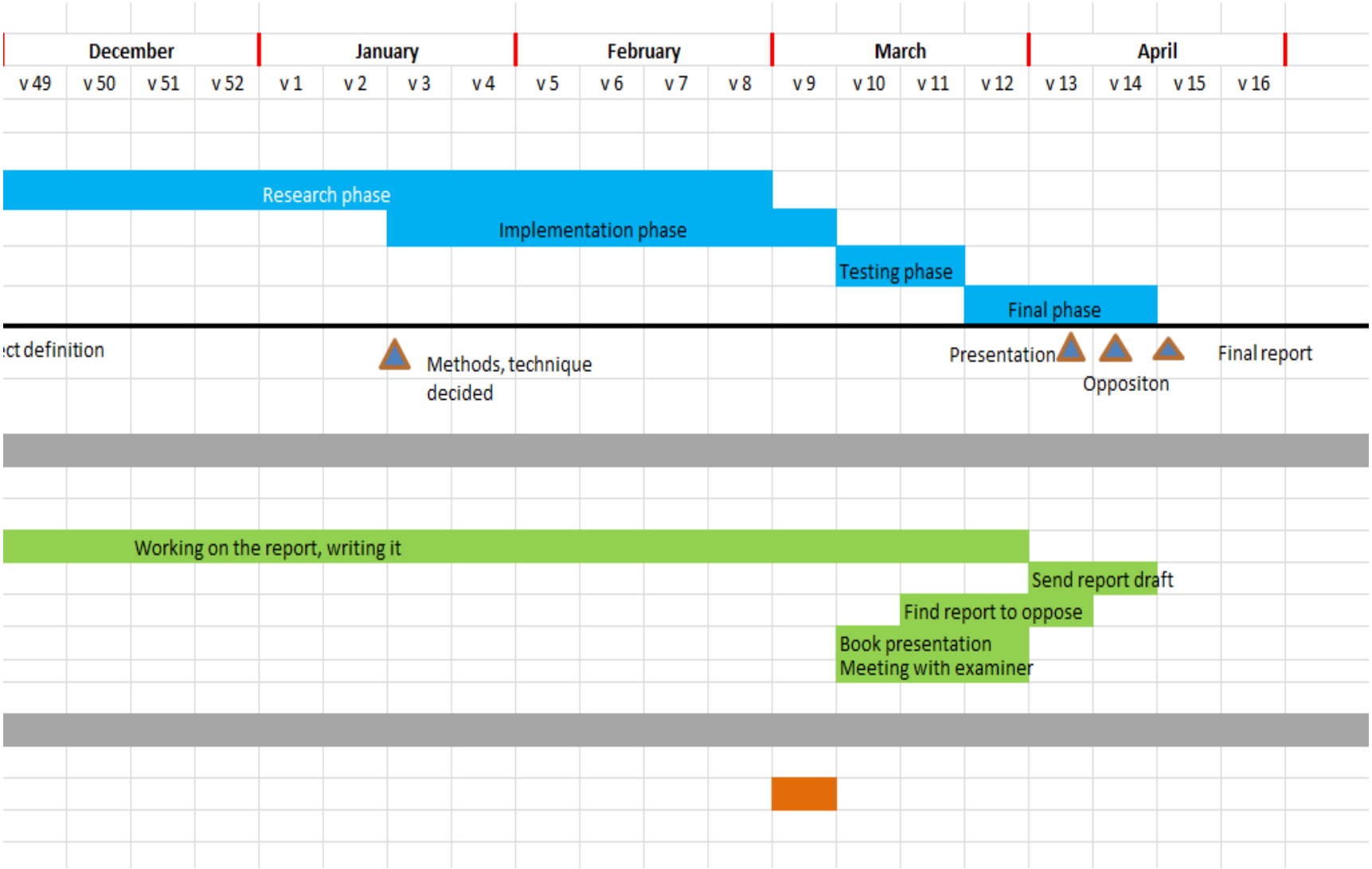
- Performance
    - Improves productivity
- Dependability
    - Minimizes support and maintenance cost
- Usability
    - Increases customer satisfaction. Minimizes support costs.
- Accessability
    - Increases potential market and/or audience

Environmental Sustainability

- Safety:
- Energy efficiency:
- Performance
    - Minimizes e-waste by extending hardware lifetime
    - Minimizes energy consumption through less computer time
- Dependability
    - Indirect benefit
        - Minimizes energy waste
- Usability
    - Indirect benefit is less waste of resources used in training (books, training rooms, energy, etc.)
- Accessibility
    - Indirect benefit
        - Increases multicultural awareness and provides equal opportunities.

Appendix C – GANTT chart




December
January
February
March
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v 10
v 11
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v 14
v 15
v 16
Research phase
Implementation phase
Testing phase
Final phase
ct definition
Methods, technique decided
Presentation
Oppositon
Final report
Working on the report, writing it
Send report draft
Find report to oppose
Book presentation
Meeting with examiner

Appendix D – Interviews

Anna Björklund
ASSOCIATE PROFESSOR (FOR SUSTAINABLE DEVELOPMENT AND ENVIRONMENTAL SCIENCE)

How do you define sustainability and what does environment mean to you?

What we teach on environmental and social grounds, not deplete the ability of future generation or other people and live a good life. What we do and what we consume affects the environment and affects other people. I work mostly with technology solutions and how that affects them. My focus is the life cycle approach; how things are made and how they are used and what happens to them and what happens to them in the waste phase. If you think in a engineers perspective then it's what we do, how it affects and also the things we consume how does it affect.

How did you get introduced to environmental and sustainable development and why do you feel that it is important to take that into account in the technology industry?

I was introduced to environment when I was in high school but then we wouldn't speak about sustainable development in 80s-90s, we would then talk about environmental emissions chimneys, fishes that would die, waste, debris, etc. I didn't understand that the environment had so much to do with technology and society; instead there was a lot of focus on what there is in the environment.

I studied at KTH to become a chemist and thought that chemists are those who can do something about environmental problems but it was not included in the education, not until when I was doing my masters. But even then it was a lot of focus on ecology. When I did my PhD I got an insight of how much engineers can do and they can solve the problem with the new technology.

What is missing for the students today to take environmental and sustainable development into account?

The thesis reports that I mentor have that as a basis. But I can understand that is is difficult to take it into account especially if you get a project from the industry. When developing e.g. algorithms there is no immediate sustainability clutch and I actually think there are some IT thesis reports that don't have a sustainability disposition. Some tasks will never have a environmental bond but on the other hand, as an engineer, you most often start here in the little problems in the small problem solutions and quickly sail up in the hierarchy of the company.

Today, most of the students are reactive rather than proactive in their consideration regarding environmental and sustainable development aspects in their reports. Why do you think that is?

Many students will of course find it difficult to come up with what to write about, but considering that you can give them leading questions in project plan. In the sustainable development course, that I run, we mention some things with the impact on the life cycle, indirect and direct effects, rebound effects and the impact on personal and professional level (does it affect the everyday lives or the company/industry). Maybe give a number of key concepts to get started with this way of thinking, because if it just says "what does this have to do with sustainable development?" the answer will most likely be "I don't know". Put it in as a checkpoint so that the students can't move on until they've talked about it, commented on it and written a motivation on how they will handle it when working with problem solution or will I not handle it, describe why.

It is better to work proactively so that you have planned it, because after it becomes too late.

How important is it for students to have a basic understanding of environmental and sustainable development during the thesis work, given that they will later need to consider the subject in their work life?

It is a requirement of the Higher Education that everyone should study sustainable development in order to graduate, but there are no requirements on how to do it.

ICT engineers have to talk to environmental experts about the how the problem looks. You can't control everything but as much as possible.

Mira Kajko-Mattson
ASSOCIATE PROFESSOR, DOCENT KTH

Are you familiar with any framework where sustainability is regarded in software projects? Nothing is mentioned about sustainability in SEMAT.

There is a concept called sustainability however, I am not familiar with any framework and sustainability can be perceived as a complex concept with many different meanings. Sustainability for a system can be if the system is maintainable, i.e. if the system is maintained easily then automatically it will be considered as sustainable. Only the most crucial parts that are needed for system development are included in Essence (the result of SEMAT). If you, as a developer or a project member, has included the aspects then your system can be considered as sustainable. The different alphas, i.e. Customer area of concern, System area of concern, Team, Way-of-Working and Work are the most essential aspects that needs to be included, however, many can agree that planning and sustainability are important aspects that are missing.

Based on your role, experience and knowledge – how do you think students can consider Environmental and Sustainability aspects in their thesis work?

Once again, it is important to define what we mean with environment; is it the working environment we are referring to or the systems environment. In regards of considering sustainability aspects, it should be considered in every project and not only school projects. For instance, if project members choose to meet virtually it will result in less contribution to air pollution caused by public transportation.

When and if you have been supervisor for thesis work, has there been anything missing which they could have used for considering sustainability aspects in their work?

I have never required that my students should consider sustainability aspects in their thesis work.

During the course Software Engineering, sustainability aspects were not regarded during the project work and this can be considered as problematic; how do you think students can consider these aspects in:

1. ***the product they are developing***
2. ***the way of working***

This is a task which the education programme is responsible for and they should provide a way for how students should incorporate these aspects into their thesis work. I only teach how students should work together, how they should build teams and how this will contribute to the mental and physical

environment. How a team is shaped is more important for me to teach during a development course rather than explaining how to be energy efficient.

Which guidelines (regarding Sustainability) are needed in order for students to use in their degree work?

Students should be given the opportunity to work at any desired place as long as the job gets done and they should of course follow methods. This is on the other hand education and if the project members of a group decides to work remotely at different locations in the world the task will not be done as well as if they work closely where they can discuss ideas, react to and regard different problems. We are working with distributed development and within distributed development there are major issues due to them not being physically close to each other since some developers are situated in India, some in Germany and the rest of them in Sweden.

What kind of problems can arise?

Many different, for instance if you want to ask a quick question to an individual or that if you don't work in the same office you don't get the opportunity to familiarize yourself with the other group members which will affect the relationship. This leads to working in the opposite direction of considering sustainability aspects since companies choose to fly-in developers from India so they can work together due to the physical distance can be disadvantageous to the development.

How can guidelines be developed for students which they can implement in their own work (within the project) but also in the product?

Regarding the product, when the product is being developed you evaluate how it will affect the environment or how the environment will affect the product, because that is equally important. For instance if you design a car which can be used in a tropical country then it is not properly designed to be used in a cold country and vice versa. The same idea can be implemented regarding sustainability; the sustainability of the system and how it affects the environment.

Anne Håkansson
ASSOCIATE PROFESSOR, DOCENT

How do you define sustainability and what does environment mean to you?
Sustainability includes three pillars – environment, economy and society. For me, environment means the surrounding nature.

Based on your role, experience and knowledge – how do you think students can work with Environmental and Sustainability issues in their thesis works?
By providing information about what Sustainability is and by helping the students to apply Environmental and Sustainability aspects into their own work.

What is missing today which students can use to incorporate Environmental and Sustainability aspects in their thesis works, such as guidelines for instance?
Understanding how Environmental and Sustainability aspects can be applied on ICT-subjects

Today many students take a reactive approach rather than a proactive approach regarding considering Environmental and Sustainability aspects in their thesis works, what could be the reason behind this?
People are generally more reactive than proactive. It is not easy to be proactive if you cannot foresee what obstacles you might come across.

Which guidelines (regarding Sustainability) are needed in order for students to use in their degree work?
In the report template today, there is a heading called Sustainability and perhaps subheadings can be developed for each of the pillars mentioned previously below the first question. In addition to this, sustainability regarding the ICT-area can be exemplified.

How can guidelines be developed which students can implement both in their work (within the project) but also in the product?
This question is hard to answer. Again, examples of works within the surrounding area could help.

Have you ever encountered problems with a project when sustainability has not been considered?
Yes, many times. For instance, sustainability for an algorithm and it is difficult to see sustainability in a broader perspective.

Madeleine Bergrahm
Sustainability Manager, HP (Hewlett-Packard)

How do you define sustainability and what does environment mean to you?
Resource efficiency regarding time and materialistic resources. If time is released from operational work which is performed the same way every time (for instance on an IT department at an institution like KTH or a company) then the staff can devote time for innovation instead.the time can be devoted to how repetitive work can be done smarter and more fun. Environment is a broad concept, with different meanings at different times.

Based on your role, experience and knowledge – how do you think students can work withEnvironmental and Sustainability issues in their thesis works?
It is important for the student to see the big picture. If they are for instance going to optimize a way to calculate the material consumption in production and only focuses on the weight of the steel/plastic without looking at the energy consumption, storage requirements for alternative materials (time, humidity, temperature, heat etc.) then it can lead to a sub-optimization. I also think that students should ask themselves whether the product or the process they are viewing has a positive value for society.

Are there any guidelines regarding sustainability which project groups can follow?
HP has worked with global citizenship since the 1950s; "doing well by doing good". We do have guidelines for the own work, for the supply chain and for how to communicate with our customers.
Please look at our Policies (http://www8.hp.com/us/en/hp-information/global-citizenship/governance/policies.html)
And Global Specification for the Environment
(http://www8.hp.com/us/en/hp-information/global-citizenship/society/general-specification-for-the-environment.html)

If there are any guidelines for consideration of sustainability aspects in projects, how have these been developed? How can this development method be used to develop similar guidelines for students in their thesis work?
The various guidelines have been developed over time, i.e. environmentally sound construction DfE, Design for Environment 1992 etc. For the work within the supply chain HP has worked with other companies in the EICC. Here is a summary of how we work with sustainability and human right in the supply chain:
(http://www8.hp.com/h20195/v2/GetDocument.aspx?docname=c04945685)

In other words, there is no single method for developing guidelines. Within the supply chain we analyse where there may be risks and then evaluate them. It is a continuous process.

How important is it for students to have a basic understanding of sustainability already during the thesis work, given that they will later need to consider if when stepping into the industry?

I think the question formulation reflects a particular approach to sustainability since it is expressed as something that they "will have to take into account". You can turn the argument and express it in a way that via sustainability a broader perspective is being opened. Students who acquire a basic understanding will be able to evaluate future employers on more parameters. Both legislation and market requirements regarding sustainability are being strengthened (in Sweden and internationally) and not having the basic knowledge about sustainability can result in businesses becoming unprofitable.

Have you ever encountered problems with a project when sustainability has not been considered?

Since I am specifically working with the topic this is not something I have experienced. On a local level there can possible be a need for a process for our offices that may not have been implemented since a lot is controlled on a regional (EU) level.

During the course Software Engineering sustainability aspects were not regarded during the project work and this can be considered as problematic; how do you think students can consider these aspects in:

1. ***the product they are developing***
2. ***the way of working***

Please see the answer to question 4.

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