The evolving perceptions of sustainability in CS and SE education: findings from a master's programme

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***Abstract— Context**: Sustainability and sustainable development are emerging trends all around the world. The need for changes is evident and immediate. **Problem**: In order to address all the technical and social sustainability challenges people need to be educated. So far computer science and software engineering education has not fully answered to this need. **Contribution**: This paper presents one sustainability-focused ICT programme and analyses its evolution in order to find out the lessons learned after three cohorts of graduated students. This analysis is based on an evaluation model built based on literature. **Results**: The outcome of the analysis shows that understanding of the sustainability and thus the ways to increase the impact increases year by year. Although the evolution is quite evident and follows the general research trends the better impact and better readiness can be achieved through increased understanding.*

Keywords—Sustainable development; Sustainability; CS education; SWE education; Green IT; ICT for Greening

I. INTRODUCTION

Sustainability and sustainable development are key concerns that need more attention in software engineering and computer science education. Earth, our living environment, has severe problems in its ability to support the humankind. The earth's overshoot day[1], the date when humankind has exhausted nature's budget for the year, is becoming earlier and earlier and as such expressing the over usage of natural resources. This year, the global overshoot day will be August 2nd meaning that we need approximately 1,7 earths to support our living. In some places the overshoot day is much earlier, e.g. in Finland and in Germany in April and in USA and in Australia in mid March. This means that Australia and USA needs more than 5 earths to support their living and Germany and Finland more than 3 earths. The earth's overshoot day is evidence that "*We are living beyond our means largely by borrowing against the future*" [9]. This borrowing happens in a way that does not allow sustainable future. The question lies how much we really have time? Rockström et al. presents in the article [28] nine planetary boundaries for safe operating space for humanity. Out of these the climate change has been emphasized the most. The Paris climate conference (COP21[2]) achieved the first-ever universal, legally binding global climate deal. Governments agreed to sets out a global action plan to put the world on track to avoid dangerous climate change by limiting global warming to well below 2°C above pre-industrial time. The action plan requires strengthening the society's responsibility in the process. Education is one way of increasing the knowledge that lead to actions towards sustainability. Unfortunately, education is not emphasizing the sustainable development as it could.

Education for sustainable development has been proclaimed during the last three decades by several international declarations to be essential in order to promote responsible and sustainable conducts of societies [35-37]. In order to design a longstanding sustainable future, certain mind-sets need to be changed to embrace more participative and collaborative cultures where human activities are sustainable rather than environmentally degrading. Education in all levels is the mean to achieve such transition [1]. One of the emerging fields incorporating sustainability concerns into their curricula and research is ICT (Information and Communication Technology) [14]. This field has been recognized as an essential mean to enable all industries towards a low carbon circular economy. Technologies offer a major opportunity to achieve emission savings by its enabling effect on many industries. The SMART2020, SMARTer2020 and #SMARTer2030 reports [32-34] have highlighted the ICT power for environmental, social and economic benefits, from greening up to 98% of human activity sectors (e.g. logistics, building, power transmission, transport, and industry) through improved techniques, tools and methods to enabling 20% of reduction in CO2 emissions by 2030. Yet, to achieve sustainability, we do not only need more efficient systems, but behavioral changes in humans to enable a true transition from consumerist cultures to participatory ones - that solve problems collectively- [5,7].

In computer science and software engineering, sustainability is a rather new perspective. While first sustainable ICT articles are from the beginning of the millennium, the focus moved on software engineering just few years back [24]. It has been also reported that traditional software engineering has not fully supported sustainability [25]. Moreover, there is little guidance on how software engineering can contribute to improving the sustainability of the systems under development [23]. Software engineers approach specific topics that have to do with sustainability in our discipline, for example, green IT, efficient algorithms, smart grids, agile practices and knowledge management, but

[1] http://www.overshootday.org/
[2] http://www.cop21.gouv.fr/en/

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lack of a common understanding of the concept of sustainability and if and how it can be applied or integrated into software engineering [15]. This is evidenced by looking at curricula guidelines by IEEE/ACM. The most recent releases of the IEEE/ACM Curriculum Guidelines for Undergraduate Degree Programs in Software Engineering (SE) [31] or Computer Science (CS) [6] do provide only slight indication to the sustainability topics. The SE curriculum guidelines mention sustainability only once, in the example of SE program in Mississippi State University. Sustainability perspective could be included into several locations (e.g. REQ – Requirements analysis and specification [25], PRF – professional practice [6], DES – software design [31], QUA – software quality [31]), as elective topic. The newest version of CS curriculum guidelines [6] has included sustainability as one topic in Social issues and professional practice knowledge area (with 2 hours of coverage). In addition sustainability is covered shortly as a topic in Design-oriented HCI under the HCI (Human-Computer Interaction) knowledge area (elective). With current knowledge the sustainability elements could be implemented also in software engineering knowledge area. Although sustainability has only a minor role in these curriculum guidelines the ideology can already be seen in the documents and example implementations.

On one hand, the latest version of the Software Engineering Body of Knowledge (SWEBOK[3]) mentions sustainability in only one instance under economics. This gives the impression that sustainable development under CS or SE have not been considered at all. On the other hand the reports from the global e-sustainability initiative [32-34] have illustrated the sustainability aspects of ICT (includes both hardware and software solutions) as well as the impact of ICT to sustainable solution in other fields for some time already. Hilty and Aebischer [14] also show that sustainability perspective has been around in different fields for some time. Few curricula approaches have been proposed here and there [3,19,29,42] proposing some courses or programs in software sustainability or green software engineering. The examples are still rare and as such the sustainability within and through Computer science and Software engineering needs to be addressed better in near future.

In this paper, we present the existing multi-country and inter-university PERCCOM (Pervasive computing and communications for sustainable development) programme focusing on sustainability aspects in and through ICT (CS/SE perspective). The goal is to analyze the education content of PERCCOM program and especially the master's thesis topics to see how the perception of the sustainability education has changed during the PERCCOM programme. In the beginning we had a vision but our assumption is that the original perception has changed. Thesis topics give a nice perception how the sustainability ideology has been applied and in which domains the sustainability and ICT can be combined. As we now know roughly the current status of sustainability education in CS/SE fields we want to find answers to the following research questions:

1. How does PERCCOM theses works reflect the current status of sustainability education in CS /SE fields?
2. What are the impacts of SE/CS solutions from sustainability perspective?
3. How the perception of sustainability education has changed during the execution of PERCCOM programme?

In order to find the answers to these questions we first present the outlines of the PERCCOM programme, its structure and approach we have to the thesis process. Based on literature on sustainable development and sustainability dimensions we present a framework for evaluating the impacts of the thesis works towards sustainability. Each work is read by the main author of this paper and analyzed based on this framework. Research objectives, research questions and methods, perspectives to sustainability as well as technological readiness and application domain of each thesis work is noted and saved to a worksheet. As we combine the results of the analysis we will see the development of the perception to sustainability in PERCCOM programme. In the end of this paper we present the outcomes of the analysis and lessons learned from these four years so far.

II. PERCCOM PROGRAMME

PERCCOM – Pervasive computing and communications for sustainable development is an Erasmus mundus master's programme (2013-2019) on sustainable development. Objective of this programme is to fill the gap between sustainable development challenges and education activities, especially on ICT sector. PERCCOM aims to transfer emerging sustainability challenges of the businesses and society into educational activities with the emphasis on ICT as a main driver. PERCCOM is a multi-perspective approach as it aims to combine the strengths, competences and views of experts in different ICT domains [17, 26].

PERCCOM programme was applied three times before it was finally accepted by European Commission. The original proposal was tied closely to the technical aspects of sustainable development, just like the name of the programme presents (i.e. computing and communications). The subsequent proposals added a bit more social and application aspects to the programme structure. The perception of sustainability was mainly tied to the environmental aspects and perceptions. This is partly due to the partners of the project and partly because of sustainability trends at the time of the application process.

- The project coordinator, University of Lorraine, Nancy, France has long history in engineering education and research on networks and network protocols.
- The second host, Lappeenranta University of Technology, Finland, is a technical university focusing on engineering education with some business flavor. The current trailblazer strategy[4] of the university ties every degree program somehow to the sustainable development.
- Luleå University of Technology, Sweden, is also an engineering oriented university focusing its research and teaching efforts to pervasive systems combining networks and software skills.

[3] https://www.computer.org/web/swebok/index

[4] http://www.lut.fi/web/en/get-to-know-us/introducing-the-university/strategy

A. *Structure of the programme*

PERCCOM programme was built to be a two-year multi-national programme that is arranged in four separate semesters. Three semesters are used for education and one semester is dedicated for the master's thesis work. Students start their studies in Nancy, France in their first fall. The first spring semester will be taught collaboratively in Lappeenranta, Finland and St. Petersburg, Russia and the second year, i.e. third semester, starts in Luleå/Skellefteå, Sweden. The fourth and last semester is reserved for thesis work in any of the programme partners, not only in hosting partners. Figure 1 shows the general structure of the PERCCOM programme.

B. *Contents and its evolution*

The content of the PERCCOM programme was roughly designed at the application document. In general the contents were divided in four distinct parts 1) Technical courses, 2) Industry-based courses, 3) Cultural courses, and 4) Student project / thesis work. Each educational semester was supposed to follow similar structure. The sustainability aspects were covered in every course rather than having separate sustainability courses. This follows modular approach presented by [3]. The key outcome of the PERCCOM programme is the ability to move into the integrative and transformative approach of [3]. Semesters were further divided content-wise into different high-level themes.

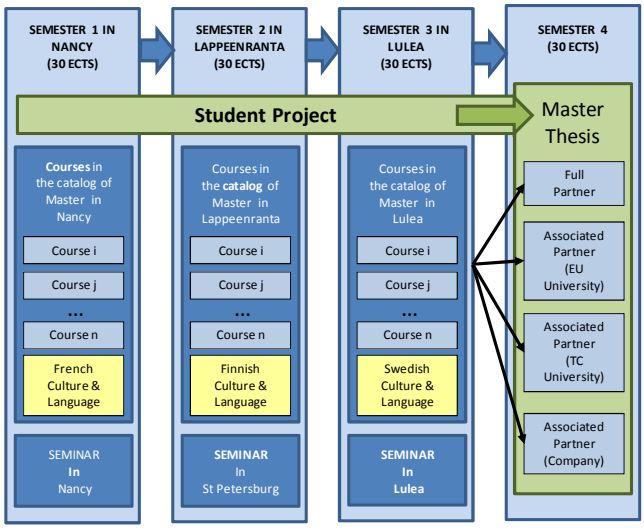

Figure 1. General structure of the PERCCOM programme[5].

- **Semester 1: Eco-design and green networking**

  The first semester in Nancy is focusing on communications and networks related issues. The objective of this semester is to provide students with fundamental competences in computer networks and systems engineering in a sustainable way. This semester is focusing on green IT perspectives, i.e. how to make the IT solutions more efficient. With the content remaining consistent, the main evolution in this semester has been to improve student project management with regard to the emphasis of sustainability aspects and research methods skills.

- **Semester 2: Sustainable software and services (Lappeenranta), green computing (St. Petersburg)**

  The aim of the second semester in Lappeenranta is to focus on ICT for sustainability, i.e. how ICT can be used in different domains for reducing environmental effects [22]. Lappeenranta was responsible for the technical courses (from the software perspective), cultural courses and student projects. In St. Petersburg the aim of the courses were to connect students with the software industry and to focus on computing related topics. Both Lappeenranta and St. Petersburg parts have evolved during the programme execution, especially from the technical and industry perspectives as well as student project management. The content of the technical courses in Lappeenranta has followed software architecture and service-orientation emphasis with a practical code camp course. The biggest changes in Lappeenranta have been a) the introduction of a course (Green IT and sustainable computing) that combines sustainability ideas with software solutions and b) management of student projects. As the PERCCOM programme has started to introduce research methods and literature reviews already in the first semester, the need for that has decreased in Lappeenranta. Instead more emphasis is given to the intermediate reporting of results. The contents of ITMO has been focusing on cloud computing and IoT issues.

- **Semester 3: Smart systems**

  The aim of the third semester is to focus on wireless networking and systems perspective as well as combining networking and software into efficient pervasive systems. Courses have included topics as network programming, distributed applications, and advanced wireless networks, and lately a course on cloud services was added considering the new local economic activities around datacenters in North Sweden (like Facebook, Hydro66, etc.). Moreover, a cultural course including a short introduction to the Swedish language and the Swedish society is included. A code lab or hackaton on green challenges is also being held during this semester. Some courses have been changed but in general the topics have remained the same.

A more detailed analysis of the PERCCOM programme contents and outcomes can be found in [17,26,27].

C. *Students and thesis works*

PERCCOM programme started in fall 2013 with the first cohort of 18 students (out of which 5 female), followed by second cohort of 15 students (3 female) and third cohort of 17 students (7 female). One of the novel approaches in PERCCOM programme is the assignment of the thesis topics in the beginning of the programme. Each student selects or is assigned a thesis topic based on the research issues presented by the supervisors. Students will then work on their own thesis topics in all possible courses, i.e. practical exercises are done with the thesis topic in mind. This gives the students 2 years of time to work on their thesis works rather than the normal 5-6 months typical for Master's thesis research. Our hypothesis is

[5] http://perccom.univ-lorraine.fr/

that these thesis topics represent the up-to-date perceptions of the needs for sustainable solutions in academia and industry. Therefore, the evolution of these topics represents the directions into which the sustainable development in ICT sector is going can reveal how the perception of the sustainability education has changed during its execution.

III. THE VARYING AND MULTI-PERSPECTIVE PERCEPTIONS OF SUSTAINABILITY

The Erasmus Mundus PERCCOM programme represents one of the first education programmes focusing on sustainable development in the ICT area. As sustainability aspects have not been considered before as whole educational programme, we decided to analyze how our perception of sustainability has evolved during the project and how that is seen in the practical research work given to the students in the form of thesis topics (we claim that the experience we have gathered during the project can be seen in the thesis topics).

First we created an evaluation model for the sustainability perspectives and effects in ICT projects [27]. This model is based on literature and consists of three levels: Effects, Domains and Readiness. The Effects level can be seen from sustainability dimension and from sustainability impact perspectives. The Domains level aims to tie the solutions into some application domain. Various application categorizations could be used but in this analysis we use mainly the categorization provided by global e-sustainability initiative [32-34]. The Readiness level is evaluated by using technology readiness levels (TRL) proposed by Mankins [18]. More details of the evaluation framework are presented in [27].

The analysis process was performed based on the elements of the evaluation model and the following information was collected into a worksheet.

- Background information: Thesis topic, source university, research objectives, questions, methods and results [12,25,39],
- Sustainability perspective dimension and proportion: Ecological, economical, social, individual and technical,
- Sustainability impact (1st, 2nd and 3rd order) the work is focusing on [2,10,14],
- Application domain [32-34] of the thesis work, and
- Readiness level of the outcome [11,18].

In the analysis we visualize the thesis topics in three different figures representing different levels of the models. This visualization is to be developed further in future. In our visualization we also show the origin of the thesis topic (inside the markers) as it allows each partner to evaluate how the perception towards sustainability has evolved during the project. We also show the topics for each cohort in separate pictures (green, yellow and turquoise) to allow comparison of perceptions and the changes in those. It should be noticed that at the moment only first 2 cohorts have finished their works while the third cohort is still working on their thesis works and will graduate in September 2017.

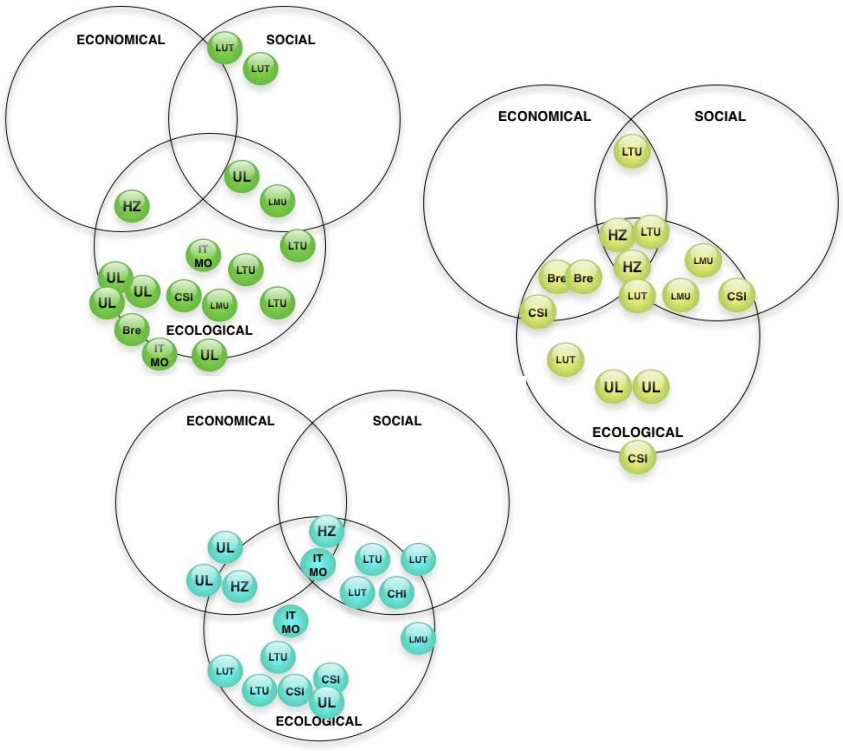

Figure 2. Thesis topics by their impact and readiness level (Green – topics of the first cohort, Yellow – topics of the second cohort, Turquoise – topics of the third cohort)

A. Sustainable development dimensions

One of the first definitions for sustainable development has been presented by the UN report on environment and development, so called Brundtland Report "Our common future" [39]. In this report three dimensions to sustainability were given, namely Ecological, Economical and Social. Later on other dimensions have been proposed, e.g. individual dimension [12] and technical dimension [25]. Although the technical dimension is considered important, we analyzed these thesis topics based on the original three dimensions and how well the thesis works aim to answer to those dimensions, because the PERCCOM project is highly technical by its nature. This analysis aims at showing which dimensions are affected by the thesis studies.

Figure 2 presents the analysis of the thesis topics given to the three cohorts (First cohort - Green, upper left corner; Second cohort – Yellow, right side; Third cohort – Turquoise, lower left corner). Some of the works, especially in the beginning of the programme, were highly technical with only a slight emphasis on sustainability aspects and those works are presented in the edge of the appropriate dimension. The more we have learned from sustainability perspectives, the more we have been able to add various dimensions of sustainability into the topics of the thesis works. The second year topics show a bit more emphasis on social aspects while the third year has added also economical considerations. This shows the very technical starting point of the programme and its evolution towards a more encompassing consideration of sustainability. Originally PERCCOM was an approach to greener technology, meaning emphasis on environmental dimension of the sustainability. The technical nature of the thesis works has also diminished a bit (i.e. not so many topics are in the outer border of the dimension). It should also be noticed that more topics consider multiple dimensions of sustainability in the second and third year than in the first year.

B. Impacts of sustainable solutions

The impact of sustainable solutions can be measured and presented in many ways. The three-level perception to the impacts of ICT on environmental sustainability was given by Berkhout and Hertin in their report to OECD [2]. Using the different levels of impact gives a possibility to combine that with other sustainability dimensions. The European Information Observatory in their article about the impacts of ICT on sustainable development [10] connected the impacts to the different sustainability dimensions. Later on Hilty [14] connected the impacts to the perception of "ICT as a part of the problem" and "ICT as a solution to the problem" giving a two dimensional presentation of the impacts. This is a slightly ambiguous presentation as the first order approach looks for direct impacts, i.e. how ICT can itself be improved, which is actually similar perspective as "ICT as a problem". In a similar way "ICT as a part of the solution" represents the 2nd order, indirect, or enabling effects. All this follows the development seen also in the publications of global e-sustainability initiative [32-34] where the first publication focused mainly on the direct life-cycle impacts [32] and later on the focus moved to the next level enabling impact. These approaches represent the traditional "Green ICT" and "ICT for Greening" approaches. Hilty and Aebisher [14] present another perspective to the three level model, the LES model focusing on Life-cycle, Enabling and Structural impacts.

While analyzing the PERCCOM thesis topics the three-level model by Berkhout and Hertin [2] was used. Instead of linking the impacts to sustainability dimensions like in [10] or to the problem / solution dimension [14], we decided to look at the topics and realizations of the thesis works from the "technology" readiness perspective. Technology readiness levels (TRL) like presented by Mankins [18] can be used to evaluate how far the solution is from actual utilization. Some studies have shown that it is not easy to use the approach [11], especially when not all of the topics focus on technology as such. The EU program Horizon 2020 has defined[6] technology readiness in a technology agnostic way based on the model by Mankins and we apply those definitions for the analysis.

Figure 3 presents the analysis of the thesis topics by their impact and readiness level. Most of the PERCCOM thesis works are of theoretical (i.e. up to TRL 4, below x-axis) nature. Some thesis works end up to achieve TRL 5 or 6, especially those that represent the first order impacts.

C. Application domains of the PERCCOM thesis topics

The previous analyses in Figures 2 and 3 provide insights of what kind of impacts the thesis works will have and how fast we may expect these impacts to happen. What the previous analyses do not reveal is in which application domains the impacts will happen. The publications on global e-sustainability initiative [32-34] have presented both the enhancement possibilities of ICT technologies as well as the possibilities for ICT to enhance other fields. It seems that the emphasis is ever more to move the focus from direct enhancements (life-cycle effects) to indirect (enabling impact) and structural changes [14]. The e-sustainability initiative categories emphasize 8 application areas (Health, Learning, Building, Food, Mobility, Energy, Work and Business, Manufacturing) as they provide biggest potential for impacts. Other categorization approaches could have been used like the one presented by the standard industrial classification [38]. We selected the approach by e-sustainability initiative (due to its direct links to sustainability) and analyzed the thesis works based on those 8 application domains given.

Figure 4 presents the analysis of thesis topics of the first three cohorts using their impact and application domain. It can be seen from the figure that with the first set of students the thesis topics were quite focused on direct impacts on just few application fields while the perceptions for the second and third set of students were broadened in sense of impact level and the application field.

D. Limitation of this analysis

We are aware that the number of analysed works (18, 15 and 17) is too small to generalize the findings, but we find the analysis provides important insights and indicators that may help shape future thesis topic proposals and programmes.

[6]https://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf

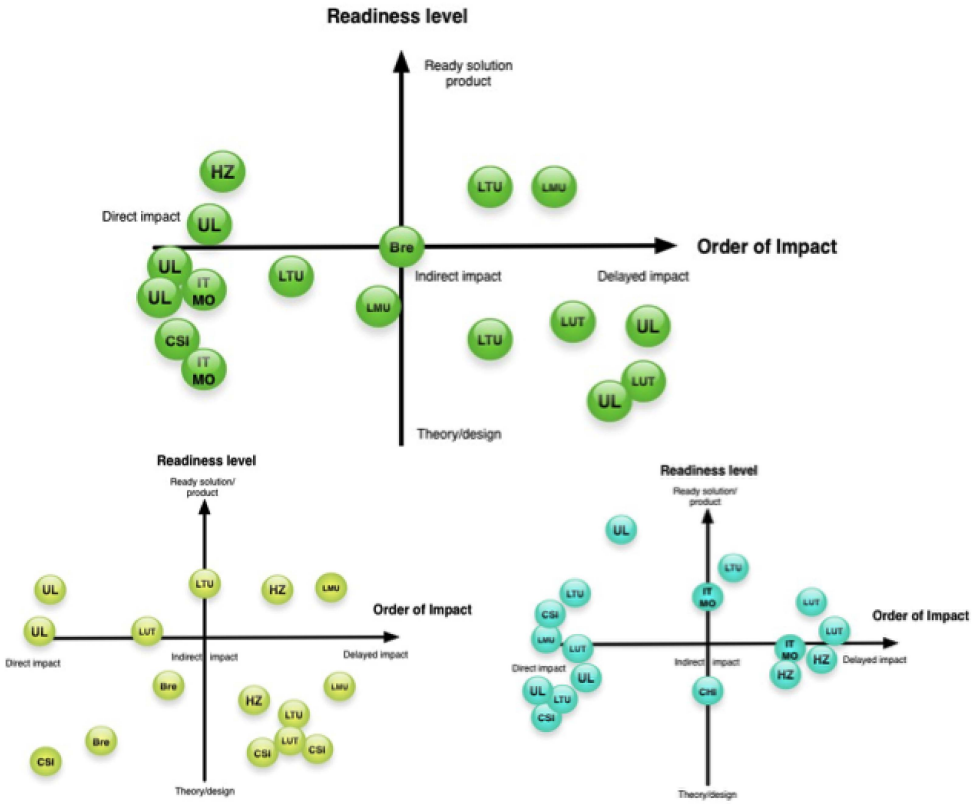

Figure 3. Thesis topics by their impact and readiness.

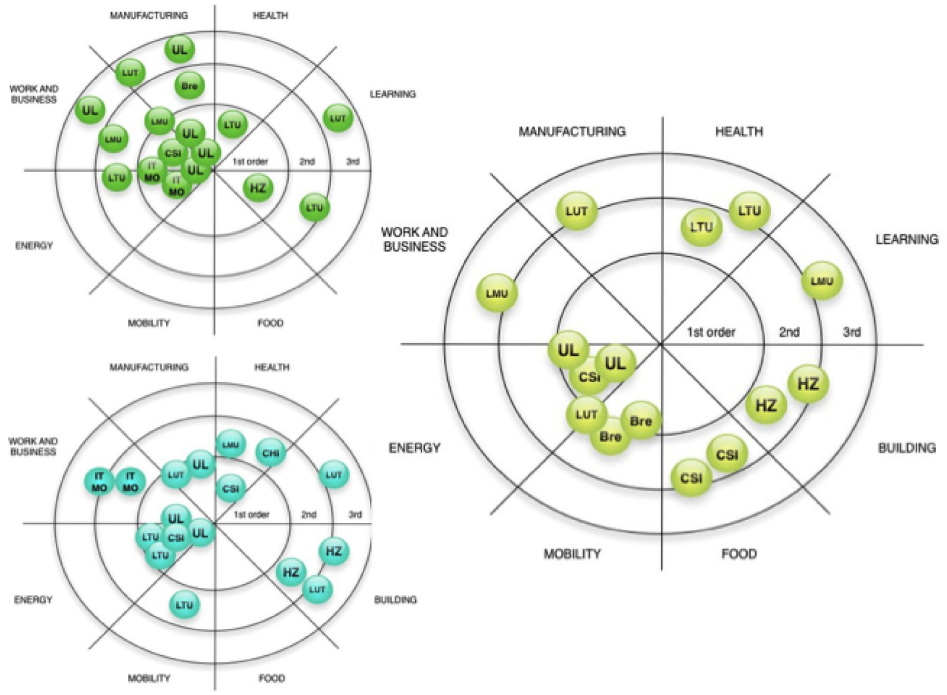

Figure 4. Thesis topics by their impact on different application domains.

IV. KEY FINDINGS AND RECOMMENDATIONS

The Erasmus Mundus PERCCOM programme has now run for 4 years and two student cohorts have graduated, third cohort has worked on their thesis topics for almost two years and the fourth cohort have selected their thesis topics. First and second semesters have been already implemented 4 times and the third semester 3 times. As such we may summarize few lessons we have learned so far and how the perception towards sustainable development has changed in different organizations.

A. About content evolution

The content of the PERCCOM programme has stayed consistent during these years. The original structure of semesters with specific themes based on the expertise of the partners has shown to work pretty well. The technical courses fulfill the sustainability context while cultural and industry courses support these actions. Content wise the biggest change has been the reconsideration of courses (and their content) that would best support the different sustainability perceptions. Different hosts focus on slightly different perceptions (e.g. LUT emphasizes the users and society i.e. social aspects in many of the courses). The most notable changes in the contents have happened with the student projects i.e. thesis works. As each partner, especially the three hosting universities, has different requirements for the thesis evaluations, it took some time to get the common understanding of what to emphasize in the sense of research work and when. Even today the best part of the early selection of thesis topics is the possibility for the students to work on their own topic throughout the education. The PERCCOM programme has shown that various sustainability perceptions can be integrated as a part of ongoing courses (RQ3). Certain sustainability basics are needed but otherwise sustainability can be integrated into the programme using modular or integrative approach like Cai presented in [3, Figure 1].

B. About the perception towards sustainability education

As the thesis topics reflect the research and perceptions of the supervisors, they can be seen more influential while analyzing how the perception towards sustainability education has changed. The literature on ICT and sustainability [14,32-34] shows clearly that the emphasis on impacts of sustainable development is moving from pure green IT (direct impact) to IT for greening i.e. more indirect impacts. A similar trend can partly be seen in the thesis topics given to the students (RQ1). This is a rather evident outcome. However, how we see this outcome is that it takes some time to get an understanding of sustainability in the ICT sector and how to best apply that knowledge in other sectors. This understanding should later on show as increased impact on these application domains (RQ2).

Naturally there are differences between partners and their orientation. University of Lorraine as a responsible for the networking focused semester clearly focuses on direct impacts in networks while Lappeenranta University of Technology has a more indirect emphasis in their focus (and especially social aspects). In addition to differences between partners there exists synergies as well. The strength of the PERCCOM consortium is on different focuses. A purely technical consortium would probably not achieve a similar kind of impact as this consortium has been looking at sustainability from many different perspectives. This has led to broader understanding of sustainability both in technical and social fields. Even though the students would get employed into some technical engineering area they will have understanding of the impacts of their solutions as well as the skills to affect these impacts.

V. CONCLUSION

Sustainability is still an evolving concept with diverse definitions and perceptions. Various avenues have explored on what is the place of sustainability in CS/SE education and how it should be integrated [3]. Programmes addressing sustainability are still emerging and often narrow focused, e.g. on environmental aspects or just adding sustainability as a separate course like presented [3]. The PERCCOM programme presented in this paper is among the first Master's programmes of sustainable CS/SE in the European Community entirely dedicated to sustainability and sustainability development in ICT and software systems.

This paper highlights the perceptions, definitions and dimensions of sustainability in the PERCCOM programme both by students, researchers and all partners.

The first finding is that our investigations confirmed the current tendency in scientific literature on ICT and sustainability. The emphasis on the impacts of sustainable development is moving from pure green IT (direct impact) to IT for greening i.e. more enabling impacts. One question being investigated by researchers and Masters' students involved in PERCCOM includes how ICT and software systems can contribute to support green technology and sustainability development. One underlying issue is how ICT can change the human mindset both via education and persuasion? Future programmes should move towards this third level of impact (i.e. societal impacts) regarding sustainability [14].

A second finding is that a large share of the PERCCOM thesis works are theoretical. This also conforms to the current situation in literature; there are only few case studies on how sustainability is really being considered in software development teams and organizations in industry. Only few of our Master students were able to conduct their research thesis in industry though the number of these students have increased over the years. Education and research are required on a clear approach to greening IT/Software systems and organizations encompassing green/sustainability use, measures, design, and green/sustainability-driven software engineering. It also illustrates how to strategically apply sustainability in practice in several types of IT and software systems. In the future, thesis works should engage industry and society more to achieve real impact on sustainable future.

The collected data would allow various other analyses. The PERCCOM programme attracts a bigger proportion of female students than traditional CS/SE programmes. The analysis of thesis works has not considered the gender aspect partly because of the thesis allocation process that ensures that almost all students get a topic that is of their interest. This analysis can be done in future when having results from all cohorts. Another interesting but still missing analysis is on the partner profiles. Partners allocate thesis topics based on their visions and general trends. Especially the emphasis on various

sustainability dimensions in different universities could make the difference in future. Economical and social aspects were not so well covered in this set of thesis works but will emerge in the near future.

This programme has had a strong scientific impact in different fields from advancing the discussion about sustainability in CS curricula [17,26,27], promoting practices in environmental and sustainability studies [22] and providing examples of ICT for sustainability applications in engineering [4, 13, 40, 41]. Moreover, several papers have been published from the student thesis works in the fields of ICT for sustainability [13], industry studies [20], smart cities [30,8], E-health [16] and networks and telecommunications [21].

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APPENDIX 1: THESIS TOPICS OF THE FIRST 3 COHORTS (AVAILABLE AT DORIA REPOSITORY [7])

Cohort	Thesis topic	Location
1	Power consumption measurement and scenario based energy model in wearable computing applications	Bremen
1	Load balancing in p2p smartphone based distribution system	CSIRO
1	Analyzing and computing the sustainable gains of building automation	Harz
1	Development of an Ecology-Oriented Software-Defined Networking Framework	ITMO
1	Implementing Green IT approach for transferring Big Data over Parallel Data Link	ITMO
1	Energy consumption of applications on mobile phones	Leeds
1	A web-based environmental toolkit to support small and medium-sized enterprises in the implementation of their own environmental management system	Leeds
1	CloudSimDisk: Energy-aware Storage Simulation in CloudSim	LTU
1	A Bayesian approach for forecasting heat load in a district heating system	LTU
1	Sensor communication in smart cities and regions: An efficient IoT-based remote health monitoring system	LTU
1	Green aspects study in game development	LUT
1	Sustainable computer science education	LUT
1	Green ICT metrics and Biomimicry	UL
1	Benchmark of routing protocols regarding green considerations	UL
1	Modeling energy consumption of a switch using fuzzy-rule classifier	UL
1	Analyzing the power consumption behavior of Ethernet switch using Design of Experiment	UL
1	Green service level agreement under sustainability lens in IT industry	UL
2	Nested Rollout Policy Adaptation for Optimizing Vehicle Selection in Complex VRPs	Bremen
2	Optimizing Last Mile Delivery using Public Transport with Multi- Agent based Control	Bremen
2	Mobile-GSN For Enhanced Sensor Management	CSIRO
2	Reasoning over Knowledge-based Generation of Situations in Context Spaces to Reduce Food Waste	CSIRO
2	RCOS: Real Time Context Sharing Across Multiple Smartphones	CSIRO
2	Specification of a smart meter/actuator description mechanism & development of a mobile application	HARZ
2	Front-End Development for Building Automation Systems using JavaScript Frameworks	HARZ

[7] www.doria.fi

2	A Belief Rule-Based Environmental Responsibility Assessment System for Small and Medium-Sized Enterprises	Leeds
2	Embedding Sustainability Into The New Computer Science Curriculum For English Schools	Leeds
2	Performance Analysis of IP Based WSNs In Real Time Systems	LTU
2	The Viability Of A Tool For Fetal Health Monitoring	LTU
2	Early Investigation Towards defining and measuring sustainability as a quality attribute in software systems	LUT
2	Cyber foraging for green computing, improving performance and prolonging battery life of mobile devices	LUT
2	Using ICT Energy consumption for monitoring ICT usage in an enterprise	UL
2	Developing Strategies To Mitigate The Energy Consumed By Network Infrastructures	UL
3	A smart risk assessment system for river flooding using BRB and WSN	Chittagong
3	Distributed context acquisition and reasoning for annotating data streams in the Internet of Things for green smart cities	CSIRO
3	Opportunistic collection of sensor data in IoT applications	CSIRO
3	Fostering the uptake of home automation by improving the usability of infrared controllers	Harz
3	Improving the effectiveness of building automation by user context detection	Harz
3	A method and programming model for city data evaluation	ITMO
3	Pervasive computing for decision support systems in the context of green ICT	ITMO
3	Project Nocturne: Bed occupancy sensor system	Leeds
3	Simulation of Energy Efficient Storage in Clouds	LTU
3	Making green transportation fun through gamification	LTU
3	Ultra dense deployment for multi connectivity and energy efficiency	LTU
3	Engineering and Incorporating Sustainability into Software Development Lifecycle: A design pattern Approach	LUT
3	Capturing human behavior by home automation infrastructure	LUT
3	Enabling distributed citizen observatory	LUT
3	Software defined network for greening internet communications	UL
3	Software Eco-design based on resource budget	UL
3	Software Consumption Learning Machine	UL