

Erasmus Mundus Master Programme



PERvasive Computing and
COMmunications for sustainable
development

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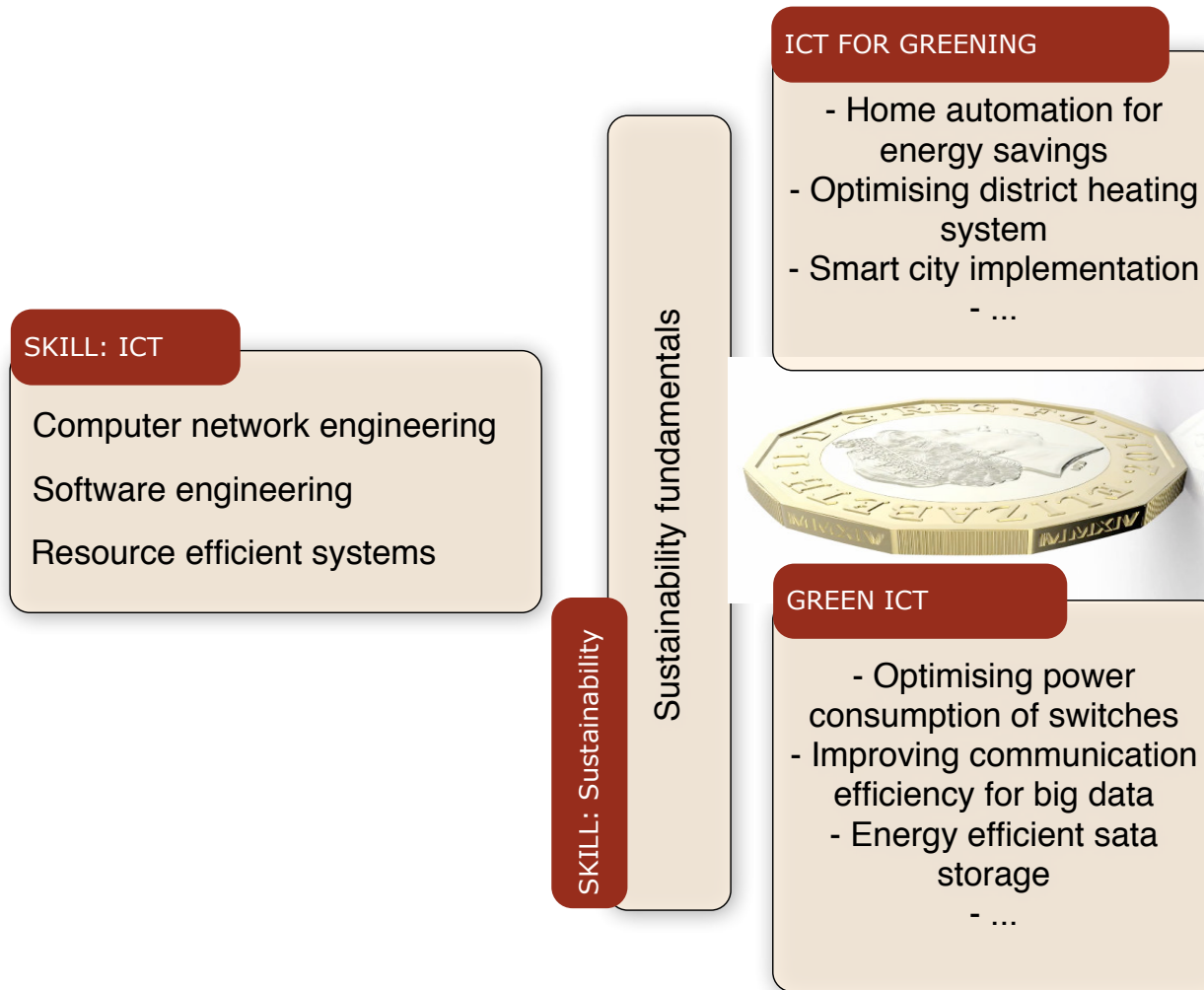
Background

- Erasmus Mundus (Erasmus+)
 - The European Union's programme that aims to enhance quality in higher education through **scholarships** and **academic cooperation** between Europe and the rest of the world.
- PERCCOM 2013-2019
 - The Erasmus Mundus Master program in Pervasive Computing and Communications for Sustainable Development aims at combining advanced Information and Communication Technologies (ICT) with environmental awareness to enable world-class education and unique competences for ICT professionals who can build cleaner, greener, more resource and energy efficient cyber-physical systems.

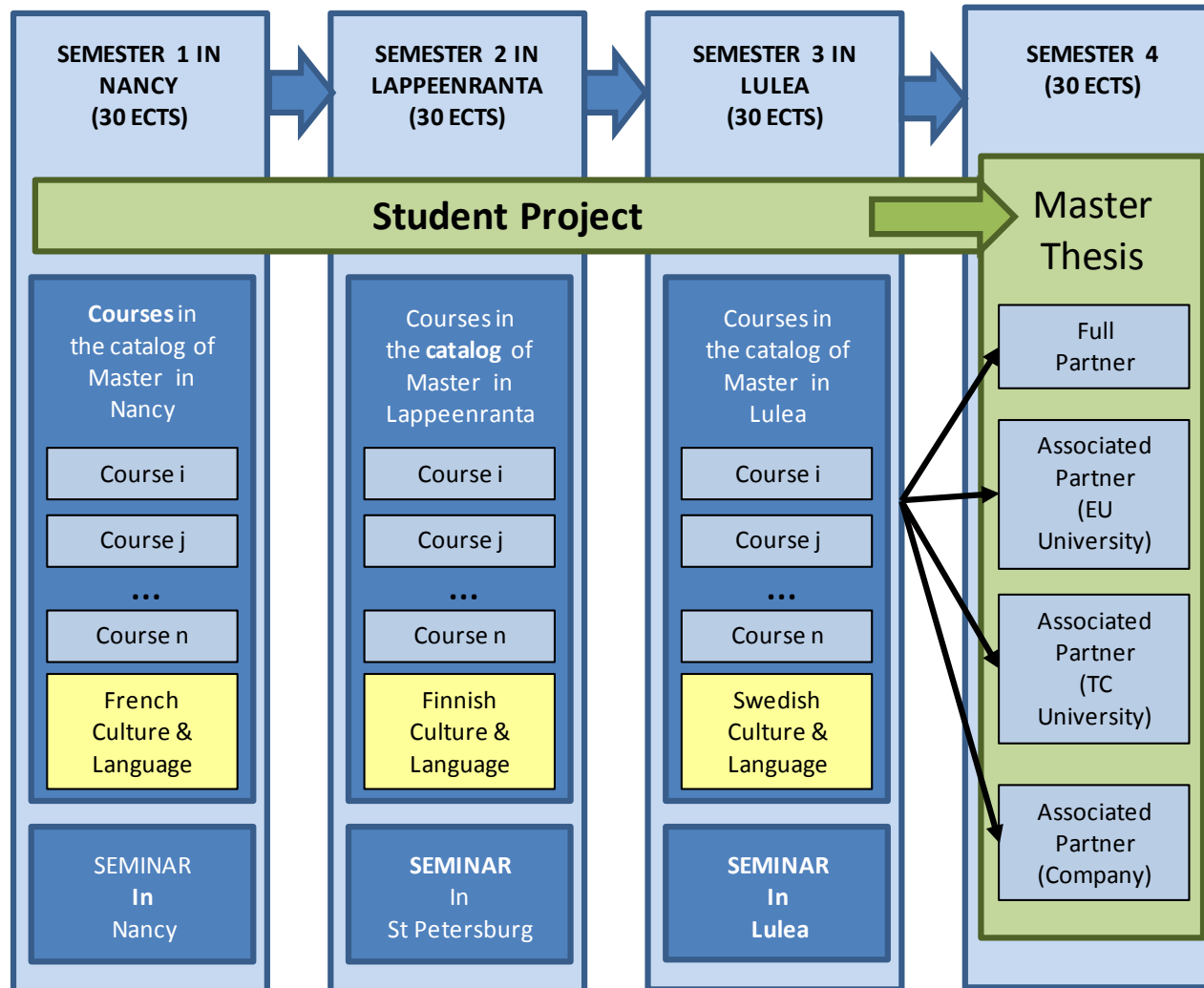
PERCCOM Objectives

- To **understand the emerging sustainability challenges** within society and businesses and to transfer them into educational solutions with ICT as a key element,
- To combine the strengths, competences and experience of experts in **different ICT perspectives** (e.g. elements of systems as well as whole systems, hardware as well as software, communication and computation, a single phase of an element as well as the whole lifecycle) and thereby develop a common platform of competence within the guidelines of the Bologna process,
- To propose the new International Master degree with no currently available match at international level filling the gap between **ICT skills and environmental considerations**,
- To provide the prospective students with knowledge, skills and finally competencies in sustainability and ICT to enable a true **impact on ecological, economic and social aspects of sustainability**, and
- Finally to fulfill the needs presented by those various reports on **ICT's role as a solution** or a part of it.

Sustainability perspectives in PERCCOM



Programme structure



PERCCOM Semesters

- Semester 1 : **Eco-design and Green networking** (University of Lorraine, France)
- Semester 2 : **Green software and services, Green computing** (Lappeenranta University of Technology, Finland and St Petersburg University of ITMO, Russia)
- Semester 3 : **Smart systems** (Luleå University of Technology, Sweden)
- Semester 4 : Master Thesis (*Academia*: Leeds, Bremen, Harz, CSIRO, ... *Companies*: Orange, Cisco, Ericsson,... *Associations* : Ellen Mac Arthur Foundation, Fondaterra)

Triple degree programme, diploma supplement approach

Sustainability contents

- ***Semester 1 - Sustainable Computer Network Engineering***
 - Communication protocols (6 ECTS) – ICT and Sustainability
 - Quality of Sustainable Service (6 ECTS) – ICT and Sustainability
 - Automatic Control for Sustainable Development (3 ECTS) – ICT and Sustainability
 - Systems Engineering (3 ECTS) – ICT, Sustainability and Green ICT
 - Sustainable development & circular economy (3 ECTS) - Sustainability
 - Specification definition of Master thesis project (3 ECTS) – ICT and Sustainability
 - French Culture and Language (3 ECTS) – Sustainability (social aspects)

Sustainability contents

- ***Semester 2 – Smart software and services***
 - Green IT and Sustainable Computing (5 ECTS) – Sustainability and ICT for Greening
 - Architecture in Systems and Software Development (7 ECTS) - ICT
 - Software Systems as a Service: Technology and Engineering (5 ECTS) – ICT and ICT for Greening
 - Code camp on Platform Based Development (4 ECTS) – ICT and ICT for Greening
 - Transformation of a modern industrial society: The Finnish Model (2 ECTS) – Sustainability (social aspects)
 - Towards Semester 3 (1 ECTS) – Sustainability and ICT
 - ITMO - Seminar 1 & 2 (6 ECTS) – Green ICT

Sustainability contents

- ***Semester 3 - Resource efficient pervasive computing systems and communication***
 - Network programming and distributed applications (7.5 ECTS) – ICT and ICT for Greening
 - Wireless sensor networks/ Wireless Mobile Networks (7.5 ECTS) – ICT and Green ICT
 - Multimedia systems (7.5 ECTS) – ICT and ICT for Greening
 - Special Studies in Pervasive and Mobile Computing (Project) (3 ECTS) – ICT and Sustainability
 - Swedish for Beginners AI:1a - (3 ECTS) – Sustainability (cultural aspects)
 - Seminar: (1.5 ECTS) – ICT and Sustainability



Some results

Selection of students and gender balance

- Good number of applicants
- The percentage of female applicants much higher than in our traditional ICT programmes

Cohort	Applicants Female/Male (Total)	Selected Female/Male (%)	Started Female/Male (%)
2013-2015	78/378 (456)	6/12 (33%)	6/11 (35%)
2014-2016	27/155 (182)	3/12 (20%)	4/11 (26%)
2015-2017	56/235 (291)	8/7 (53%)	7/11 (38%)
2016-2018	47/164 (211)	4/6 (40%)	7/14 (33%)
2017-2019	55/175 (230)	3/7 (30%)	6/13 (31%)

Analysis of the thesis topics

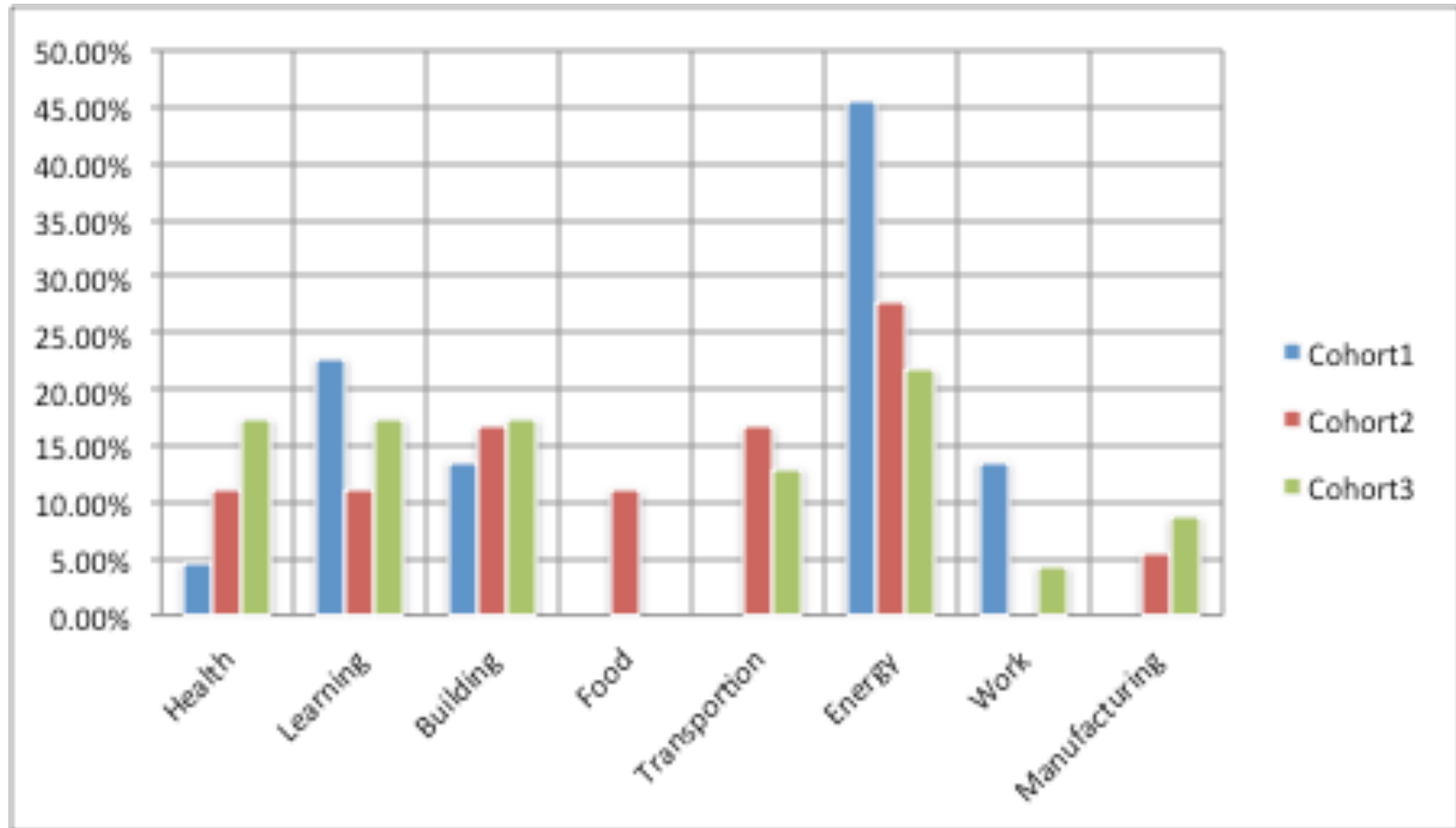
- Based on the three first cohorts
 - 2013-2015: 18 students
 - 2014-2016: 15 students
 - 2015-2017: 17 students
- Cohorts 1, 2 & 3 finished thesis works, cohorts 4 & 5 still working on those (not analyzed here)
- Thesis topics given in the beginning of the studies

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

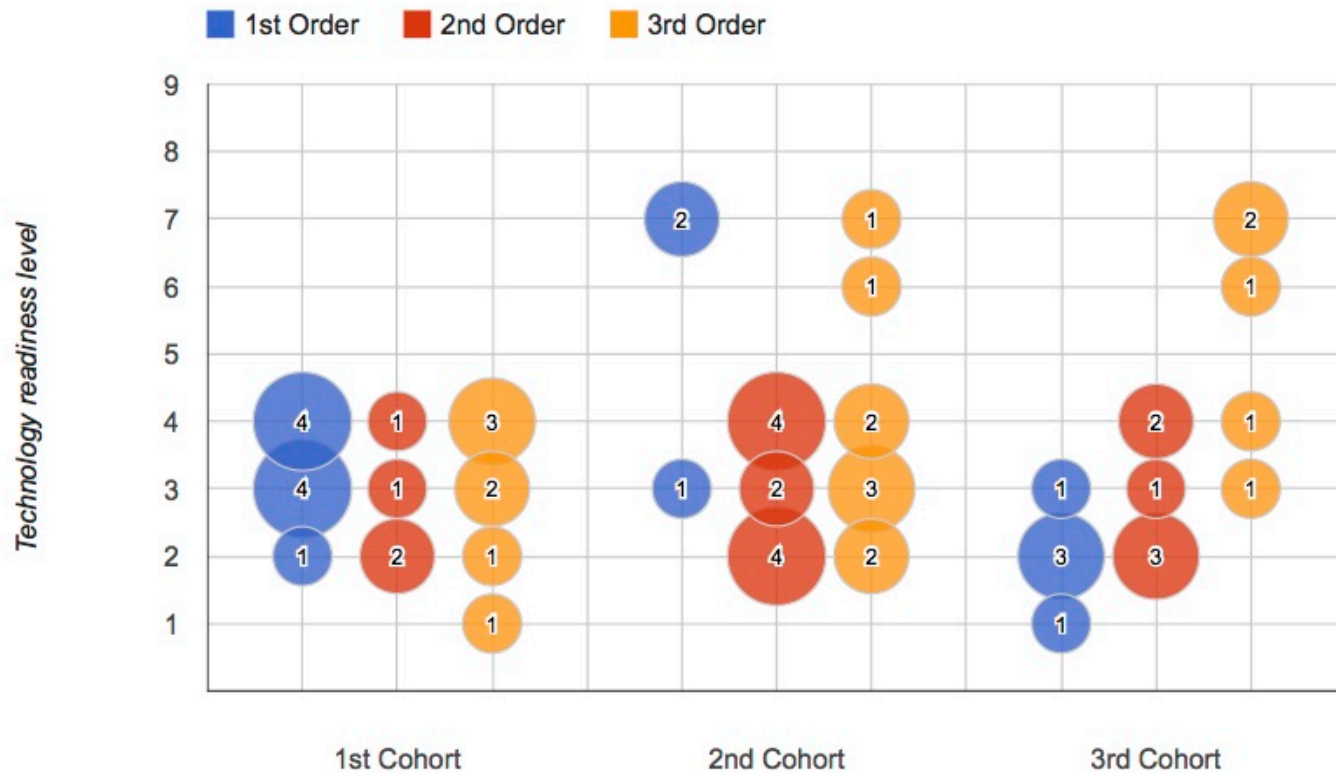
2	Nested Rollout Policy Adaptation for Optimizing Vehicle Selection in Complex VRPs	Bremen
2	Optimizing Last Mile Delivery using Public Transport with Multi- Agent based Control	Bremen
2	Mobile-GSN For Enhanced Sensor Management	CSIRO
2	Reasoning over Knowledge-based Generation of Situations in Context 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
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

Thesis works on various domains



Readiness of the results of thesis

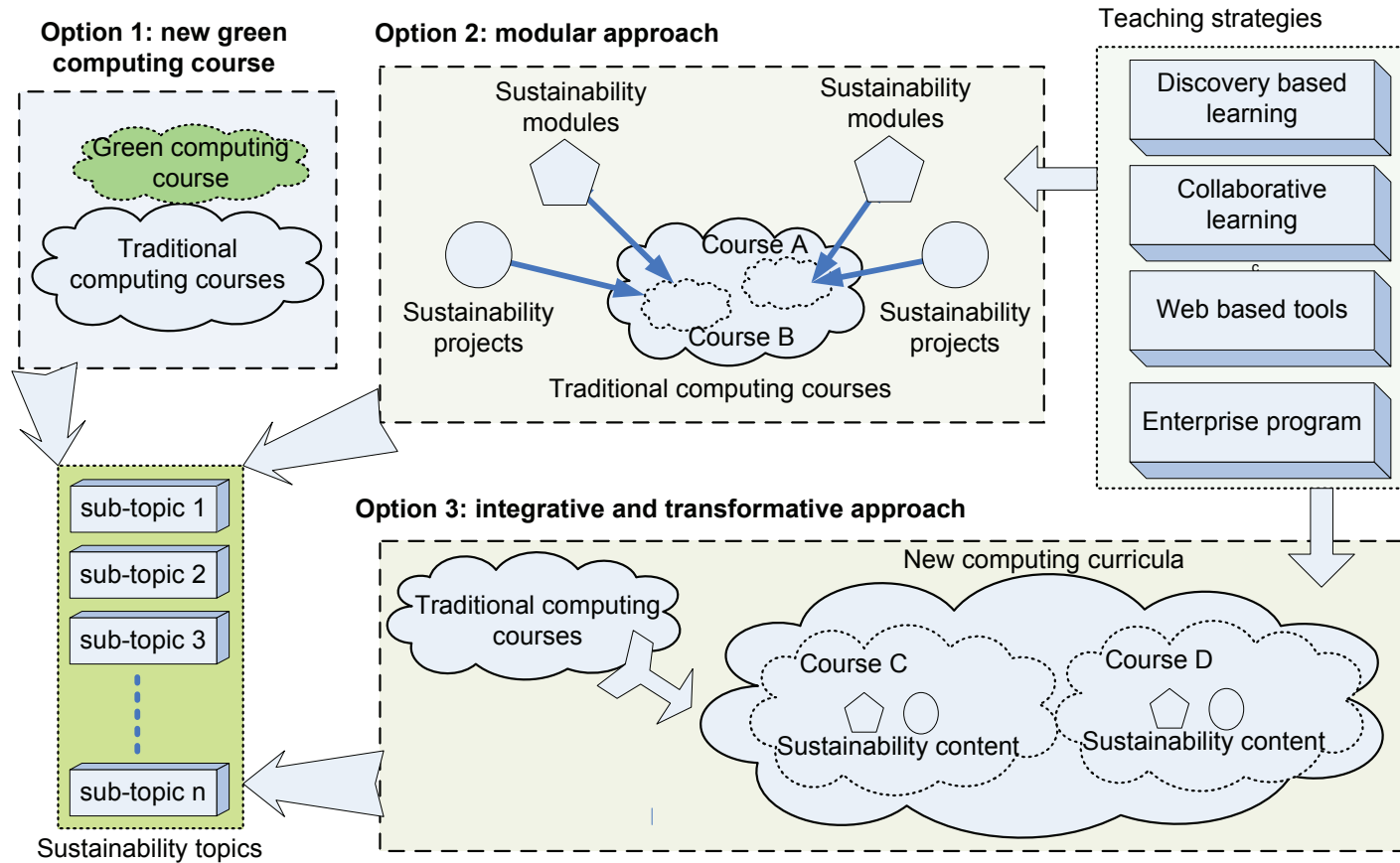


Number of thesis works on each technology readiness level compared between cohorts

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**Reflections to existing
knowledge and lessons
learned**

Cai Y. – Options for sustainability integration



Lesson learned from PERCCOM

- This is not a pure software engineering or computer science programme
 - International programme that could not have happened in a single university due to perspectives to ICT education
 - The perception of sustainability varies in the programme and was not anticipated in the beginning
- The programme evolves continuously while we learn
- The multiperspective approach gives pretty good basis for future
 - 9 / 17 continue as doctoral students, 4 work for companies in SW or networking, 2 work in academia
 - 50+% females (1st cohort)

Lessons learned – content evolution in PERCCOM

- The main structure has remained the same
 - Themes of the semesters have emphasized local strengths
- Biggest challenge has been in taking all sustainability perceptions into account
 - Not necessarily good view to these
 - Student projects (where's the sustainability?)
- Integration of sustainability perceptions to existing projects

Lessons learned – sustainability education

- Literature shows change of emphasis from pure Green IT to IT for greening.
 - Same trend in thesis topics
 - Increased understanding of sustainability ?
- Strength of the programme is in different approaches to sustainability
 - Broader understanding of the sustainability and ICT

Innovation, Design and Engineering of Usable ICT Solutions for Sustainability

Erasmus Mundus proposal to produce
Sustainability literate SE graduates



Sustainability literate graduates

Usable sustainability
- for/with people and society

Challenges

Solutions

Dissemination

User-centric Design principles

Software engineering methods and tools

Sustainable mindset

User-centric Design principles

- Understanding of the users
- Participation
- Patterns

Software engineering skills

- Professional and technical knowledge
- Teamwork
- End-user awareness
- Solutions in context

Sustainable mindset

- Understands the need for change, individually and collectively
- Has sufficient knowledge and skills in own profession to act in favor of sustainable development
- Recognize decisions and actions towards sustainable development and is able to utilize these in own actions

Competence	Sustainable mindset											
Elements of the competence	Eco-literate (knowledge)		Sustainable lifestyle (competence)				Sustainability literate (knowledge and skills)				Global orientation (knowledge)	
	Understanding the environmental limitations		Long-term vision	Desire to change	Courage to act		Ability to identify needs and opportunities	Innovation and knowledge management competencies	Skills and competencies for right decisions		Understanding of the cultural differences	
UNESCO skills for sustainable development												
21st century skill categorization												
Reflex study												
Competence	Software engineering methods and tools for sustainability (ACM/IEEE SWE curricula guidelines)											
Elements of the competence	Hard (knowledge, skills and competencies)						Soft (knowledge, skills and competencies)					
	Professional knowledge			Technical knowledge			Teamwork		End-user awareness		Design solutions in context	
UNESCO skills for sustainable development												
21st century skill categorization												
Reflex study												
Competence	User centric design skills											
Elements of the competencies	User strengths			Soft skills			Designer strengths			Hard skills		
	Subject domain experience	Context availability	User cultures, social networks and practices	Communication	Multidisciplinarity and collaboration	Motivation and ambitions	User involvement	Problem solving and designerly ways	Conceptualization, visualization and validation	Process and methods	Technology and market potential	Subject domain knowledge
UNESCO skills for sustainable development												
21st century skill categorization												
Reflex study												