Co-funded by the Erasmus+ Programme of the European Union

Project:	Boosting the telecommunications engineer profile to meet modern society and industry needs [BENEFIT]
Project ID:	585716-EPP-1-2017-1-AT-EPPKA2-CBHE-JP
Work Package 1:	Consolidation of ex-ante analysis and preparation of implementation actions
Title:	D1.1 Consolidated ex-ante analysis and guidelines aimed at boosting the telecommunications engineer profile including a projection of needs for ICT engineers in the future
Lead Organization:	UNI-KLU (project-benefit@aau.at)
Participating Organization:	UL, FERIT, UBL, UNSA, UNTZ, UB, UNI, UNS, ENT, BICOM, BIT, CISCO, NiCAT, RT-RK
Editors:	A. Tonello, D. Righini, M. Zajc, A. Mujčić, N. Suljanović, S. Rimac-Drlje, D. Žagar, V. Križanović
Contributors:	S. Rimac-Drlje, D. Žagar, V. Križanović, M. Zajc, A. Mujčić, N. Suljanović, D. Boskovic, J. Ćertić, M. Koprivica, A. Nešković, Z. Babic, A. Tonello, D. Righini

Deliverable data	Work Package and Outcome ref.nr	WP1 D1.1
	Title	Consolidated ex-ante analysis and guidelines aimed at boosting the telecommunications engineer profile including a projection of needs for ICT engineers in the future
	Type	☐ Teaching material ☐ Event ☐ Learning material ☒ Report ☐ Training material ☐ Service / Product
	Description	The document provides: i) a snapshot of the present situation about the telecommunications engineering curriculum development both in EU and WB HEIs, ii) analysis of the existing industry, employment status, employment perspectives, competencies and skills needed, iii) a survey of the existing policies, local constraints, guidelines and best practices addressing the reform of curricula at EU and WB universities. The document aims at providing necessary guidelines for the following project activities according to industry inputs and good examples from EU.
	Date	14.04.2018
	Language	English and Croatian
Target groups	☒ Teaching staff ☒ Students ☐ Trainees ☒ Administrative staff ☐ Technical staff ☐ Librarians ☒ Industry partners, WB Higher education authorities	
Dissemination level	☐ Department / Faculty ☐ Local ☐ National ☐ Institution ☐ Regional ☒ International	
Lead Organization	UNI-KLU	
Participating Organization	UL, FERIT, UBL, UNSA, UNTZ, UB, UNI, UNS, ENT, BICOM, BIT, CISCO, NiCAT, RT-RK	
Task	T1.1 Survey and analysis of telecommunications engineering study programmes in relation to modern society and industry needs (Task leader: FERIT). T1.2 Consolidate guidelines for curriculum modernization in cooperation with industry (Task leader: UL).	

Revision History				
Version	Date	Author(s)	Organization(s)	Brief description of change
1	14.3.2018	A. Tonello	UNI-KLU	Super draft
2	19.3.2018	M. Zajc	UL	Industry survey
3	19.3.2018	M. Zajc, A. Mujčić, N. Suljanović	UL UNTZ UNTZ	Guidelines for modernization
4	21.3.2018	S. Rimac-Drlje	FERIT	Academic TOC
5	6.4. 2018	M. Zajc A. Mujčić N. Suljanović With UBL inputs for 4.3 With UNS, UB and UNSA inputs for 4.4.	UL UNTZ UNTZ	Revision of Chapter 3 and Chapter 4 based on Novi Sad meeting.
6	20.4.2018	D. Righini	UNI-KLU	Revision of the document.
7	28.4.2018	D. Žagar S. Rimac-Drlje V. Križanović	FERIT	Revision of Chapter 3
8	15-5-2018	D. Righini	AAU	Revision of the document.
9	03-06-2018	D. Žagar S. Rimac-Drlje V. Križanović	FERIT	Revision of Chapter 3
10	15-5-2018	D. Righini	AAU	Revision of the document.
11	03-08-2018	D. Righini	AAU	Corrections after the first review

Table of Contents

1. Introduction

This deliverable “Consolidated ex-ante analysis and guidelines aimed at boosting the telecommunications engineer profile including a projection of needs for ICT engineers in the future” reports the results of the activities carried out in tasks T1.1 and T1.2.

Task 1.1: Survey and analysis of telecommunications engineering study programs in relation to modern society and industry needs (Task leader: FERIT)
An academic survey has been prepared and delivered. The responses have been analysed to understand the status quo at the participating universities.
Moreover, an industry survey has been prepared and delivered. It is meant to understand whether companies are looking for ICT specialists, in what fields the specialist are employed, and what knowledge areas are mostly required. Analysis is limited to the surveys filled in by companies that are partners of BENEFIT.

The plan is to keep the surveys alive and gather data during the whole project duration.

Task 1.2: Consolidate guidelines for curriculum modernization in cooperation with industry (Task leader: UL)
Guidelines have been prepared and have been conceived as a methodological tool, i.e., a flow chart of steps to be followed in the development phase to modernize the study programs. These guidelines will guide the partners on the development phase of the modernized programs, labs, and teaching methodologies. They refer to relevant document where teaching methodologies, learning outcomes and areas to be covered are described in detail.

The document provides:
a snapshot of the present situation about the telecommunications engineering curriculum development both in EU and WB HEIs,
analysis of the existing industry, employment status, employment perspectives, competencies and skills needed,
a survey of the existing policies, local constraints, guidelines and best practices addressing the reform of curricula at EU and WB universities.

The document aims at providing necessary guidelines for the following project activities according to industry inputs and good examples from EU.

2. Objectives of the Deliverable

See above.

3. Analysis of telecommunications engineering study programs in relation to modern society and industry needs

During the last decades, partner universities went through different higher-education reforms and structured the studies in different ways. Novel trends in development of technological solutions are driving the market needs away from the traditional telecommunication engineering towards the information and communication technologies profiles. This engineers should be trained to understand and respond to new information-based market and industry needs.
Therefore, the starting point for desired changes of the existing study programs has been the identification of the study programs in all involved universities as well as the preparation of unique templates for self-assessment in both domains – academic and industry.
A template for self-assessment for academic part has been prepared by FERIT and distributed to all universities included in the project. Furthermore, an industry survey has been prepared by UL and delivered to BENEFIT industry partners. The idea behind this survey was to better identify the required profiles of ICT specialists, in what main fields the specialists are employed, and what knowledge areas they need.
FERIT and UL collected inputs from academic partners and representatives of industry partners. The responses have been analysed determining key similarities and differences among participating universities and industry needs given by industry partners.
In order to investigate legal limitations in the study program modernization process Section 3.2 provides brief overview of legislation in Bosnia and Herzegovina and Serbia, as target countries in which the project results should be implemented.
The acquired data have been e valuated and analysed and results given in Section 3.3 and 3.5. Section 3.3 present the current status of study programmes in Telecommunication engineering and academically acquired skills, as well as some partnerships in education with the industry.
The Sections 3.4 and 3.5 present the methodology of the conducted survey as well as the analyses and relevant information from the industry in the region giving academic partners valuable information for the process of modernization of the study programs in telecommunications engineering.
Section 3.6 gives an overall analysis of status quo giving some initial recommendation for the implementation phase of the project, which includes the modernization of the curricula (WP2), the creation of new labs and adoption of new teaching methodologies (WP3) and the training and internship activities (WP4).
Analyses of telecommunications engineering study programs in relation to modern society and industry needs are essential starting points for Section 4, which gives the guidelines aimed at boosting the telecommunications engineer profile projecting the needs for the future ICT engineers.

3.1 Academic survey

An academic survey has been conceived to collect information from academic partners in form of unique template, which should be a base for the essential comparison of study programs structures, legislations, competencies acquired, industry cooperation, procedures and guidelines related to the curriculum implementation etc. The main aim is to gather relevant information from academic partners in the region presenting similarities and differences as a basic point for the process of modernization of the study programs in telecommunications engineering and necessary curricula harmonization, as well.
After a few iterations the final questionnaire, in electronic form (Excel file) has been prepared, comprising the agreed main points of interest as an input for academic analyses. The questionnaire is composed of three basic parts (data sheets): General, Competences and Courses.
The questionnaire gives an overview of the study structure, general competencies obtained through the study programme, subjects' distribution by Compulsory/Elective and by groups Fundamental/Professional/General. Furthermore, it provides an overview of the main documents, procedures and guidelines related to the curriculum implementation as well as some information about

cooperation with the industry. Study program courses have been classified into preselected categories/groups of familiar courses.
The questionnaire is divided into several groups of questions based on their related topic categories. These categories comprised general data considering institutions (Universities), structure of the related ICT study programmes, important regulations, industry cooperation, professional activity, teaching methodologies, and the list of core competences acquired.

The group of questions related to the official data considering institution comprise:

- The University name
- The official University web page
- The contact person name
- The contact person e-mail

The group of questions related to study structure comprise:

- The study programme title
- The study programme type:
    - the 1st Cycle Study Programme (BSc) or
    - the 2nd Cycle Study Programme (MSc)
- The duration of the study programme (in years)
- The number of ECTS points acquired upon study completion
- The professional title conferred
- The study programme web page
- The basic objectives of the study programme (up to ten)
- The general competences obtained through the study programme (up to ten)
- The number of ECTS acquired for final/diploma thesis
- The number of ECTS for professional practice
- The duration of professional practice (in weeks)
- The number of students enrolled in the first year of study in academic 2016/2017
- The number of students graduated in academic 2016/2017
- The specifics of the study programme

The group of questions related to regulations comprise:

- Existing institutional regulations
- Existing strategies, recommendations and other legal documents of the Faculty / the University related with the curriculum
- Existing national regulations
- Existing policies / laws defining high education in the country

The group of questions related to achieved cooperation with industry comprise:

- The number of realized student internships (within the last two years)
- The number of created BSc/MSc theses with cooperation of external experts (within the last two years)
- The number of industry experts involved in student training
- Involvement of industry experts in shaping the study programmes
- The number of developed joint industry-academia labs

The group of questions related to professional activity comprise:

- The number of start-ups (started within the last five years)
- The number of spin-offs (started within the last five years)

The group of questions related to teaching methodologies comprise:

- The courses titles
- The type of the courses:
    - compulsory or
    - elective
- The category of the courses:
    - fundamental
    - professional or
    - general
- The group in which the courses belong:
    - Mathematics
    - Physics
    - Fundamentals of electrical engineering
    - Measuring and instrumentation fundamentals
    - Information theory
    - Electronics engineering
    - Radio communications
    - Communication networks
    - Communication systems
    - Software engineering
    - Computer engineering
    - Information and data management
    - Signal processing
    - Multimedia
    - Other engineering courses
    - Communication and presentation skills, foreign languages or
    - Business economics, management and organization
- The number of ECTS credits acquired
- The hours per week (total for all teaching forms)
- The hours per week for practical work (lab, projects, etc.)
- The usage of e-tools

The questions related to the competences comprise:

- The list of core competences for each group of courses (up to ten)

The acquired data gives a qualitative/quantitative insight into the study structure, basic and advanced competences, ECTS structure, subjects' distribution etc., giving the input data for analyses of academic survey in Section 3.3.

3.2 Legislation in higher education

In order to investigate legal limitations in the study program modernization process, this section provides brief overview of legislation in Bosnia and Herzegovina and Serbia.

3.2.1 Legislation in higher education in Bosnia and Herzegovina

Higher education system in Bosnia and Herzegovina is fragmented and regulated by three B&H entities, "Federation of Bosnia and Herzegovina", "Republic of Srpska", and "Brčko District". Framework law of Bosnia and Herzegovina is adopted in 2007 [1] as higher education regulation at the state level. The framework law determines higher education organization, introduces Bologna concept and ECTS system as well as quality assurance in higher education. However, state is not responsible for higher education according to Dayton agreement. Each canton in Federation of B&H regulates higher education by own laws. Public universities are financed by canton budgets. Republic of Srpska have a different law for higher education and finances public universities. Agency for Development of Higher Education and Quality Assurance, established in 2007, is responsible for external quality assessment and accreditation of higher education institutions [2] [3]. The statue of UNI BL is available on line at the following link [4].

3.2.2 Legislation in higher education in Serbia

Higher education in the Republic of Serbia is regulated by the national Law on Higher Education, which came into force in 2017 [5] [6]. This Law governs the higher education system, conditions and manner of carrying out HE activities, financing and other matters of importance for the performance of these activities. The objectives of this Law include teaching scientific, professional and artistic knowledge and skills, development of science, ensuring a source of young researchers and professionals, as well as providing equal access to HE as well as opportunities for education and training throughout life. The Law also ensures the autonomy of universities and other HE institutions, which implies the right to decide on study programmes, to determine the rules of study and admission requirements, the right to regulate the internal set-up, the right to decide on the acceptance of projects and on international cooperation as well as other rights in conformity with the Law.

The National Council for Higher Education (NCHE) is established to ensure the development and promotion of the quality of higher education. The NCHE oversees the development of higher education and its conformity to European and international standards, recommends policies to the Ministry responsible for HE affairs (the Ministry of Education, Science and Technological Development), enacts standards for internal assessment and quality evaluation, enacts standards and procedures for accreditation of HE institutions and study programmes. Each independent HE institution or a HE unit thereof, by its Statute or a general legal act, defines bodies and procedures concerning overseeing, assurance, promotion and development of the quality of study programmes, teaching and working conditions. The National Council submits to the National Assembly a report on its work at least once a year.

For the purpose of carrying out the tasks relating to accreditation, quality evaluation of HE institutions and evaluation of study programmes, the National Council establishes a separate working body called the Accreditation and Quality Evaluation Commission. The accreditation process establishes whether a given HE institution [7] [8] [9] and its study programmes comply with the standards as set out in the national Law on Higher Education. All accredited universities form the Conference of Universities, whose purpose is the coordination of work, formulation of common policies, realisation of shared interests and carrying out other tasks defined by the Law.

3.3 Analysis of academic survey

The acquired data has been analysed aiming at identifying current status of the academic study programs in fields of telecommunication engineering and related to ICT professionals. Nine university partners answered the survey identifying the key points of existing programs.

The analysed data gives a good insight into main objectives, competences, specifics, highlighting the aspects important for this deliverable, as well as determining main similarities and differences between universities.

The survey template is attached in Annex 7.3.

List of the study programmes included in the academic survey is given in Table 1.

Table 1.: List of the study programmes

STUDY PROGRAMMES		
	University	Study programme title
1st Cycle Study Programme (BSc)		
UNI-KLU_BSc	University of Klagenfurt, Faculty of Technical Sciences	Bachelor study programme in Information technology
UL_BSc	University of Ljubljana, Faculty for the Electrical Engineering	Undergraduate study programme in Electrical Engineering; Branch: Information and Communication Technologies
FERIT_BSc	University of Osijek, Faculty of Electrical Engineering, Computer Science and Information Technology	Undergraduate study programme in Electrical Engineering; Branch: Communications and Informatics
UB_BSc	University of Belgrade, School of Electrical Engineering	Undergraduate study programme in Electrical Engineering and Computer Engineering; Module: Telecommunications and Information Technology, Submodules: Audio and Video Communications (UB_BSc (AVC)), Microwave Engineering (UB_BSc (ME)), Radio Communication (UB_BSc (RC)) and System Engineering (UB_BSc (SE)).
UBL_BSc	University of Banja Luka, Faculty of Electrical Engineering	Undergraduate study programme in Electronics and Telecommunications
UNI_BSc	University of Nis, Faculty of Electronic Engineering	Basic academic studies of Electrical engineering and computing; Module: Telecommunications, Submodules: Radiocommunication Engineering and Technology (UNI_BSc (RET)) and Telecommunications and Signal Processing (UNI_BSc (TSP))
UNS_BSc	University of Novi Sad, Faculty of Technical Sciences	Undergraduate academic studies in Power, Electronic and Telecommunication Engineering; Module (from the 2nd year): Communications Technologies and Signal Processing
UNSA_BSc	University of Sarajevo, Faculty of Electrical Engineering	Bachelor study programme in Electrical Engineering; Telecommunications
UNTZ_BSc	University of Tuzla, Faculty of Electrical Engineering	Undergraduate study programme in Electrical and Computer Engineering
2nd Cycle Study Programme (MSc)		
UNI-KLU_MSc	University of Klagenfurt, Faculty of Technical Sciences	Master study programme in Information and Communication Engineering in: Autonomous Systems and Robotics (UNI-KLU_MSc (ICE-ASR)), Business Engineering (UNI-KLU_MSc (ICE-BE)) and Networks and Communications (UNI-KLU_MSc (ICE-NC))
UL_MSc	University of Ljubljana, Faculty for the Electrical Engineering	Graduate study programme in Electrical Engineering; Branch: Information and Communication Technologies

FERIT_MSc	University of Osijek, Faculty of Electrical Engineering, Computer Science and Information Technology	Graduate study programme in Communications and Informatics; Elective blocks: Network Technologies (FERIT_MSc (NT)) and Communication Technologies (FERIT_MSc (CT))
UB_MSc	University of Belgrade, School of Electrical Engineering	Master study programme in Electrical Engineering and Computer Engineering; Module System Engineering and Radio Communications
UBL_MSc	University of Banja Luka, Faculty of Electrical Engineering,	Master study programme in Electronics and Telecommunications
UNI_MSc	University of Nis, Faculty of Electronic Engineering	Master academic studies in Telecommunications; Modules: Radiocommunication Engineering and Technologies (UNI_MSc (RET)) and Telecommunications and Signal Processing (UNI_MSc (TSP))
UNS_MSc	University of Novi Sad, Faculty of Technical Sciences	Master academic studies in Power, Electronic and Telecommunication Engineering; Module: Telecommunication Systems
UNSA_MSc	University of Sarajevo, Faculty of Electrical Engineering	Master study programme in Electrical Engineering Telecommunication
UNTZ_MSc	University of Tuzla, Faculty of Electrical Engineering	Master study programme in Electrical and Computer Engineering

3.3.1 Studies' structure

Study programs of all three EU university partners have a structure 3 + 2, i.e. 3 years of undergraduate or bachelor study (BSc) and 2 years of graduate or master degree (MSc) (Figure 1). On the other hand, all programs in Serbia and Bosnia and Herzegovina (besides programme at the University of Sarajevo) have a 4 + 1 structure, i.e. 4 years for undergraduate and 1 year for graduate studies. Following the rule of 30 ECTS for one semester, distribution of the ECTS are according the studies structure, as shown on Figure 2.

These differences in duration of the 1st cycle and 2nd cycle study programmes can be an obstacle to the full harmonization of programs and especially to the establishment of joint studies between EU and WB partner institutions.

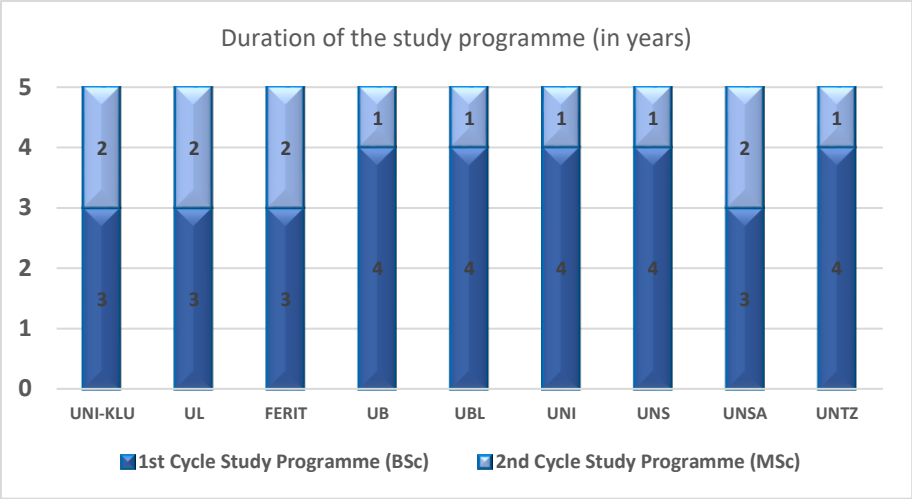


Figure 1: Duration of the study programmes

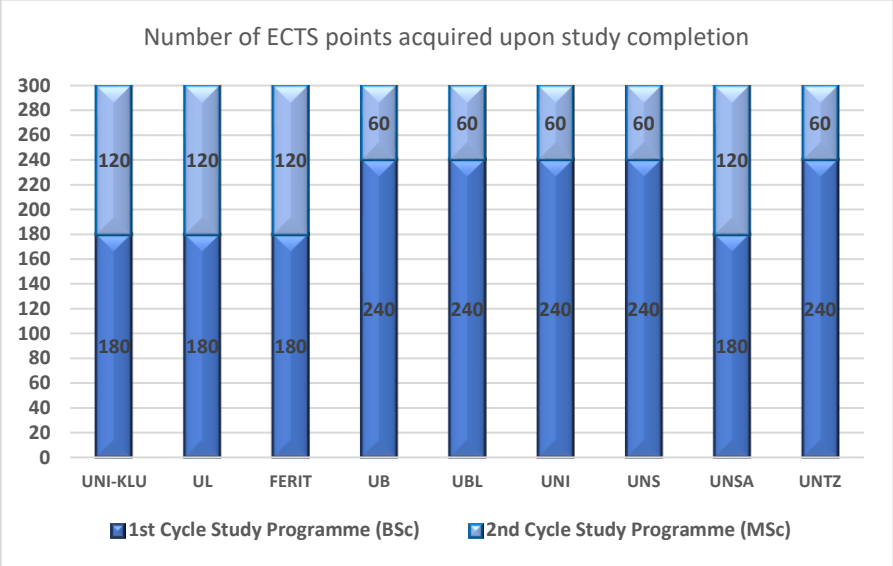


Figure 2: Number of ECTS points acquired upon study completion

Basic objectives of the study programmes and general competences obtained through the study programmes are presented in Table 2. Despite the differences in duration of the graduate and undergraduate studies, objectives and general competences are quite similar for all corresponding studies.

Table 2: Basic objectives of the study programmes and general competences

BASIC OBJECTIVES OF THE STUDY PROGRAMME AND GENERAL COMPETENCES OBTAINED THROUGH THE STUDY PROGRAMME		
	The basic objectives of the study programme	General competences obtained through the study programme
1st Cycle Study Programme (BSc)		
UNI-KLU_BSc	Prepares students for the design and operation of modern information and communications technologies Students are equipped with a sound fundamental knowledge in the following areas: • electronics • circuitry • signals and systems • measurement and control systems engineering • computer and network technology • informatics and software development	• Prepares student to develop basic skills in the areas of electrical, electronic, signals, computers and networking engineering. • Professional experience at industry partners • Research experience through allowing the students to participate in the research activities at the university. • Develops hand on expertise in the above-mentioned fields of engineering through labs and projects
UL_BSc	• to offer high-quality knowledge in electrical engineering, • to provide an excellent foundation for 2nd cycle study not only in electrical engineering but in any technical discipline, • to enable efficient entry to the labour market through employment and independent tracking of the most recent achievements, • to provide a good basis and incentive for further autonomous study within the framework of lifelong learning, • to enable mobility between related and other study programmes and to ensure Europe-wide comparability of the achieved education.	• the ability to define, understand and creatively solve problems in the field of electrical engineering and in other fields, • critical thinking on the basis of analysis and synthesis, • professional, environmental and social responsibility, • active professional written and oral communication, • optimal use of ICT and its advancement, • independent tracking of the most recent achievements and acquisition of new knowledge, • teamwork with experts from various fields
FERIT_BSc	• to provide students with high-quality education in the fields of electrical engineering and information and communication technologies • to provide basic engineering knowledge for the labour market • to provide a basis and incentive for further study within the master study programmes • to enable mobility and compatibility between related and other graduate study programmes	• using basic mathematical and physical knowledge, construct a model for solving engineering problems and a model for evaluating experimental results in the fields of electrical/computer engineering, • create a project plan using appropriate project planning and management tools and techniques, • solve (non) linear and time-(in)variant power networks, conduct electrical measurements in the network and evaluate the obtained results.

		• solve simpler problems in steady-state electric and magnetic fields and in electric circuits. • design and evaluate digital circuits based on defined functionalities and features. • develop one's own software solutions by applying operation principles and technologies for developing computer and software systems, • analyse and evaluate the functionality and efficiency of one's own software solution, • develop a model and simulate a specific system by applying the principles and mechanisms of modelling and simulation, signals and systems theory, • analyse and distinguish between different types of communication networks, and the physical and logical structure of modern wired and wireless communication networks, • design amplifiers for a defined frequency band and amplification amount and perform an analysis of their operation, • define basic concepts in the field of information theory, • analyse the structure and protocol stack in modern communication networks.
UB_BSc	• to provide students with high-quality education in the field of electrical engineering and computer science • to encourage their creativity, responsibility, research interest and team work • to provide companies with outstanding engineers who will be able to enhance companies productivity, innovation and market competitiveness both in Serbia and world wide • to make continuous contribution to technological development, informatization and overall development of our country	• the ability to apply the knowledge of mathematics, physics, science and engineering to identify, formulate, and solve problems in the ICT field • the ability to develop critical judgment about proposed concepts and solutions in the ICT field • the ability to develop mathematical models of the physical phenomena and transform the model into the software code • the ability to perform experiments and draw conclusions related to different types of measurements in telecommunications devices and systems • the ability to understand whole chain of the process, analysis, design, implementation and verification of the devices and systems in the ICT field • the ability to work in team with practitioners specialized in fields other than ICT

		• the ability to continue a career within research and further education • the ability to upgrade their competencies upon changes of the technologies and social impact of ICT • the ability to clearly and with arguments express opinion about general topics related to ICT
UBL_BSc	• to provide quality knowledge and skills in telecommunications engineering • to provide a good foundation for further education in similar disciplines • to advance soft skills in preparation, management and overseeing of projects in all areas of telecommunications engineering • to ensure that students obtain knowledge and skills matched to the market requirements • to enable mobility of students • to provide in-depth understanding of a specific aspect of engineering, with sufficient focus for employment in an initial role • to provide the basis for continuing and lifelong learning • to establish national and international partnerships in the implementation of the study programme	• fundamental knowledge of mathematics, physics, electrical and electronic engineering, and information technologies • specialist knowledge in the areas of telecommunication systems, networks and signal processing • ability to choose and apply relevant methods to solve problems in telecommunication engineering • ability to participate in design, build and maintenance of complex telecommunication systems • ability to design and perform experiments, to interpret the results and make conclusions • understanding of the impact of the specific engineering discipline to environment and society • demonstrating professional ethics, responsibility and adherence to moral principles in engineering work • oral and written communication abilities • recognizing and accepting the need for continuing and lifelong learning
UNI_BSc	• to educate engineers, competent for design, fabrication and maintenance of hardware (electronic circuits, devices and systems) and software in all forms of their application • to enable a good basis for continuation of schooling in master and doctoral studies in electrical engineering (and other technical disciplines) • to enable applicable knowledge and skills ensuring students inclusion in the labour market through employment • to include education in the field of telecommunication for the networks and systems exploitation, planning and maintenance to provide the education in the field of telecommunications	• to understand and apply fundamental knowledge in mathematics, physics and electrical engineering • to understand and apply knowledge in engineering disciplines • to observe, formulate and solve engineering problems • to use modern measurement and computer instruments in engineering practice and to use engineering approach in measurement, analysis and interpretation of data received • to design electronic circuits, devices, systems, software and databases based on given specifications • to follow technology development and upgrade their knowledge • to work in multidisciplinary team

	assemblies and devices development and design • to provide the knowledge for understanding and application of new technologies and modern trends in telecommunications	• to take initiative, develop work enthusiasm and have the feeling of professional responsibility • to preserve environment • to use natural resources of the Republic of Serbia economically, in accordance with sustainable development principles
UNS_BSc	• to educate students for the profession of an engineer of electrical and computer engineering-bachelor in accordance with the economy needs, knowledge based economy and society at large • to provide acquisition of competencies necessary for the graduated engineer of electrical and computer engineering (Communications Technologies and Signal Processing) • to educate top engineers ready for active involvement in the regional development and responsible for the maintenance of the high-tech and research potential of Vojvodina and Serbia • to educate engineers of electrical and computer engineering who possess knowledge necessary for the labour market in Serbia, the region and beyond • to produce qualified engineers-bachelors who are highly competent for the development and design of complex systems and their parts (Communications Technologies and Signal Processing) • to produce qualified engineers-bachelors who possess the fundamental knowledge necessary for further master and doctoral studies • to produce qualified engineers-bachelors who are able to keep step with the fast technological development in the fields of communication systems, software and signal processing systems • to enable students to analyse problems and develop ability of critical thinking, the development of team work skills and the acquisition of practical skills necessary for successful professionals • to develop ability of students to present (in oral and written form) their results to professional and wider public • to develop of students' awareness of the necessity for permanent education and advancement in the field of electrical and computer engineering	• students will be competent for the development, engineering, design and application of modern complex systems and their parts in the field of Communications Technologies and Signal Processing • the ability to understand and apply fundamental knowledge in electrical engineering (particularly in Communications Technologies and Signal Processing) • the ability to apply knowledge in mathematics, physics and engineering disciplines, as well as to use engineering approach and modern software tools in engineering practice • the ability to design systems, components and processes based on the provided specifications • the ability to design and carry out engineering experiments and afterwards analyse and interpret obtained data • the ability to understand, notice, formulate and solve engineering problems • the ability to advance their knowledge and follow technological development • the ability to communicate efficiently and work in a team composed of experts in different fields • the ability to understand professional and ethical responsibility of electrical and computer engineers • the ability to accept the need and actively participate in life long education, as well as to understand impact of engineering solutions on society and environment

UNSA_BSc	• educate a young professional to pursue career in industry in the field of telecommunications and engineering • prepare graduates for challenges in further academic education • provide graduates with appropriate soft-skills • basis for life-long learning and independent studies	• knowledge and understanding of mathematics and natural sciences including linear algebra; analytic geometry; vector calculus; matrix calculus; elementary analysis; complex numbers; finite and infinite sequences and series; analysis, differential and integral calculus of the functions of one real variable, and functions of multiple real variables; differential equations of the 1st and higher order; Fourier series and integrals; Laplace transform; linear, surface and volume integrals; probability theory and statistics; mechanics, thermodynamics, mechanics of fluids, heat transfer, radiation; • engineering analysis: ability to apply their knowledge and understanding to identify, formulate and solve medium complexity engineering problems in telecommunications using methods established in first cycle studies. • engineering design: Ability to design according design specifications • ability to study independently and conduct literature surveys • development and maintenance of telecommunication systems • transferable skills
UNTZ_BSc	• to prepare graduates who are able to practice electrical engineering in its major areas, such as telecommunications. • to further develop skills pertinent to electrical engineering problem definition, formulation, design, and analysis. • to apply and practice the electrical engineering knowledge in a professional setting such as ethics and safety. • to demonstrate ability for long life learning, leadership and service among the graduates. • to produce graduates who further develop team work and effective communications skills.	• ability to analyse and solve problems in the field of electrical engineering and computer science by applying fundamental knowledge in the field of natural sciences (mathematics and physics) and engineering; • knowledge to apply skills, techniques and engineering tools; • knowledge to communicate, cooperate and work in engineering teams; • ability to acquire new technologies and techniques, as a part of a lifelong learning process.
• 2nd Cycle Study Programme (MSc)		
UNI-KLU_MSc	• improve concepts and methods from the field of information technology, • identify and comprehend new problem definitions in this field, • recognise technological paradigm shifts	• informatics (artificial intelligence, system security, human-machine interaction) • mathematics (stochastic processes, data analysis, optimisation) • autonomous systems and robotics (autonomous robotics, automation

		engineering, intelligent traffic and transport systems) • networks and communications (sensor networks, digital signal processors, wireless networks)
• UL_MSc	• to offer top-notch professional knowledge in electrical engineering, • to promote creativity and critical thinking in exploring new solutions, • to enable efficient involvement in R&D efforts through employment and innovative exploration of new solutions, • to provide an excellent foundation for 3rd cycle study in electrical engineering or any other technical discipline, • to convince students of the necessity of further autonomous study within the framework of lifelong learning, • to enable mobility between related study programmes and to ensure Europe-wide comparability of the achieved education.	• creative scientific research and development work in the field of electrical engineering and in other fields, • independent tracking and critical evaluation of the most recent achievements in electrical engineering, • active written and oral communication both at a high professional level as well as at a non-technical level, depending on the target audience, • efficient use of ICT and its advancement, • professional, environmental and social responsibility, • teamwork with experts from various fields.
• FERIT_MSc	• to offer high quality professional knowledge in network technologies • to provide a good foundation for the doctoral level study programmes in communications and informatics (and other technical disciplines) • to enable efficient entry to the labour market through employment • to provide a basis and incentive for further study within the framework of lifelong learning • to enable mobility between related and other graduate study programmes • to ensure comparability of the achieved education with other EU faculties	• identify engineering tasks, necessary knowledge and skills related to manufacturing technologies, measures, procedures, regulations and norms for ensuring work safety and employment protection, • design fundamental computer network parameters and integrate the network into the global network, • analyse the procedures for video coding and develop still image and video processing algorithms, • calculate the RF signal coverage of a radio communications system.
• UB_MSc	• to provide students with high-quality education in the field of electrical engineering and computer science • to encourage their creativity, responsibility, research interest and team work • to provide companies with outstanding engineers who will be able to enhance companies productivity, innovation and market competitiveness both in Serbia and world wide • to make continuous contribution to technological development,	• the ability to apply the knowledge of more abstract concepts to identify, formulate, and solve problems in the ICT field • the ability to develop critical judgment about proposed concepts and solutions in the ICT field • the ability to develop mathematical models of the physical phenomena and transform the model into the software code • the ability to foreseen trends in development of ICT sector

	informatization and overall development of our country	• the ability to understand whole chain of the process, analysis, design, implementation and verification of the devices and systems in the ICT field • the ability to work in team with practitioners specialized in fields other than ICT • the ability to continue a career within research and further education • the ability to upgrade their competencies upon changes of the technologies and social impact of ICT • the ability to clearly and with arguments express opinion about general and advanced topics related to ICT
• UBL_MSc	• to provide specialist knowledge and skills in telecommunications engineering • to advance skills in preparation, management and overseeing of complex projects • to further the society in domains where telecommunications engineering is applied • to ensure that students obtain knowledge and skills matched to the market requirements • to enable mobility of students • to introduce students to research in telecommunications engineering	• specialist knowledge in the areas of telecommunication systems, networks and signal processing • ability to choose and apply relevant methods to solve complex problems in telecommunication engineering • ability to design, build and maintain complex telecommunication systems • ability to read and understand research literature
• UNI_MSc	• to provide knowledge for development, design, and maintenance of telecommunications systems and devices on the actual development level • to provide all necessary knowledge and skills for further schooling in doctoral studies • to provide potential for following rapid technological development in the field of telecommunications enable • to be qualified for application of theoretical knowledge in solving professional and practical problems • to understand and apply new technologies and modern trends in telecommunications • to provide knowledge in using scientific methods and research techniques in telecommunication • to develop creative capacities in problems consideration and critical thinking	• to understand and apply fundamental knowledge in telecommunications • to design systems, components and processes based on specifications given • to observe, formulate and solve engineering problems • to upgrade knowledge and follow technology development • to work in a multidisciplinary team, composed of various profile experts • to communicate efficiently • to understand professional and moral responsibility of an electrical and computer engineer • to understand the impact of engineering solutions on the society and environment • to accept the need and get actively involved in life-long education

	• to be qualified for further scientific and research work capacity • to develop capacities for team work and cooperation with different profile experts • to be aware about the need of permanent education, upgrading, and advancement	
• UNS_MSc	• to educate students for the profession of an engineer of electrical and computer engineering-master in accordance with the society's needs • to provide the knowledge and skills that are socially justified and useful in the development of industry and raising the standard of living in many countries • to educate highly competent scientifically and professionally oriented experts in the field of electrical and computer engineering, for this field of science (telecom. And signal processing) • to produce qualified engineers-masters who are highly competent and possess the necessary knowledge and skills needed in further education at the doctoral studies • to produce qualified engineers-masters who are able to keep step with the fast technological development in the field of electrical and computer engineering (telecom. And sig. Process.) • to encourage the development of creativity in the problem solving process and the ability of critical thinking • to encourage the development of team work skills and the acquisition of specific knowledge and skills related to the chosen study group • to develop of students' awareness of the necessity for permanent education, professional development and advancement in the fast-advancing field of electrical and computer engineering • to present (in written form or orally) the scientific results to the professional and general public, especially through scientific and professional papers	• students will be competent for the development, engineering, design and application of modern complex systems and their parts in the field of telecommunications and signal processing • the possibility to continue education depending on affinities and specific competences, including education at doctoral studies • the ability of critical thinking, problem analysis, solution synthesis, prediction of the behaviour of the chosen solution with clear understanding of its advantages and disadvantages • the ability to run experiments and measuring procedures in the field of electrical engineering, to do statistical data processing, to formulate and present adequate results and conclusions • the ability of critical thinking and knowledge application in the specific field determined by the corresponding study group (telecommunications and signal processing) • the ability to solve problems in a new or unknown environment within the scientific-professional field • the ability to integrate knowledge, solve complex problems, make conclusions based on the available information, including reasoning about social and ethical responsibility • the ability to transfer knowledge in a clear, unambiguous manner and to report the knowledge to the professional and general scientific public • the ability to intensively use information-communication technologies and available modern research equipment • the ability to cooperate with colleagues in the specific professional field from educational, scientific, research or economic organizations in the country and the environment

• UNSA_MSc	• educate a young professional to pursue career in industry in the field of telecommunications and engineering • prepare graduates for challenges in further academic education • provide graduates with appropriate soft-skills • basis for life-long learning and independent studies	• knowledge and understanding of mathematics and natural sciences including linear algebra; analytic geometry; vector calculus; matrix calculus; elementary analysis; complex numbers; finite and infinite sequences and series; analysis, differential and integral calculus of the functions of one real variable, and functions of multiple real variables; differential equations of the 1st and higher order; Fourier series and integrals; Laplace transform; linear, surface and volume integrals; probability theory and statistics; mechanics, thermodynamics, mechanics of fluids, heat transfer, radiation; • engineering analysis: ability to apply their knowledge and understanding to identify, formulate and solve medium complexity engineering problems in telecommunications using methods established in first cycle studies. • engineering design: ability to design according design specifications • ability to study independently and conduct literature surveys • development and maintenance of telecommunication systems • transferable skills
• UNTZ_MSc		• knowledge and understanding of mathematical models, theoretical and scientific principles necessary for solving complex problems, including the development of new technologies. • ability to apply acquired knowledge and understanding the design of engineering models, systems and processes, and application of innovative methods for setting and solving problems. • ability to connect knowledge from different areas, detailed knowledge of applied techniques and methods, their limitation and influence on society. • ability to design, analyse, model and experimental research, and the ability to critically evaluate results, data and information, research on the application of new development technologies, and conclude.

Majority of the study programmes offer the students two or more modules and submodules in the area of telecommunications. Specifics of the study programmes are given in Table 3.

Table 3.: Overview of study programme specifics

OVERVIEW OF STUDY PROGRAMME SPECIFICS	
	Specifics of the study programme
1st Cycle Study Programme (BSc)	
UNI-KLU_BSc	Along with the mandatory and fundamental courses, the students should complete Courses from Gender Studies (6 ECTS) or Courses from the following fields (6 ECTS): Languages, Cultural Studies, economics, Corporate and legal sciences Technology Assessment. Moreover, students are free to select courses for 7.5 ECTS from any discipline from the University to widen their knowledge.
UL_BSc	In the third year students select one of four majors: Control engineering, Electronics, Power Engineering and mechatronics, and Information and communication Technologies.
FERIT_BSc	In the third semester enrols one of two elective blocks of courses: 'Power Engineering' and 'Communications and informatics'. After entering one of the electoral blocks, all the courses are mandatory for the student.
UB_BSc	When entering the School of Electrical Engineering all students opt for one of the two study programmes – either Electrical Engineering and Computer Engineering or Software Engineering. At the end of the first year students who study Electrical Engineering and Computer Engineering choose one of the following study modules for the second year: Electronics, Energetics, Computer Science and Information Theory, Signals and Systems, Telecommunications and Information Technology, Physical Electronics. At the end of the second year students of Telecommunications and Information Technology opt for more specialized modules: System Engineering, Radio Communications, Audio and Video Communications, Microwave Engineering.
UBL_BSc	The first year is common for all study programmes at the Faculty of Electrical Engineering. In the third semester students enrol one of the three study programmes (Computer Engineering and Informatics, Electronics and Telecommunications, Power Engineering and Automatic Control). In the third year students from Electronics and Telecommunication study program choose Electronics or Telecommunications branch.
UNI_BSc	The Telecommunications module has two sub/modules In the seventh and eight semesters: 'Radio communication engineering and technologies' and 'Telecommunications and Signal processing'.
UNS_BSc	Nominally 240 students are enrolled in the first year of the study programme „Power, Electronic and Telecommunication Engineering “. At the end of the first year these students choose one of the following study modules for the second year: 1) Power Engineering – Systems, 2) Power Engineering – Power Electronics and Electric Machines, 3) Measurement Systems, 4) Communications Technologies and Signal Processing, 5) Microcomputer Electronics. At the end of the third year students from „Communications Technologies and Signal Processing “, choosing among more elective subjects opt for sub-modules: 4a) Telecommunication Systems and 4b) Signal Processing (these are also the names of corresponding modules at the master study programmes). The number of students enrolled at the module „Communications Technologies and Signal Processing“ in e few previous years was even smaller – it is one of the reasons for initiating the ERASMUS project BENEFIT.

UNSA_BSc	The first year of study is common to the following bachelor study programmes: „Power Engineering“, „Control and Electronics“ and Telecommunications
UNTZ_BSc	Students are enrolled at study program “Electrical and Computer Engineering”, with five modules. Elective courses for one module are mandatory courses at other four modules.
2nd Cycle Study Programme (MSc)	
UNI-KLU_MSc	The ICE program has three specializations: Networks and Communications (NC), Autonomous Systems and Robotics (ASR) and Business Engineering (BE). These branches have a different set of mandatory courses as mentioned in the list of courses.
UL_MSc	Student selects one of study programme options: Control Systems and Computer Engineering, Biomedical Engineering, Electrical Power Engineering, Electronics, Mechatronics, Robotics, Information and Communication Technologies. There are seven elective modules.
FERIT_MSc	In the first semester students enrol elective block 'Communication Technologies' or elective block 'Network Technologies' both within the branch 'Communications and Informatics'. After enrolling into one of the electoral blocks, some courses are mandatory and some are elective for students.
UB_MSc	Each course carries 6 ECTS credits and there are usually five classes per week in each subject. There is a set list of courses in each study module. Student have to take at least three courses from the A list of subjects of the enrolled module and can choose the rest of the courses from either the same module or another module. There is also an possibility for students to take two courses from the field of humanities instead of one elective course, since these courses carry 3 ECTS credits.
UBL_MSc	All courses are elective.
UNI_MSc	The Telecommunications study programme has two modules: 'Radio communication engineering and technologies' and 'Telecommunications and Signal processing'.
UNS_MSc	Master study programme „Power, Electronic and Telecommunication Engineering“ has nine modules: 1) Power Engineering – Systems, 2) Power Engineering – Power Electronics and Electric Machines, 3) Power Engineering – Distributed Energy Resources, 4) Measurement Systems, 5) Telecommunication Systems, 6) Signal Processing, 7) Embedded Systems and Algorithms, 8) Microelectronics, 9) Applied Electronics. The study modules „Telecommunication Systems“ and „Signal Processing“ are the continuation of the bachelor study module „Communications Technologies and Signal Processing“. The module „Telecommunication Systems“ has 4 compulsory courses and 9 elective courses (2 of 9 should be chosen).
UNSA_MSc	-
UNTZ_MSc	The 2nd cycle of studies is organized as one study programme, with five modules: Automation and robotics, Electric power networks and systems, Energy Conversion Systems, and Computer and Informatics, and Telecommunications. Student choses an elective course from courses that are mandatory at other modules.

Number of ECTS scores acquired for final/diploma thesis differs for different study programmes (Figure 3). All studies give ECTS scores for final and diploma thesis, except BSc study at University of Ljubljana, Faculty of Electrical Engineering. For all studies the number of ECTS scores for diploma thesis is higher than for final thesis, reflecting the higher student engagement for preparing diploma thesis. On four graduate studies, a whole semester is dedicated to the work on the diploma thesis and student acquires 30 ECTS scores for that, since on other graduate studies number of ECTS scores is between 15 and 24.

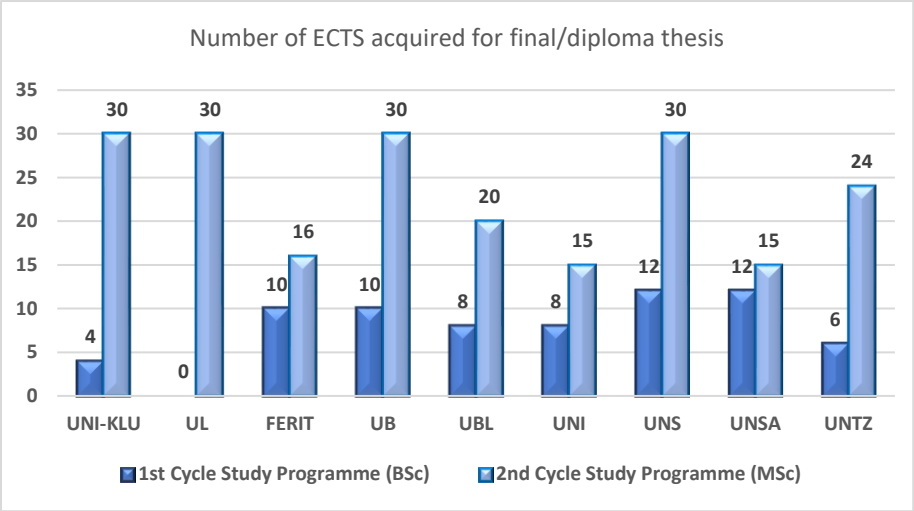


Figure 3: Number of ECTS scores acquired for final/diploma thesis

Professional practice is not a compulsory part of all study programmes (Figure 4). Faculties in Ljubljana, Sarajevo and Tuzla do not have professional practice on both undergraduate and graduate studies, Faculty in Osijek does not have practice on undergraduate, and faculties in Beograd and Banja Luka do not have practice on graduate level. Only faculties in Niš and Novi Sad have compulsory practice on both study levels. The professional experience is optional for the bachelor and master programs at UNI_KLU. However, UNI_KLU strongly encourage students to participate in it. Duration of the professional practice is between 2 and 6 weeks (Figure 5).

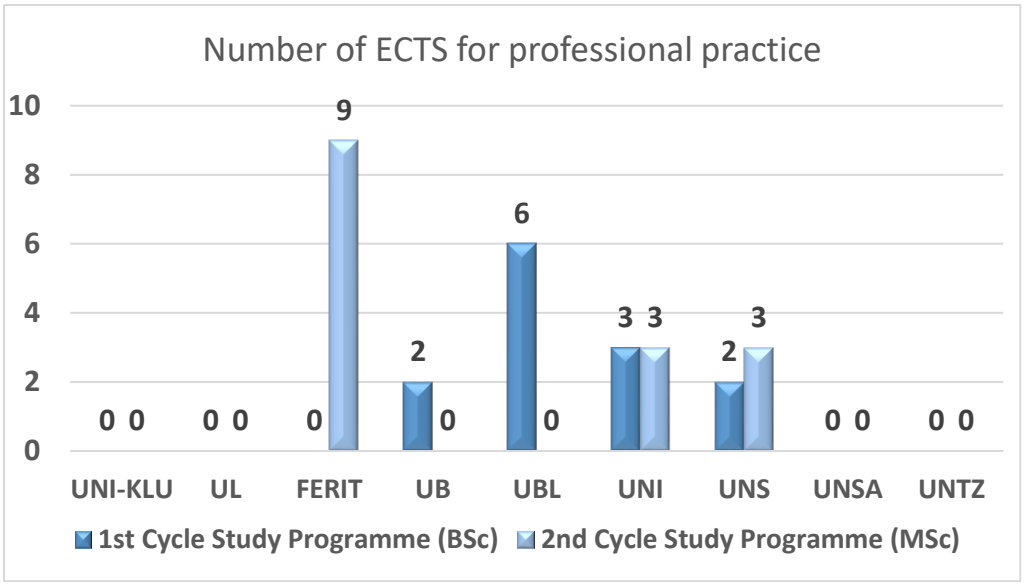


Figure 4: Number of ECTS for professional practice

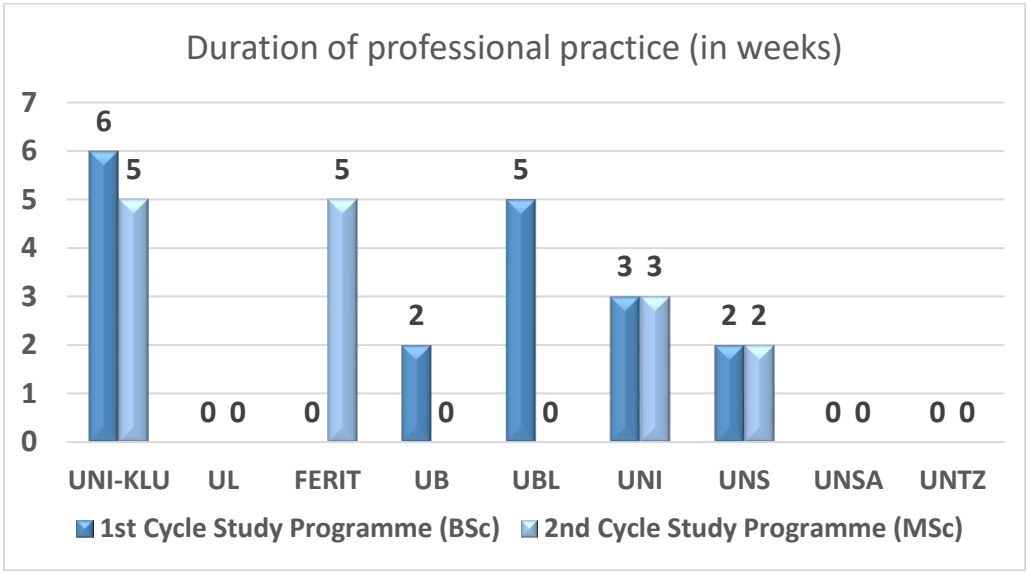


Figure 5: Duration of professional practice (in weeks)

3.3.2 Analysis of courses

In order to compare the study programs, we carried out the analysis of the allocation of ECTS credits on compulsory and elective courses as well as the average weekly total and the number of hours for practical work (laboratory exercises, projects, etc.) for compulsory courses. Results are given on Figures 6 to 9.

On BSc programs lasting 3 years, the number of ECTS points for compulsory subjects ranges from 144 at UNI_KLU_BSc to 166 on FERIT_BSc, and on 4-year BSC programs from 162 on UB_BSc (RC & SE) to 210 on UNITZ_BSc. On two-year Msc programs, the number of ECTS credits ranges from 8 on UNI_KLU_MSc to 90 on FERIT_MSc. One-year UB_MSc and UBL_MSc have no compulsory subjects, and on other one-year BSc studies the number of ECTS credits ranges from 19 on UNS_MSc to 30 on UB_MSc and UBL_MSc. The percentage of ECTS credits for compulsory courses in the total number of ECTS

credits (within the entire study program) for BSc programs ranges from 68% for UB_BSc and UBL_BSc to 92% for FERIT_BSc. Differences are higher in Msc programs, where the percentage of ECTS points for compulsory subjects ranges from 0% UBL_MSc and UB_MSc to 75% on FERIT_MSc. The higher the share of ECTS credits for compulsory subjects means that students have fewer opportunities to form their own studies through elective courses, but on the other hand, it gives the more clearly formulated competences that each student acquires upon graduation.

By analysing the average hours per week for all forms of teaching as well as separately for practical work, we wanted to compare the average student load for compulsory courses on different programs. Most of the programs have an average number of compulsory courses of about 20, except UNI_KLU_BSc having only 10 (Figure 8). On MSc programs, the difference in average number of hours is higher because there are bigger differences between the numbers of compulsory courses. It is interesting to compare the average weekly hours of practical work ranging from 2 to 6 on BSc programs and 1 to 11 on MSc programs (Figure 9). Since practical forms of teaching (laboratory exercises, projects, etc.) are important for acquiring technical skills required for the labour market, one of the ways of adjusting a program to the needs of employers could be in the direction of increasing the share of practical work in the overall student burden.

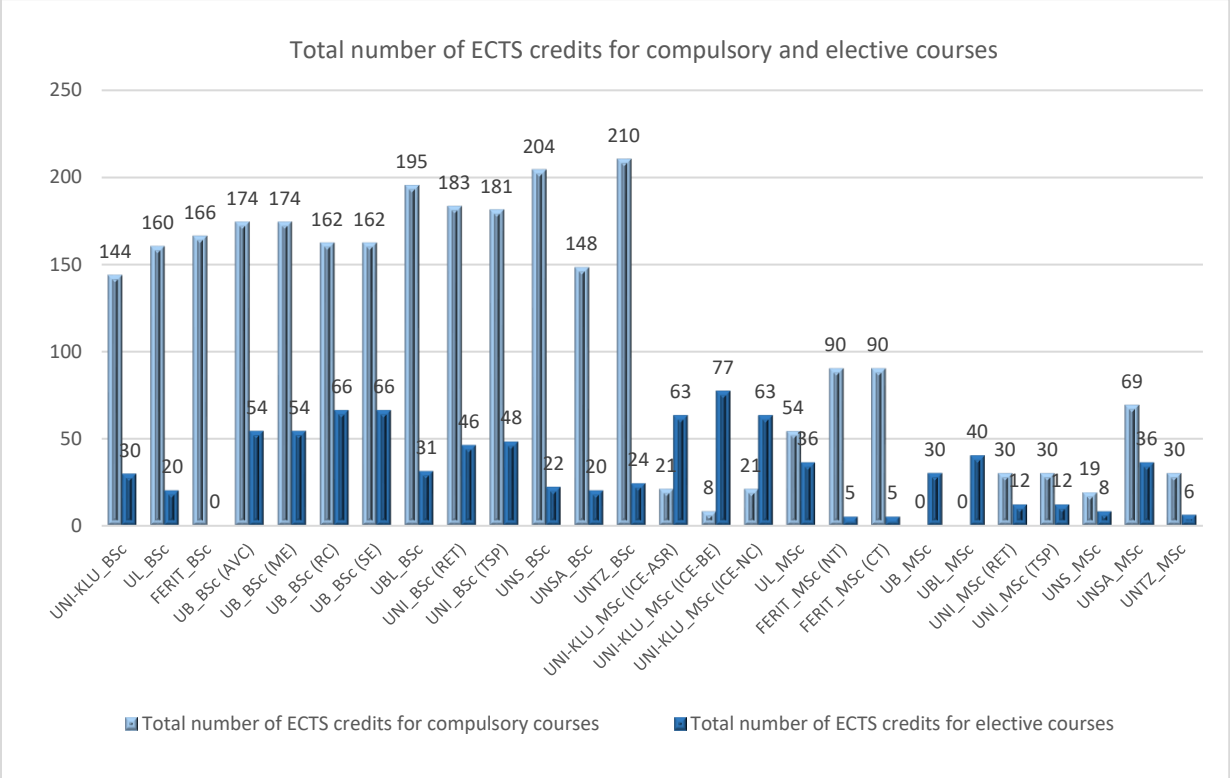


Figure 6: Total number of ECTS credits for compulsory and elective courses

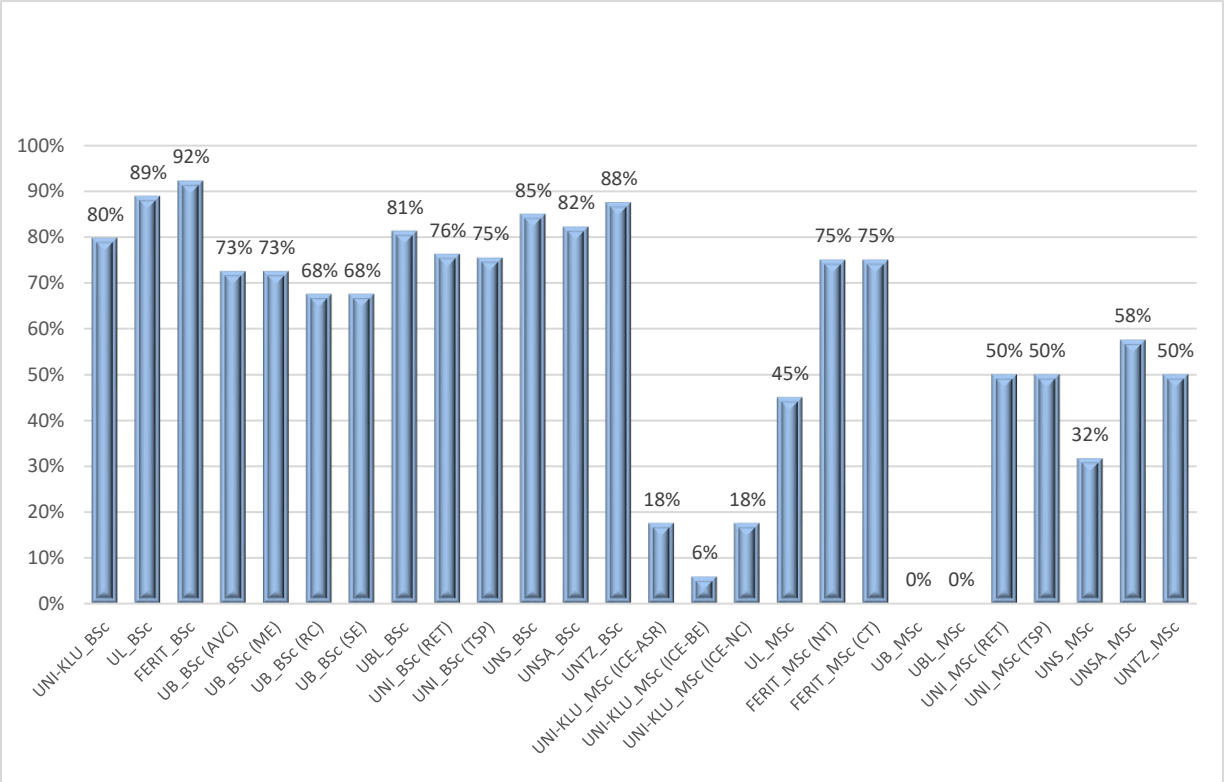


Figure 7: Percentage of ECTS credits for compulsory courses in the total number of ECTS credits within the whole study programme

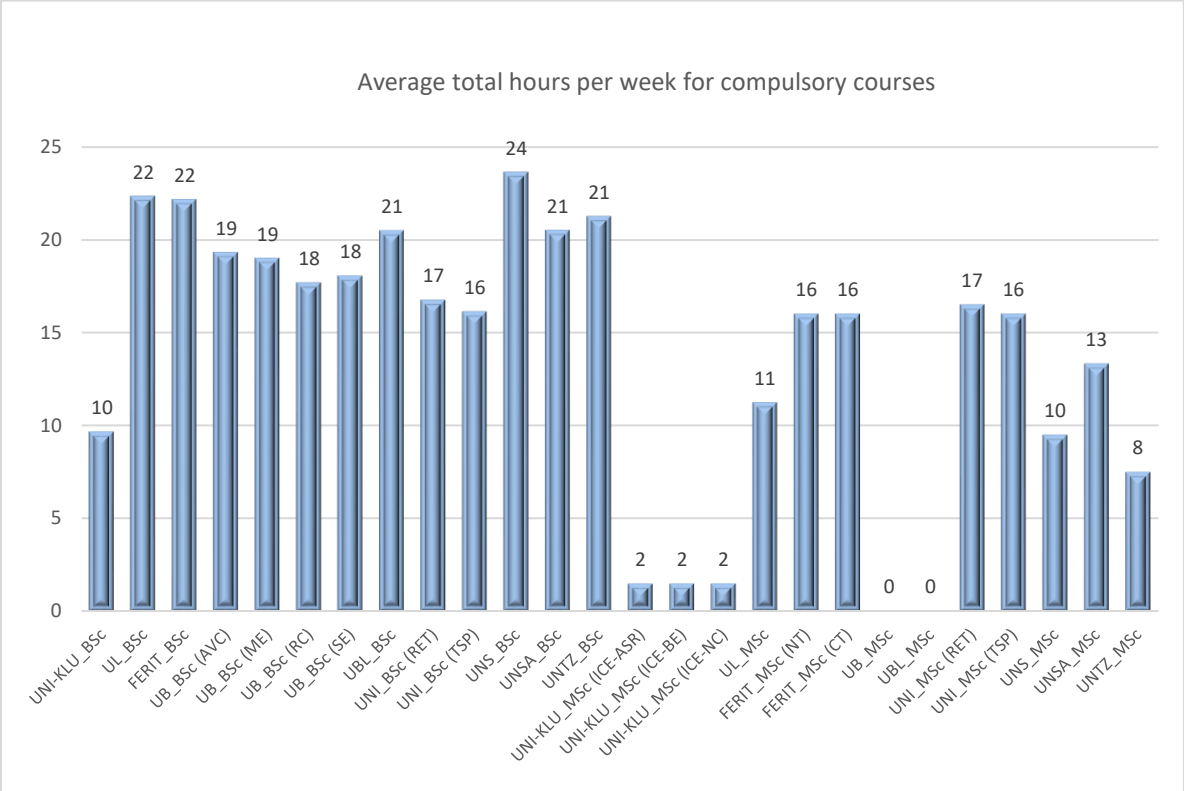


Figure 8: Average total hours per week for compulsory courses

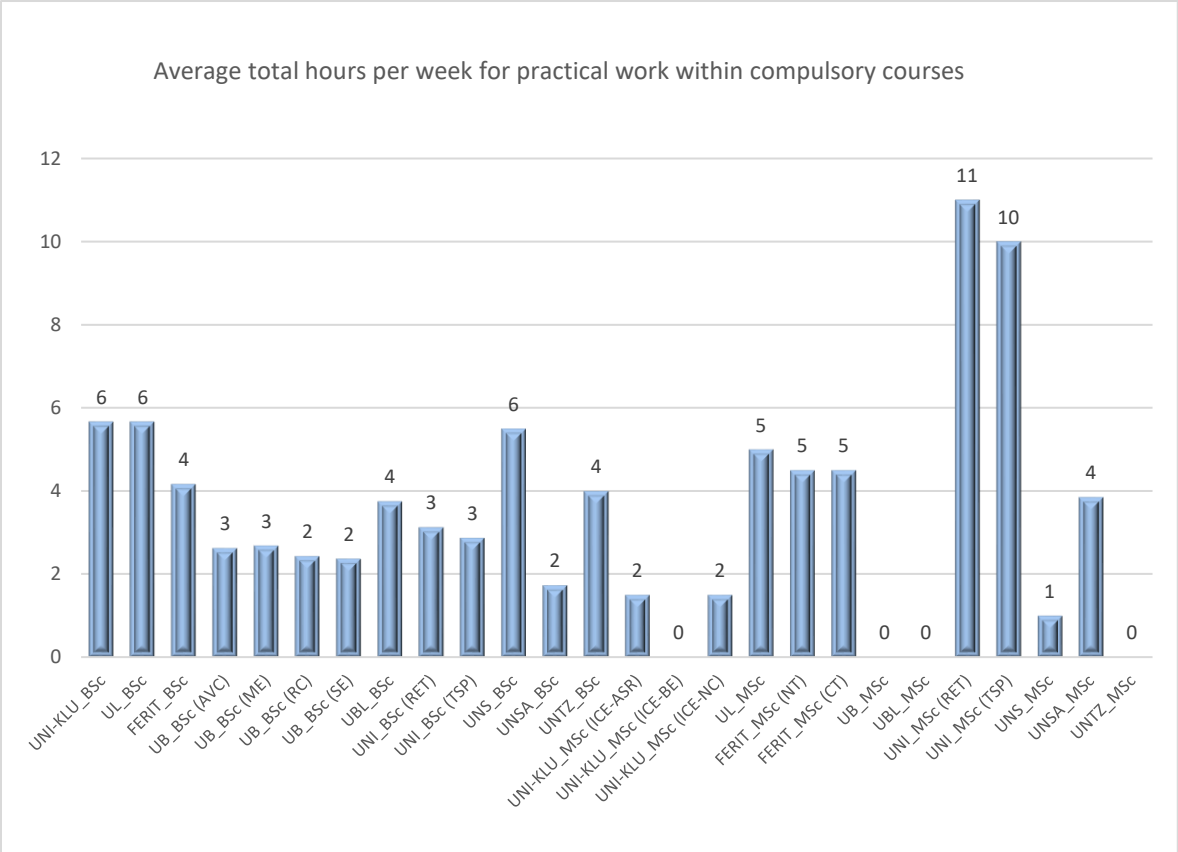


Figure 9: Average total hours per week for practical work within compulsory courses

The distribution of ECTS credits for compulsory courses by categories shows that in most BSc programs the highest percentage of courses belong to the professional category (between 58% and 89%). The exception is UL_BSc which has 31% ECTS for professional category subjects, while 69% ECTS belong to general subjects categories. On the most of MSc studies, the percentage of ECTS credits for courses in the professional category is 100% or close to 100%, except for UL_MSc where it is 33%. Basic compulsory courses are mostly on BSc programmes, and on some BSc and MSC programmes there are general compulsory courses with a percentage of ECTS between 3% and 14%.

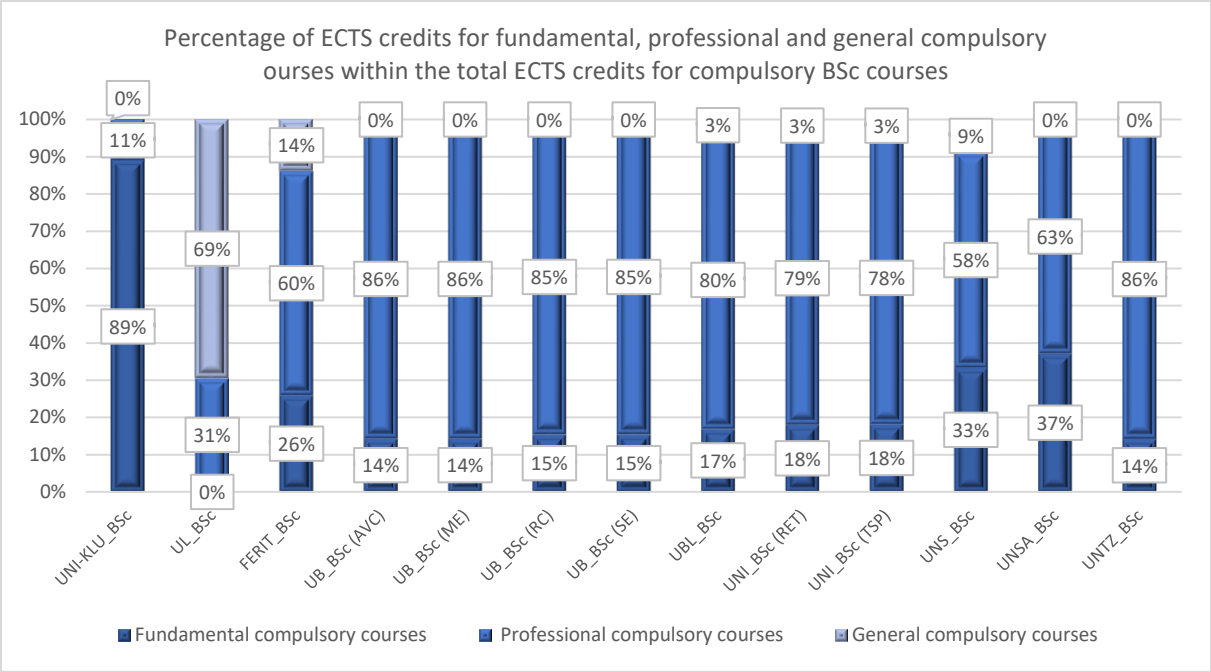


Figure 10: Percentage of ECTS credits for fundamental, professional and general compulsory courses within the total ECTS credits for compulsory BSc courses

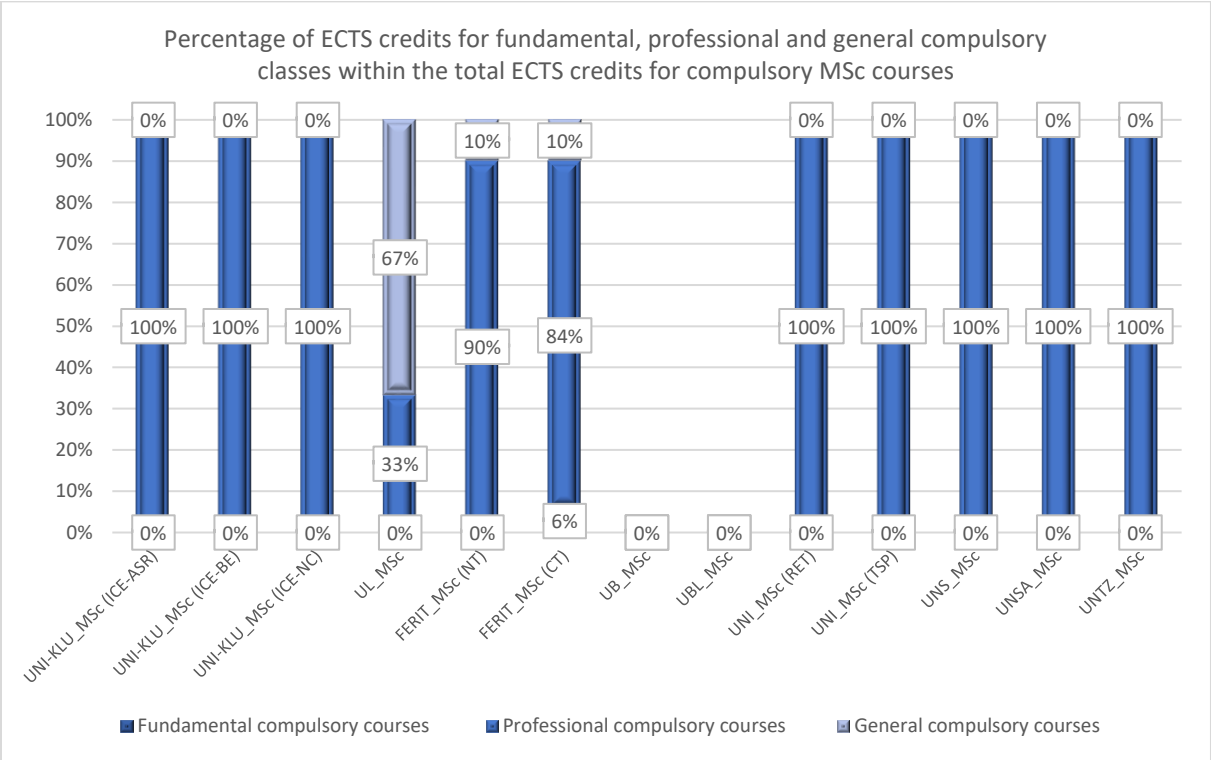


Figure 11: Percentage of ECTS credits for fundamental, professional and general compulsory classes within the total ECTS credits for compulsory MSc courses

Figures 12 to 22 show the distribution of ECTS credits for compulsory courses by groups (mathematics, physics, fundamentals of electrical engineering ...), presented for the whole 5 years study cycle (i.e. combination of appropriate BSc and MSc studies). All programs have a large share of ECTS credits for mathematics and fundamentals of electrical engineering courses, while the share of ECTS credits for other groups of courses significantly differ for different programs. BSc and MSc study programmes in Sarajevo as well as in Belgrade, submodule System Engineering (SE), have strong emphasis on communication networks with 22% of ECTS credits for this group of courses. Programmes in Niš on module Telecommunications and Signal Processing (TSP) have high percentage of ECTS credits in communication systems group of courses (24%), since programmes in Klagenfurt have 24%, 26% and 24% of ECTS credits in computer engineering group of courses on Autonomous Systems and Robotics (ASR), Business Engineering (BE) and Networks and Communications (NC), respectively. All programmes have courses from software engineering and/or computer engineering groups, with percentage for both groups between 6% and 26%.
The courses that improve the soft skills of students exist only in programmes in Banja Luka, Osijek, Niš, Novi Sad, and courses that improve managerial and entrepreneurial skills exist only in Banja Luka, Novi Sad, Osijek and Klagenfurt.

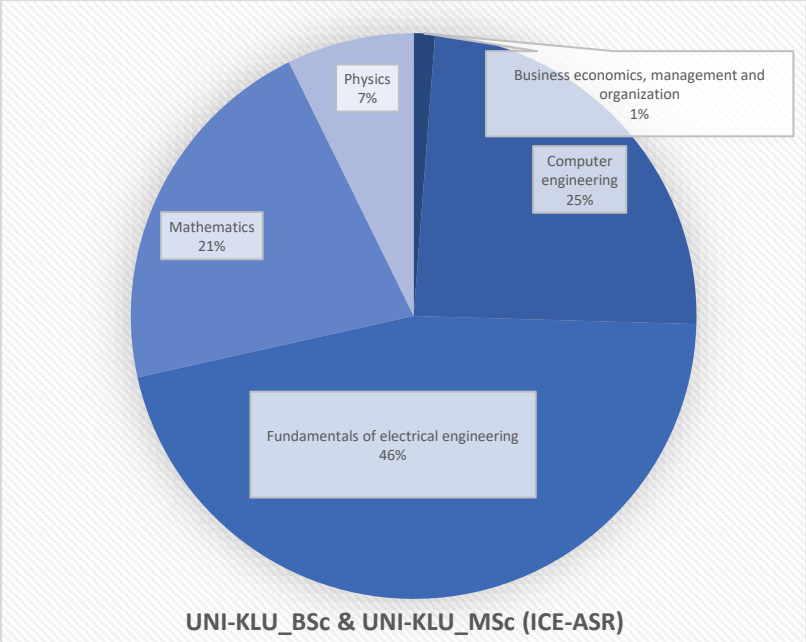


Figure 12: Distribution of ECTS credits for compulsory courses according to group for UNI-KLU_BSc & UNI

-KLU_MSc (ICE-ASR)

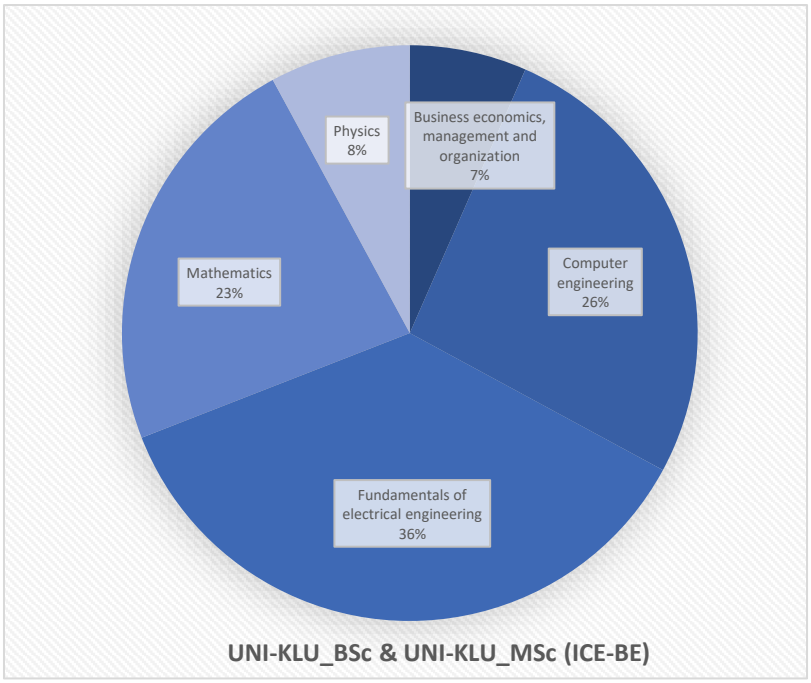


Figure 13: Distribution of ECTS credits for compulsory courses according to group for UNI-KLU_BSc & UNI-KLU_MSc (ICE-BE)

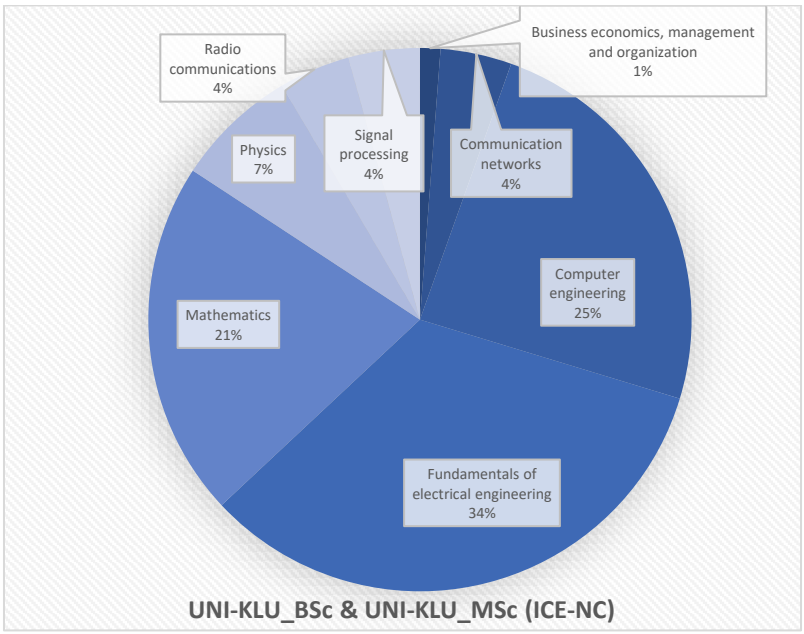


Figure 14: Distribution of ECTS credits for compulsory courses according to group for UNI-KLU_BSc & UNI-KLU_MSc (ICE-NC)

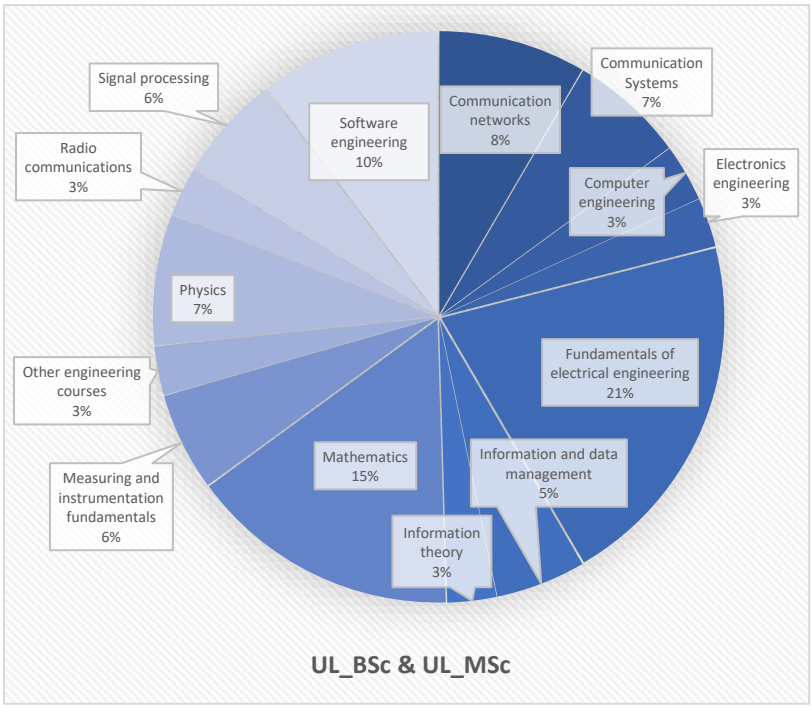


Figure 15: Distribution of ECTS credits for compulsory courses according to group for UL_BSc & UL_MSc

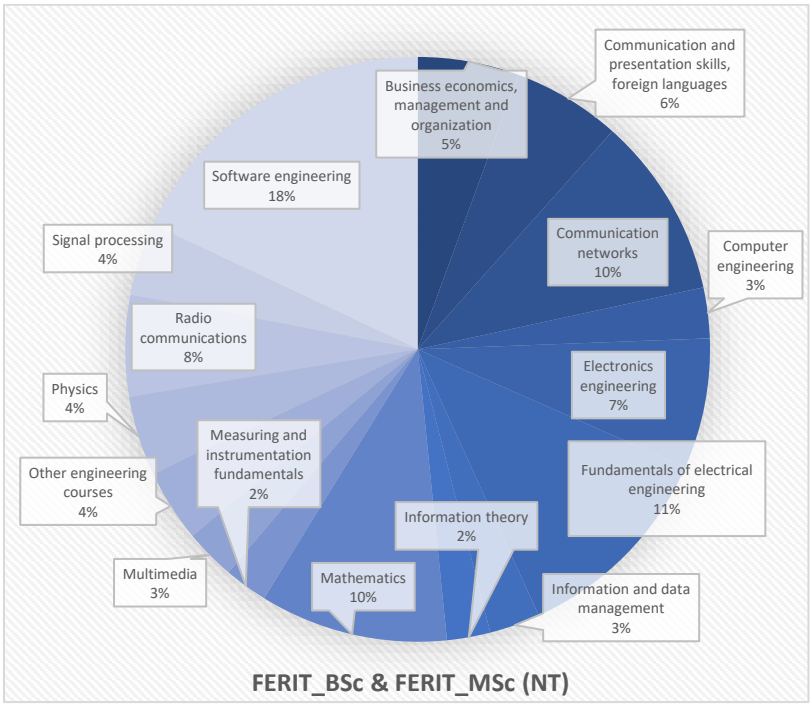


Figure 16: Distribution of ECTS credits for compulsory courses according to group for FERIT_BSc & FERIT_MSc (NT)

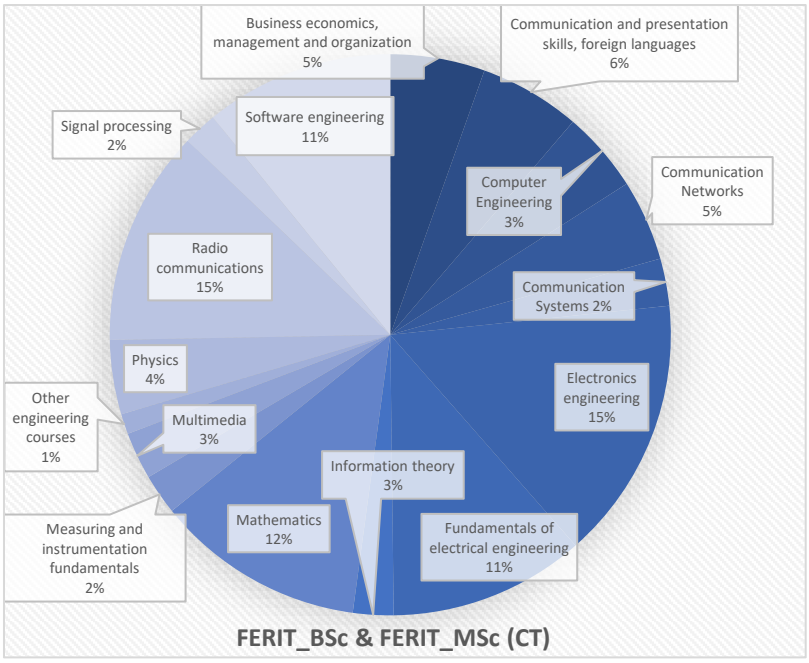


Figure 17: Distribution of ECTS credits for compulsory courses according to group for FERIT_BSc & FERIT_MSc (CT)

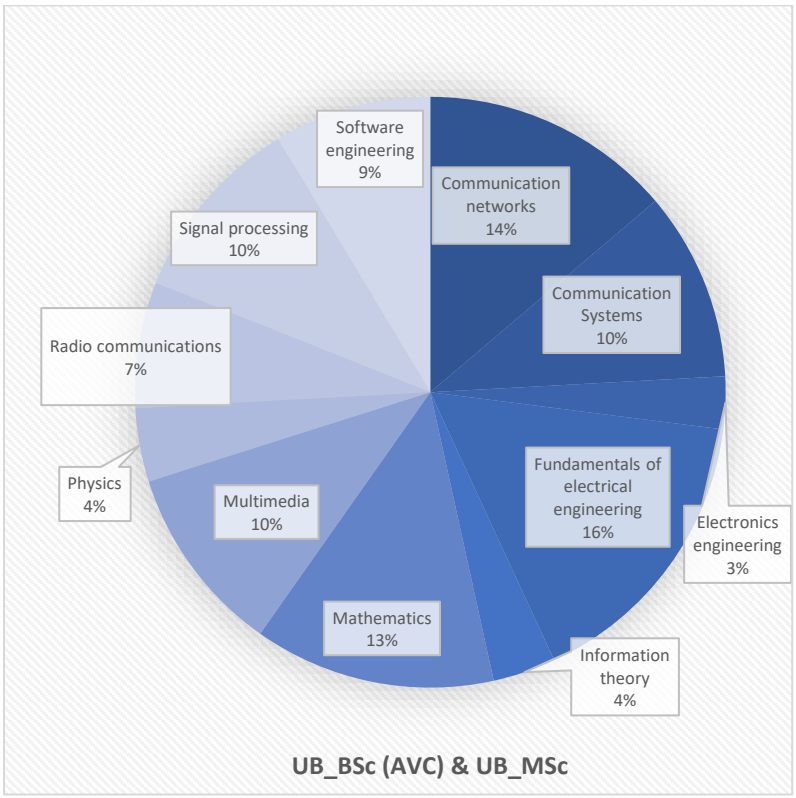


Figure 18: Distribution of ECTS credits for compulsory courses according to group for UB_BSc (AVC) & UB_MSc

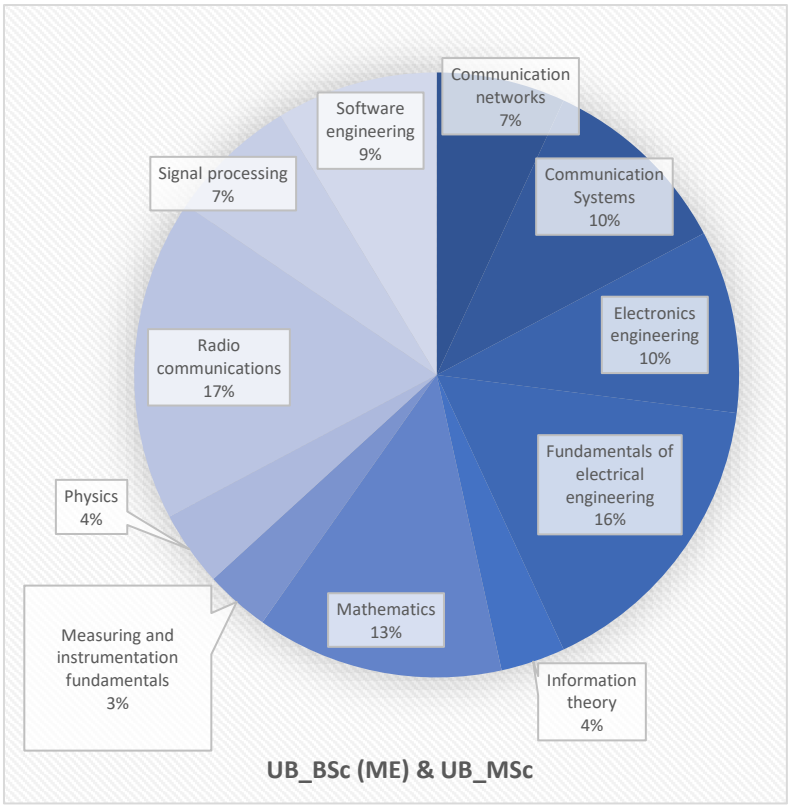


Figure 19: Distribution of ECTS credits for compulsory courses according to group for UB_BSc (ME) & UB_MSc

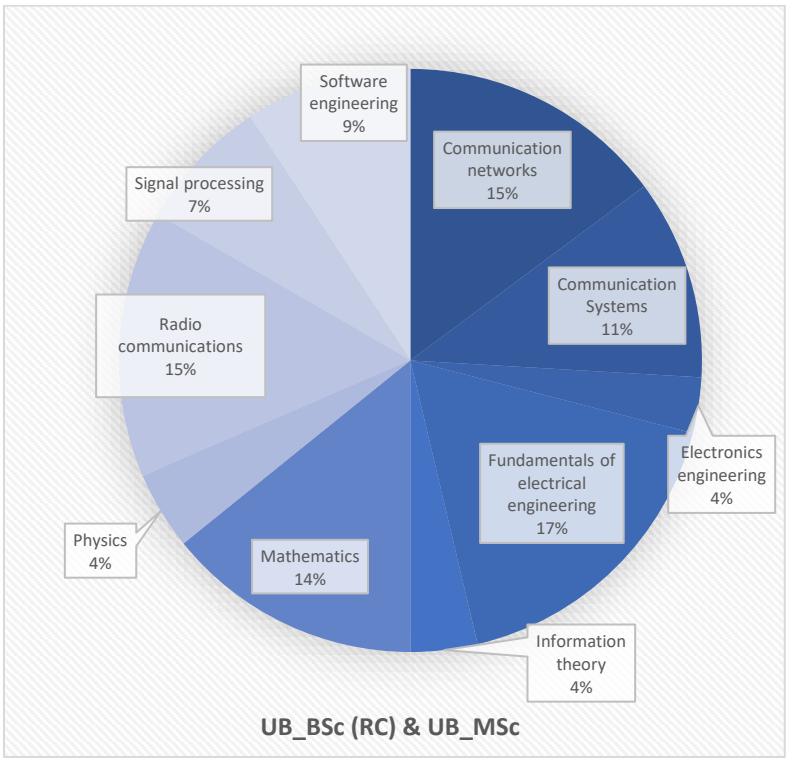


Figure 20: Distribution of ECTS credits for compulsory courses according to group for UB_BSc (RC) & UB_MSc

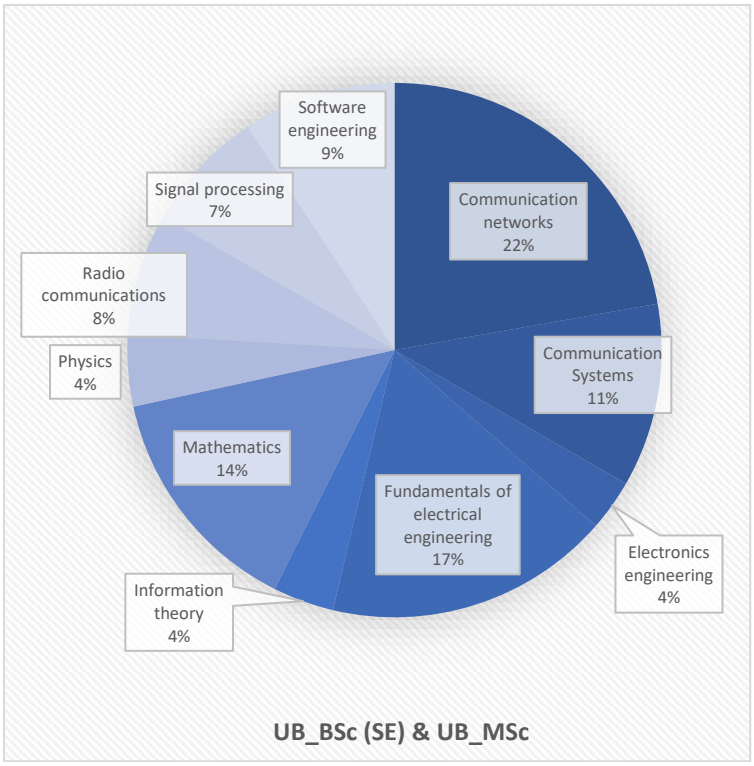


Figure 21: Distribution of ECTS credits for compulsory courses according to group for UB_BSc (SE) & UB_MSc

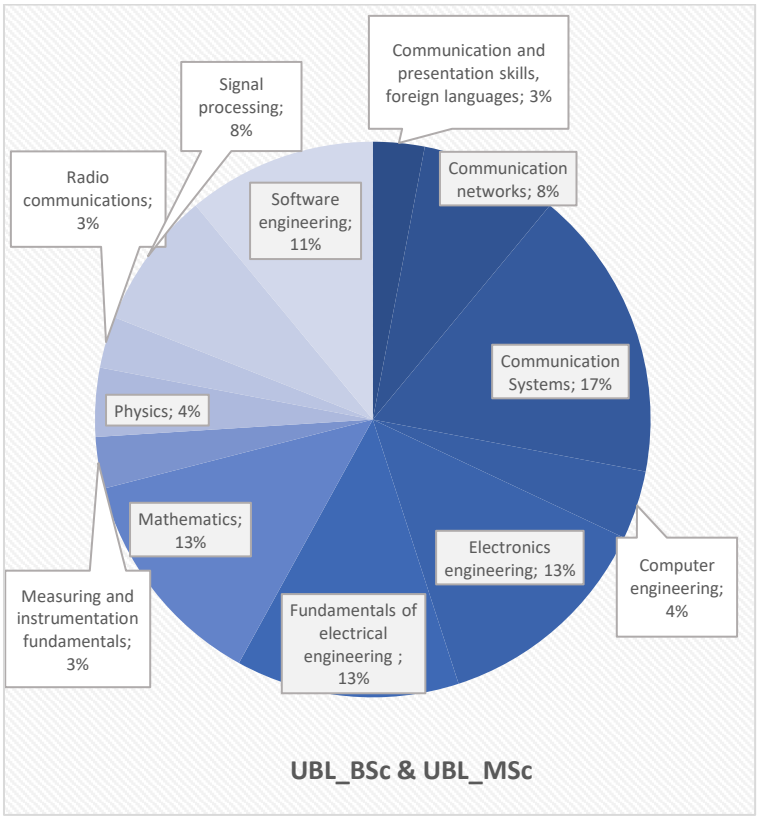


Figure 22 : Distribution of ECTS credits for compulsory courses according to group for UBL_BSc & UBL_MSc

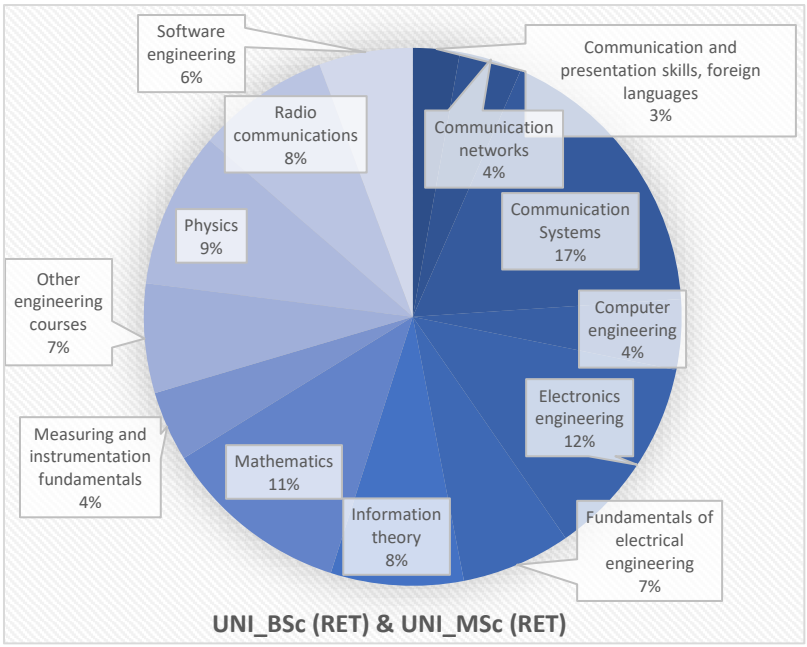


Figure 23: Distribution of ECTS credits for compulsory courses according to group for UNI_BSc (RET) & UNI_MSc (RET)

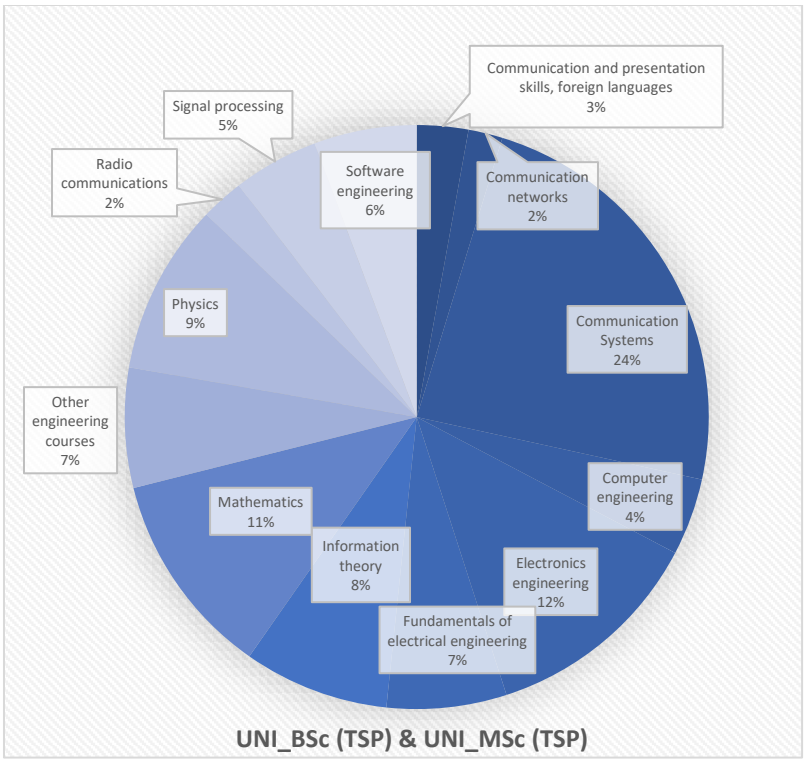


Figure 24: Distribution of ECTS credits for compulsory courses according to group for UNI_BSc (TSP) & UNI_MSc (TSP)

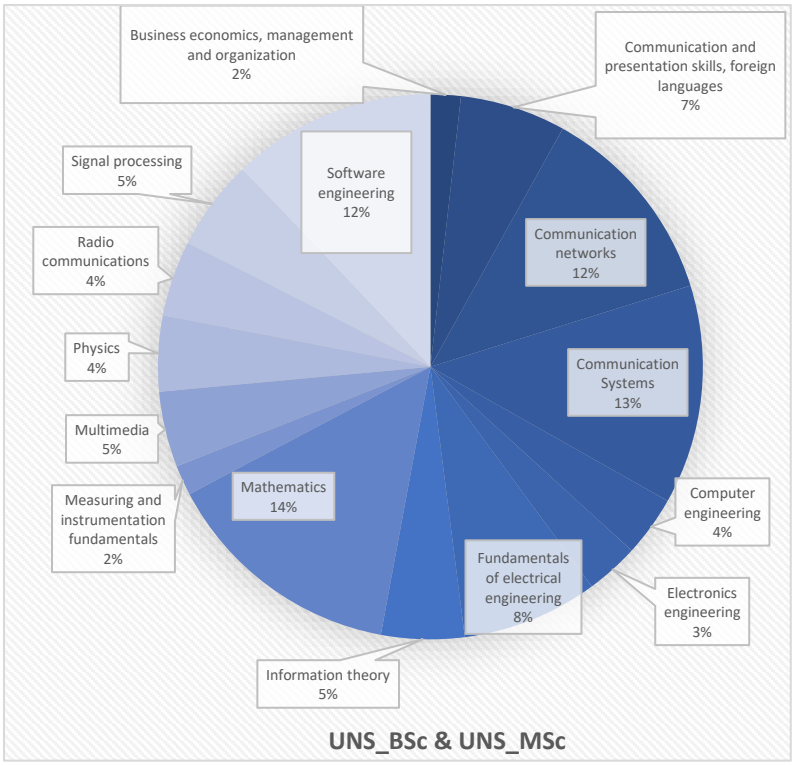


Figure 25: Distribution of ECTS credits for compulsory courses according to group for UNS_BSc & UNS_MSc

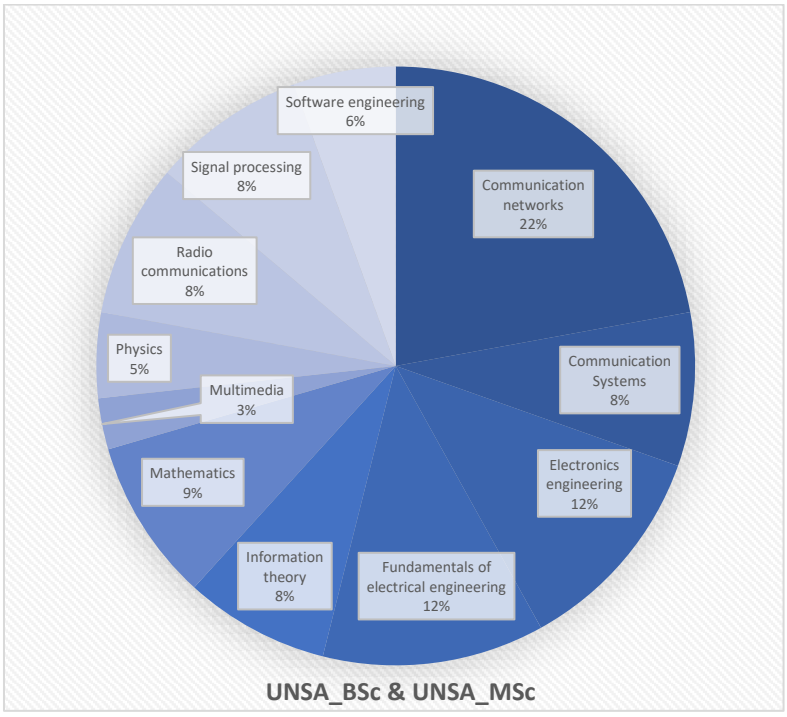


Figure 26: Distribution of ECTS credits for compulsory courses according to group for UNSA_BSc & UNSA_MSc

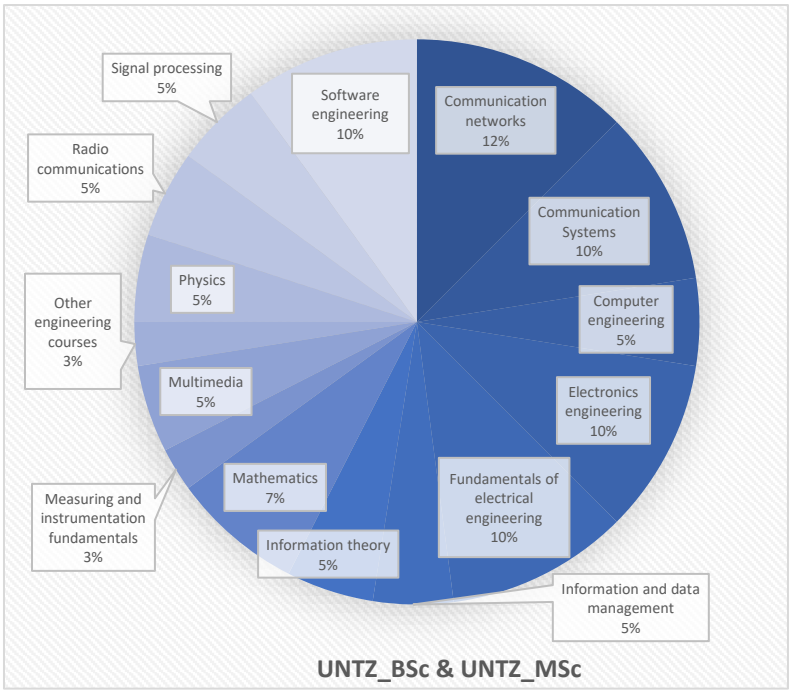


Figure 27: Distribution of ECTS credits for compulsory courses according to group for UNTZ_BSc & UNTZ_MSc

For each of the 17 groups of subjects, the academic project partners gave a list of competences that the students gained on a particular study program. List of competences for BSc and MSc programmes are given in Annex 7.2.

The mathematical competences are very similar in all BSc programmes with some additional contents in MSc level. UL and UNITZ have probability theory in MSc programmes, and FERIT and UNI have numerical mathematics in MSc programmes. In general, at the MSc level there are very few courses in the field of mathematics, but some mathematical contents are included in the professional courses, where they are related to the application in telecommunications.

Competencies in physics are mostly related to mechanics, thermodynamics, optics, structure of matters, electromagnetism and quantum mechanics. These contents are included in BSc programmes, and in MSc level no study programme has courses in the field of physics.

All BSc programme, besides UNI_KLU_BSc, in the fundamentals of electrical engineering group include competencies of electrostatics, electromagnetism and electrical circuits analyse (DC and AC). Some other topics, such as three-phase system and transformers are part of only few BSc programmes.

On the BSc level all programmes have courses that give competencies in the area of measurement and instrumentation. At UNI-KLU, UL, FERIT, UB, UBL, UNI and UNSA these are topics related to electrical engineering in general, at UNS and UNTZ these topics are related specifically to the measurements in telecommunications, while at UB these topics are related to electrical engineering in general as well as to the measurements in telecommunications.

All programmes comprise competencies in the area of information theory, including basic terms, theorems and channel models, as well as source and channel coding. These contents are distributed between BSc and MSc levels, and in some cases are included in other groups (such as multimedia, information and data management).

Basic competencies in the field of electronics engineering are offered in all BSc studies, and some BSc and MSc studies offer also some advanced topics (such as consumer electronics and embedded systems, optoelectronics, microcontrollers, biomedical electronics, etc.).

Radio communications are represented on all study programs, with the scope and depth of acquired competencies varying from programme to programme, and from module to module at the same

programme. Students acquire competences from mobile and wireless communications, propagation of radio wave, antennas as well as radio link calculation. Advanced topics include satellite communications, sensor networks, radio positioning, smart antennas and MIMO systems, as well as navigation systems.
All programmes at the BSc and/or MSc level include topics in communication networks. There are the basic (OSI and TCP/IP reference models, routing, switching, signalling protocols, LAN, MAN, WAN and WLAN, VoIP, QoS, QoE, network security), but also advanced contents (optical networks, broadband networks, software defined networks, etc.).
Within the communication systems group, most BSc programmes include modulation techniques, xDSL, OFDM, multiplexing, analysis of digital communication system performance, and some programmes include the analysis of transmission lines, UWB as well as design of matched filters and equalizers. At MSc level UL, FERIT, UNI and UNS offer advanced topics in the field of communication systems.
In the area of software engineering, study programmes enable the acquisition of competencies in C programming, object oriented programming (C #, C ++, JAVA and / or Python), internet programming (XHTML, CSS, PHP, SQL) and in the mobile applications developing (Android). These contents are included in study programmes in a lesser or greater extent, depending on the module chosen by the students. In the area of computer engineering, contents are related to computer architecture, microprocessors systems, embedded systems as well as microcontroller.
Most of the BSc programmes have databases courses, which give competences in the area of information and data management. At the MSc level, there are some advanced contents in this area, such as artificial intelligent systems at UL, M2M communications and applications at UB, cryptography systems at UNS, as well as data encryption systems at UNSA.
Signal processing is unavoidable in modern telecommunication systems, and in all BSc programs there are basic contents of digital signal processing. Advanced content and application of signal processing to speech, audio, image and video are mainly included into MSc studies.
Within multimedia group of competences, study programmes include audio and video compression, multimedia processing, information retrieval and management, as well as multimedia transmission over different networks.
Although most programmes do not have compulsory subjects that provide communication and presentation skills, almost all programmes at the BSc and/or MSc level enable students to acquire these skills. Similar situation is with competences and skills in the area of business economics, management and organization.
In order to gain insight into the options students have related to elective courses, we have analysed the number of elective courses offered at BSc and MSc levels. In addition to the number of ECTS credits that students need to achieve by taking elective courses, study programmes vary according to the number of elective courses offered to students (Figures 28 and 29). At BSc studies the number of elective courses (on programmes where there are elective courses) ranges from 4 at UNITZ_BSc to 59 at UB_BSc (SE). Number of elective courses on MSc studies range from 1 at UNITZ_MSc to 40 at UNI-KLU_MSc (BE).

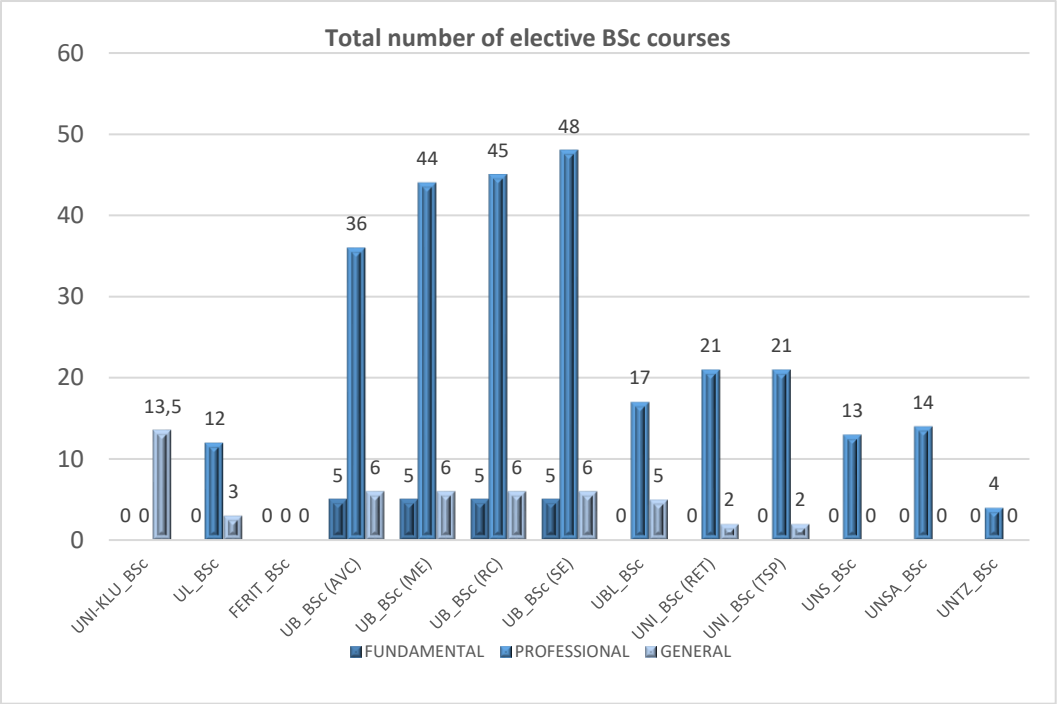


Figure 28: Total number of elective BSc courses

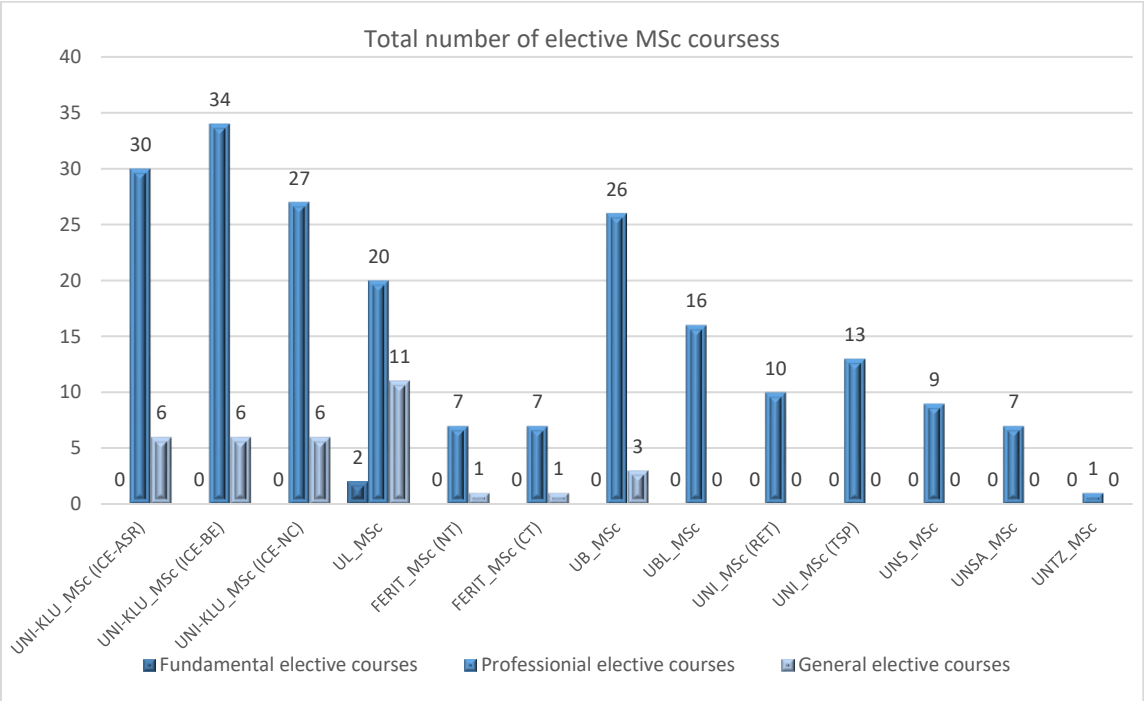


Figure 29: Total number of elective MSc courses

3.3.3 Cooperation with industry

The number of realized student internships varies depending on study cycle and category of student internship (compulsory/elective). Only for one institution student internship is obligatory for both study cycles (UNS). For some institutions internship is obligatory for one cycle (UB, FERIT), while for others it is not obligatory.

Depending on study cycle some partners have significant number of theses in cooperation with the industry and external experts while for some of them there is no official evidence. The most of this theses are realised on MSc level, and in some institutions up to 50% of theses is related to real industry problems.

Generally, relatively small number of industry experts is involved in student training. For some institutions participation of the industry experts is recently formally regulated by the Law which could improve this aspect of cooperation with the industry. The number of industry experts involved in student training is more present on MSc level. Furthermore, the Involvement of industry experts in shaping the study programmes is also more present in MSc study cycle.

The number of developed joint industry-academia labs is generally very small (0-2 per institution), and the activities planned by this project could significantly improve the current situation.

Generally, very small number of start-ups/spin offs started from the universities – the exception is University of Novi Sad (FTN) which has a long tradition and is extremely successful in generating new companies.

Table 4.: Data regarding cooperation with industry

COOPERATION WITH INDUSTRY:					
	Number of realized student internships within the last 2 years:	Number of created BSc/MSc theses with cooperation of external experts within the last 2 years:	Number of industry experts involved in student training:	Involvement of industry experts in shaping the study programmes:	Number of developed joint industry-academia labs:
1st Cycle Study Programme (BSc)					
UNI-KLU_BSc					
UL_BSc	Internship is not compulsory.	n.a., a few	small number	no	n.a.
FERIT_BSc	5	10	3	yes	1

UB_BSc	Internship is compulsory for all students. However, School of electrical Engineering usually does not offer internships by direct contract with companies. The internships are offered by state and city government, by big companies (i.e. telecom operators) and by SME companies. Students are informed about internships by School of Electrical Engineering web portal, and public announcements. School of electrical Engineering provides all necessary support to students (i.e. formal internship request or similar) but usually has no influence on the internship agreement or internship form or content.	Up to 5% of all finished BSc theses.	Including of the industry experts is formally regulated by Law since October 2017.	no	0
UBL_BSc	4	5-10 (there is no official record)	3-5 (there is no official record)	4	1
UNI_BSc	Telecommunication module: 10	0	0	no	1
UNS_BSc	All students (the internship is compulsory); most of them are realised in cooperation with industry.	Small percent.	Almost zero.	yes	0
UNSA_BSc			7		
UNTZ_BSc	Internship is not compulsory.	3-5 per year	5	no	0
2nd Cycle Study Programme (MSc)					
UNI-KLU_MSc	N/A	N/A	N/A	N/A	N/A

UL_MSc	Internship is not compulsory.	n.a., a few	small number	no	n.a.
FERIT_MSc	26	30		yes	1
UB_MSc	There is no internship at this level of studies. However, majority of the students enrolled to master degree level studies are employed (up to 75%).	There is no formal cooperation by contract of School of Electrical Engineering with companies. However, students who work for companies often choose Master thesis related to the project they are they work on. In addition, certain number of Master thesis are part of the commercial projects led by professors. In total, up to 50% of master thesis is related to real-life industry problems.	Including of the industry experts is formally regulated by Law since October 2017.	no	0
UBL_MSc	1	2 (there is no official record)	2 (there is no official record)	4	1
UNI_MSc	35	0	0	no	0
UNS_MSc	All students (the internship is compulsory); most of them are realised in cooperation with industry.	Small percent.	Almost zero.	yes	0
UNSA_MSc			7	yes	2
UNTZ_MSc	Internship is not compulsory.	Small percent	0	no	0

3.3.4 Academic survey – brief overview

The major findings of the academic survey of participating universities in partners countries are the following:
Study programmes aim to produce high-quality engineers in the field of telecommunications, also covering knowledge areas such as electronics and signal processing.
Study programmes provide strong theoretical knowledge.
Basic sciences (e.g. mathematics and physics) are present in the first two years of study.
There are differences in the study programme duration in the scope of Bologna process (180 to 240 ECTS) in Bosnia and Herzegovina.
Partners recognized as major deficiencies:
Students usually perceive the current program as a classical telecom program, since the state of the art ICT topics are not emphasised and, in some cases, not even present.
There is a need for well-equipped labs. The laboratory work for some courses are mainly performed as exercises and by means of computer simulations instead of real-life measurements and data analysis (due to the lack of adequate equipment and software).
The need for introduction of new teaching methodologies. A large number of the current courses do not include methodologies of active learning.
Currently there is no first-year course related directly to modern telecommunication technologies to encourage students to enrol to the ICT field of studies.
The programmes do not encourage enough students' initiatives towards development of their own projects
There is a lack of sustainable model of cooperation with the major ICT companies in the region, that will provide internships for the students and training of teachers.
Lack of communication between course leaders: some items duplicated.
Although the study program provides sound theoretical knowledge, it has not been fully supported by adequate equipment and new methodologies, as well as cooperation with industry in order to provide the student with many practical skills needed today – which is what we expect to overcome through the BENEFIT project. The university partners determined the main directions for improvements and modernization of the current study programme:
To enable new engineers to creatively deal with new telecommunication paradigms, thus boosting the telecommunications engineer profile to meet modern society and industry needs.
Introduction of at least some completely new courses related to modern ICT topics.
Enrichment of the existing courses with the relevant widely accepted technologies in the cooperation with industry and leading engineers with the reach practical experience. To modernize existing courses and accredit novel classes based on the adoption of new learning/teaching tools/methodologies, and entrepreneurial education of future graduates.
Incorporation of the modern teaching methodologies when it is possible and applicable - depending on the group sizes, level of studies, and laboratory capacities.
To improve the University-Industry cooperation through the implementation of new trainings and internships and the creation of joint labs that will translate into more job opportunities.
Development of the new joint laboratories with industry partners that will provide opportunity for the students and teachers to gain practical knowledge related to modern ICT topics.
Encouraging mobility and cooperation of teachers especially with the universities in WB region.

3.4 Industry survey

In addition to Academic Survey presented in Section 1.2, an Industry survey has been conceived to gather information from industrial organizations, presented in this section. The survey has been prepared to collect information on job market/needs and to map skills and knowledge areas required from ICT engineers and specialists in the ICT sector. The aim is to gather relevant information from industry in the region so that academic partners would have current information in the process of modernization of the study programs in telecommunications engineering.

The Industry Survey is based on [10], which was designed using existing international examples. The original questionnaire is composed of two parts, to be filled by: for employers and for employees. For our purpose we used modified version of the first part – questionnaire to be used for employers, in order to be able to compare the results.

It is important to emphasize that the survey in [10] was designed to assess ICT sector skills needs with a view on vocational education and training (VET) as this information is also relevant for BENEFIT project WP4.

In order to better target our needs, some questions were omitted and additional questions were designed to provide information related to most important professional skills in reference to the ICT specialists, currently lacking professional skills in reference to the ICT specialists and knowledge areas analysed in the programs of the partner universities within the Academic Survey. The Industry Survey was iteratively designed with pre-testing the draft version by selected university partners and selected companies.

In the first iteration the survey was sent to BENEFIT industrial partners and selected companies in a paper form. This preliminary data was collected and the preliminary information is analysed in Section 3.4.1.

The Industry survey is a working document so that we plan to keep it open. Based on initial analysis and feedback this survey will be updated and sent to a large number of companies in the WB region as well as EU via an online form. The results will be reported in deliverable within WP2.

The Industry survey template is attached in Annex 7.3.

3.4.1 Analysis of industry survey

The preliminary data has been analysed aiming at identifying current industry needs related to ICT professionals. Seven companies answered the survey. Selected preliminary results are analysed to highlight aspects treated in this deliverable.

3.4.2 Expected changes in the number of employees in next 12 month

To see what are your expectations regarding the changes in number of employees in the next 12 months we investigated (question B.4) whether the number of employees for the three groups under investigation (ICT specialists, managers, and marketing and sales) in the company will face and increase, remain unchanged or reduce in the next 12 months.

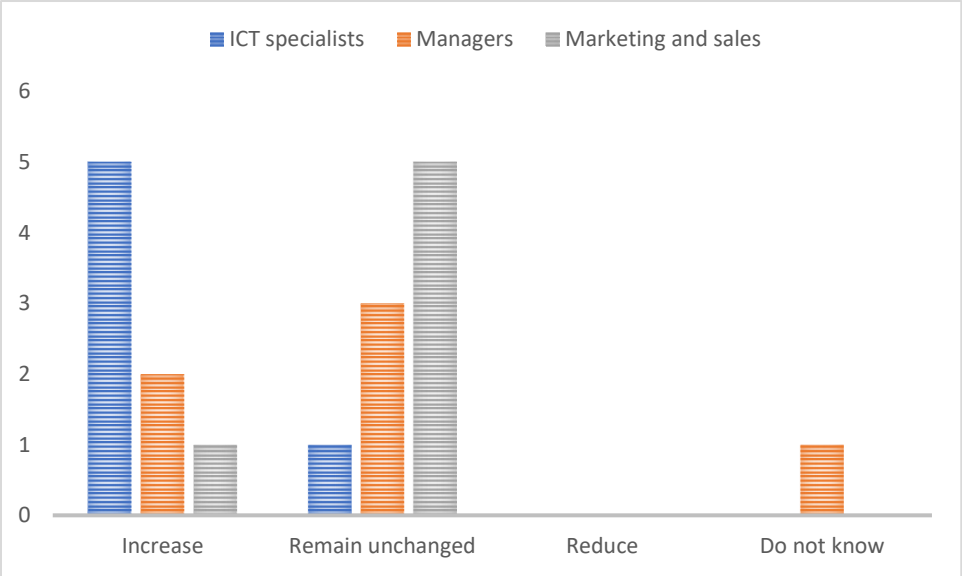


Figure 30:Expected changes in the number of employees in next 12 month

3.4.3 The sources for the recruitment of professionals

Identifying sources of recruitment is an important step in the course of the recruitment process. Question B.6 investigate the used sources to professional recruit. The most used sources are "Announcement on the company's website" and "Word of mouth" followed by "Private employment agencies" and "Recruiting employees from other companies". Collaboration with secondary schools and universities is at the third place, followed by "on-line social networks" and finally "national employment job matching services".

3.4.4 Most important professional skills for ICT specialist

To better understand current industry needs we investigated (question B.8) which professional skills are most important for an ICT specialist: software specialist, hardware specialist, system and security specialist, quality, test and certification specialist, operations and maintenance specialist, and project management.

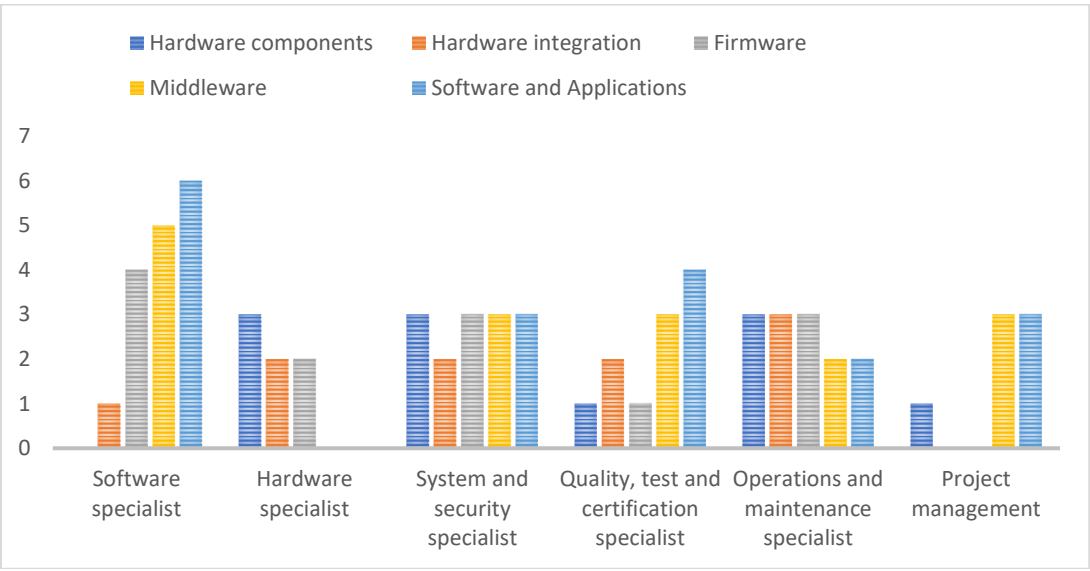


Figure 31: Most important professional skills for ICT specialist.

3.4.5 Professional skills currently lacking by ICT specialists

To progress step further, we asked companies (question B.9) which professional skills ICT specialists currently lack.

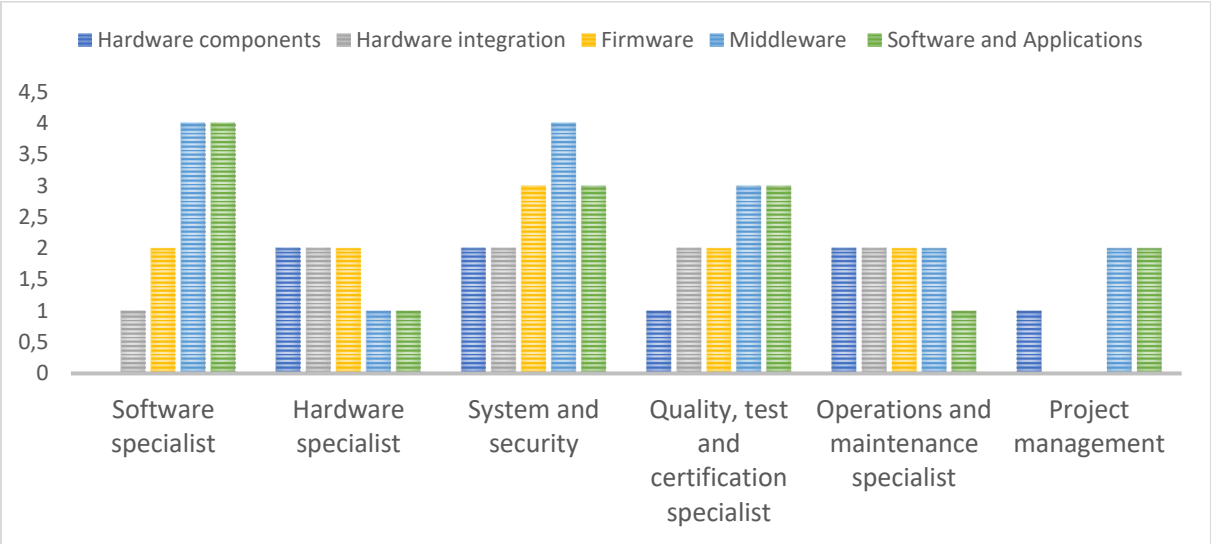


Figure 32: Professional skills currently lacking by ICT specialists.

3.4.6 Knowledge areas as observed by the industry

Question B.10 investigates the relevance of individual knowledge areas covered by current study programs in telecommunications engineering (information provided in Section 2).

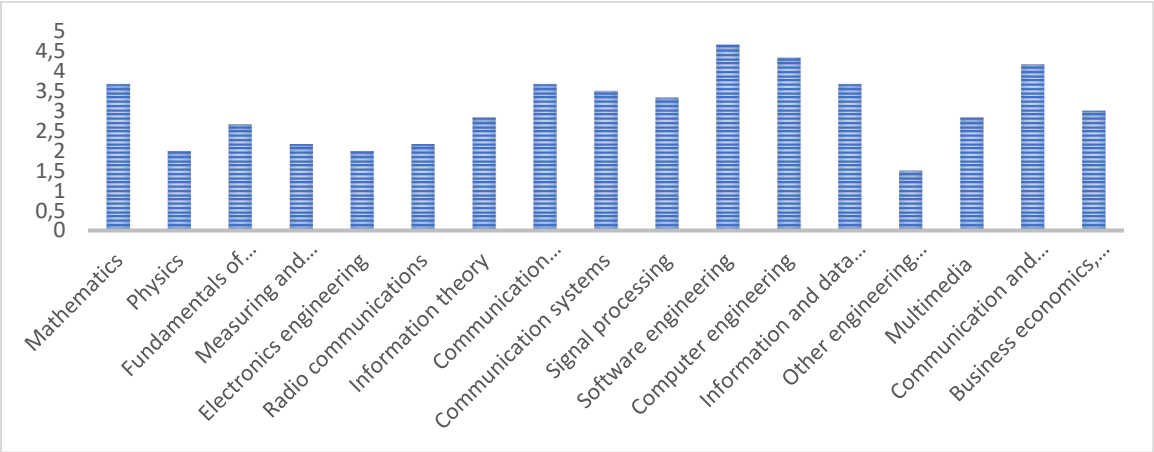


Figure 33: Importance of 17 knowledge areas: 1 – Not important, 2 – Slightly important, 3 – Moderately important, 4 – Important, 5 – Very important.

3.5 Overall analysis of status quo

The presented Industry survey is planned to be kept open to gather sufficiently large sample in the WB region. Information provided is relevant for comparison with the Academic survey and provides needed data for WP2, WP3 and WP4.

Based on the internal analysis and the evaluation of the surveys the following conclusions can be made. Most of the companies have problems with ensuring adequate skills of employees (5 out of 7). Moreover, 6 out of 7 companies experienced difficulties in filling vacancies.
The highlighted obstacles which cause difficulties in filling vacancies for ICT specialists, developers and researchers are mainly "Insufficient supply of qualified candidates who poses adequate skills" and "Candidates do not have work experience" followed by "Wages are not high enough to attract qualified candidates".
The survey shows an expected increase in the number of ICT specialists in the next 12 months. Approximately 180 new positions will be available for developers and researchers.
The sources of recruitment are mainly "Announcement on the company's website" and "Word of mouth". The less used are the "national employment job matching services".
The main skills that are most important for the interviewed partners, but are currently insufficient, are the professional, technical skills for ICT specialists, developers and researchers.
The most important professional skills shown from the survey result are "software applications for software specialists" (7 out of 7 surveys) and "software applications for quality, test and certification specialists" (5 out of 7). Also "middleware for software specialists" is one of the most important highlighted skills (5 out of 7).
More in detail, the currently lacked skills about ICT specialist that companies perceive are "software, applications and middleware for software specialists" (4 out of 7) and "middleware for system and security specialists" (4 out of 7).
The survey asked to grade the importance of the macro knowledge areas covered by study programmes in telecommunication engineering. The most important macro knowledge areas are "software engineering", "computer engineering" and "information and data management".
The interviewed opinion regarding the reason that cause the lack of skills for ICT specialist, developers and researchers are mainly "high fluctuation of employees", "market requirements", "technological change" and "lack of time due to projects deadlines".
Most of the interviewed companies collaborate with universities in terms of hiring graduates, providing work experience, scholarships and internships (6 out of 7).
The qualifications offered by the national education and training system are on average partially known.
The survey shows what are the changes that are necessary in the vocational education and higher education institutions to meet the job requirements. All interviewers suggest to "define and update educational profiles in line with labour market needs" followed by "readiness to review and change curricula in order to align them with technological change" and "focus on practical training, organisation of practice, internships at the company, etc." (6 out of 7).
Moreover, the survey highlighted that not all the interviewed companies practice continuous training and development of employees in order to meet the job requirements (5 out of 7).

The steps to be followed in the implementation phase of the project which includes the modernization of the curricula (WP2), the creation of new labs and adoption of new teaching methodologies (WP3) and the training and internship activities (WP4) are described in Section 4.4.

4. Guidelines aimed at boosting the telecommunications engineer profile including a projection of needs for ICT engineers in the future

4.1 Introduction

The main objective of the preparation work package is to consolidate initial analysis obtained from all HEI and industry partners and formulate a guidelines document for the curriculum modernization that will guide the project activities.
Combining and analysing both academic and industry inputs, this document presents consolidated ex-ante analysis and guidelines aimed at boosting the telecommunications engineer profile including a projection of needs for ICT engineers in the future. The guidelines take a snapshot of the existing status in both academia and industry and present a set of common needs and goals for the transformation of the curriculum in telecommunications into a modern ICT engineering curriculum for the WB universities.

4.2 Overview of main curriculum guidelines

4.2.1 The Bologna process

The aim of the BENEFIT project is to follow this process taking into account autonomy of the universities and changing needs of industry, students and society.

Some points from the Bologna process relevant for the BENEFIT project [11]:

- Adoption of a system of easily readable and comparable degrees
- Introduction of transferable system of academic credits to assist in promoting European cooperation and quality assistance
- The position of higher education institutions and students as essential partners.
- Promotion of European dimension in higher education through inter-institutional cooperation, curricula and mobility schemes, etc.

In this section we provide a short overview of Bologna process and major differences in partner countries that affect current programs.

As specified in the Bologna Process, all programmes in the third level institutions in EU need to be written in terms of learning outcomes [11]. Short overview with main highlights are provided in Section 4.3, to serve as quick reference.

4.2.2 ACM methodology for study programs development

In the process of initial analysis of study programs obtained from all HEI and surveys from industry partners, consortium partners decided to analyse also curriculum guidelines for undergraduate degree programs from other electrical and computer engineering fields. Our aim is to unite initial analysis obtained from all HEI and industry partners, formulate a guidelines document for the curriculum modernization and show how those graduates will differ from other computer engineering and computing disciplines.
The modernisation of telecommunications engineering study programs must provide international perspectives and reflect a global view of new telecommunications technologies related to developments in electronic, computer and software engineering.

The Association for Computing Machinery (ACM), the IEEE Computer Society, and the Association for Information Systems (AIS) provides undergraduate curriculum guidelines for five defined sub-disciplines of computing (Figure 34). The methodology for the development of study programs presented in the

ACM curriculum guidelines will be used as a basis for the development and modernization of study programs in telecommunications engineering. The Computer Engineering guidelines, as one of the representative guidelines defined by the ACM, will be used during the process of modernisation of telecommunications engineering study programmes (within 1st and 2nd cycles) in 3 B&H and 3 Serbian HEIs in cooperation with ICT industry.

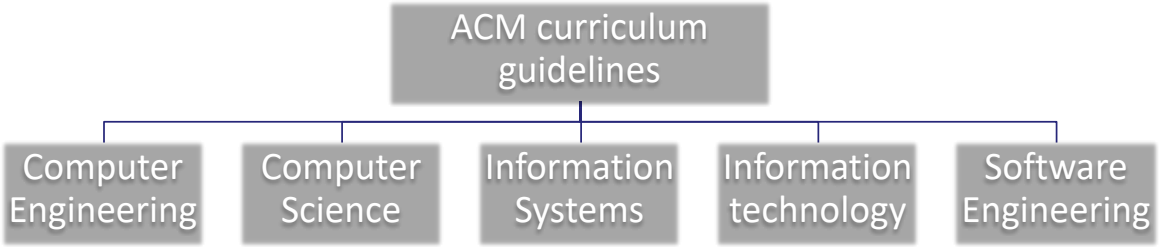


Figure 34: Undergraduate Curriculum Guidelines from ACM

The foundation of the Computer Engineering guideline, proposed by ACM, is based on definition of body of knowledge from which an institution can develop or modify a curriculum to fit its needs.

The Computer Engineering body of knowledge has a three-level hierarchical structure (Figure 35). The body of knowledge contains knowledge areas that are applicable to all computer engineering programs. The twelve knowledge areas form the Computer Engineering body of knowledge. Each knowledge area comprises a thematic scope and a set of knowledge units. A set of learning outcomes defines each knowledge unit. Learning outcomes determines what students should learn from each knowledge unit. In Computer Engineering guideline learning outcome is associated with each knowledge unit.

The Computer Engineering guideline identifies some knowledge units as core and other as supplementary. The core knowledge units should appear in every implemented curriculum while the supplementary knowledge units provide additional knowledge and they are selective. The set of requirements defined in the guidelines are defined as minimal. The teams for study program preparation at the particular universities will still have the freedom to act independently to meet the goals of a specific program and institution.

In order to produce a competent computer engineer, the additional technical areas, mathematics, science, and general studies should be incorporated into study program.

The Computer Engineering study program distinguishes three-year and four-year study model. This results in a different scope and distribution of content from mathematics, science and units defined within the Knowledge Areas. Computer Engineering from ACM presents a sample curricula illustrating possible implementations of degree programs each satisfying the required specifications of the body of knowledge. The document contains both three- and four-year programs.

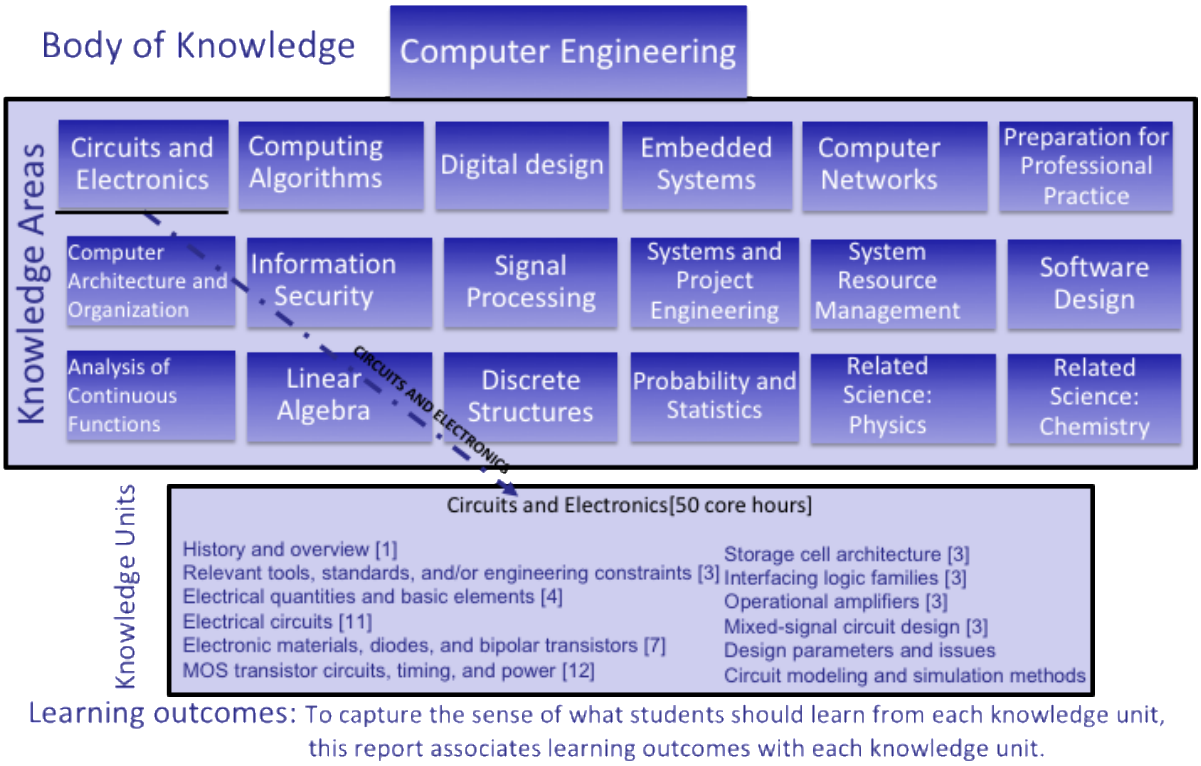


Figure 35: The Computer Engineering Body of Knowledge

4.2.3 Adoption of ACM approach in BENEFIT project

Applying the same concept presented in the ACM [12] curricula guidelines for undergraduate degree programs, the telecommunication engineering body of knowledge as a three-level hierarchical structure is presented Figure 36. Seventeen knowledge areas were identified during the analysis of existing study programs. These areas include subjects in telecommunication engineering, mathematics and physics. Also, these areas are recognized as common at all universities involved in the implementation of the project.

In the first phase of the project, knowledge units were not analysed. The aim at this phase of the project was to obtain the current status of study programs at all universities. In the upcoming period during the implementation of WP2 and WP3, it is necessary to analyse the individual knowledge areas and define the knowledge units within each field.

The study programs in telecommunications engineering should be as flexible as possible. To implement this principle, the core knowledge units or essential units in the curriculum should be the identical in all study programs. Core components include knowledge and skills that all students in all telecommunications engineering degree programs should attain. The broad consensus will be achieved between the partners on the project. On the other hand, the supplementary or extra units will be different and provide the freedom to the teams for study program to act independently to meet the goals of a specific program and institution.

The knowledge units represent individual themes within an area. Each knowledge unit is described by a set of learning outcomes. The learning outcomes represent the lowest level of the hierarchy and describe what students should learn in each knowledge unit.

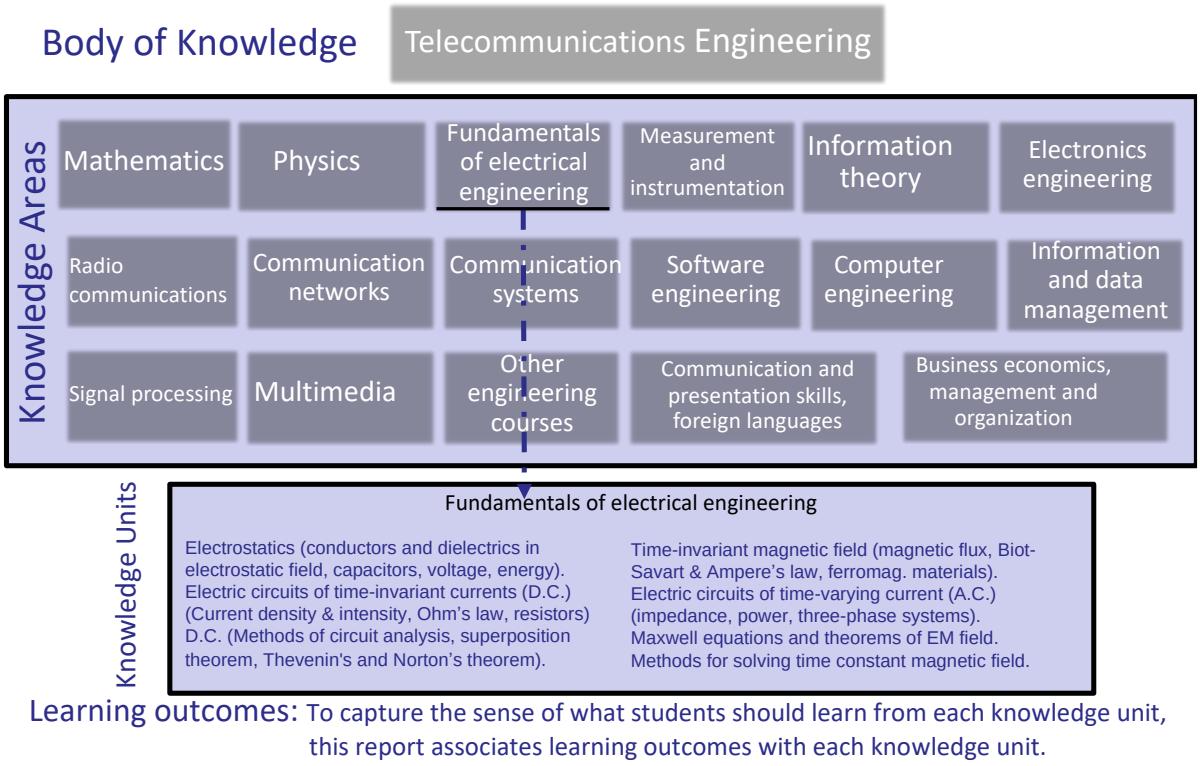


Figure 36: The creation of BENEFIT's Telecommunication Engineering Body of Knowledge

4.2.4 Telecommunications Engineering Technology defined by ABET

ABET (Accreditation Board for Engineering and Technology) is a non-profit, non-governmental organization recognized by the Council for Higher Education Accreditation in USA. ABET accredit college and university programs in the disciplines of applied and natural science, computing, engineering and engineering technology at the associate, bachelor and master degree levels.

From the ABET's criteria for Accrediting Engineering Technology Programs, we can take over a definition of study programs from telecommunications engineering. Together with the previously described methodology, we get a complete procedure that leads to clearly defined steps that need to be taken during the project in order to modernize existing study programs in the field of telecommunications engineering. It should be emphasized that industrial partners will have an important role in defining knowledge areas and knowledge units through the fulfilment of industry surveys.

The telecommunication engineering has been undergoing profound changes and this field has positioned network science and engineering at the centre of modern telecom industry. In the first step, ABET approved Telecommunications Engineering as a distinct bachelor-level education discipline with ABET's approval of its 2015-2016 Criteria for Electrical, Computer, Communications, Telecommunication(s) and Similarly Named Engineering Programs. This recognition was made successfully, based on advances in network science and engineering and developments in related areas and applications. The ABET's criteria for Accrediting Engineering Technology Programs, 2018 – 2019 recognises Telecommunications Engineering Technology and Similarly Named Programs recognised telecommunication engineering as a distinct bachelor-level education discipline.

The Engineering Technology Accreditation Commission from ABET accredits engineering technology programs at the associate (two-year degree) and bachelor (four-year degree) levels.

The objectives set in the program of Telecommunications Engineering Technology will prepare graduates with the skills necessary to enter careers in the design, application, installation, management, operation, and/or maintenance of telecommunication systems.

The accreditable program of Telecommunications Engineering Technology will prepare graduates with the skills necessary to enter careers in [13]:

- design
- application,
- installation,
- management,
- operation, and/or
- maintenance of telecommunication systems.

Graduates of associate degree programs typically have strengths in

- building,
- testing,
- operation,
- and maintenance of existing telecommunications systems.

Baccalaureate degree graduates are well prepared for

- development and
- implementation of telecommunications systems.

Graduates of associate degree programs must demonstrate knowledge and hands-on competence appropriate to the objectives of the program in [13]:

- the application of electric circuits, computer programming, associated software, analog and digital electronics, voice and data communications, engineering standards, and the principles of telecommunications systems in the solution of telecommunications problems; and
- the application of natural sciences and mathematics at or above the level of algebra and trigonometry to building, testing, operation, and maintenance of telecommunications systems.

Given the breadth of technical expertise involved with telecommunication systems, and the unique objectives of individual programs, some baccalaureate programs may focus on preparing graduates with in-depth but narrow expertise, while other programs may choose to prepare graduates with expertise in a broad spectrum of the field. Therefore, the depth and breadth of expertise demonstrated by baccalaureate graduates must be appropriate to support the objectives of the program. In addition to the outcomes expected of associate degree graduates, graduates of baccalaureate degree programs must demonstrate [13]:

- the ability to analyse, design, and implement telecommunications systems;
- the ability to apply project management techniques in the design, maintenance,
- and implementation of telecommunication systems;
- the ability to analyse and implement switching technologies, wide area networking technologies, and policy;
- the ability to manage, design, and plan wide area networks; and
- the ability to utilize statistics/probability, transform methods, or applied differential equations in support of telecommunication systems and wide area networks.

4.3 Short overview on Learning outcomes preparation

As Learning outcomes are the fundamental element in the Bologna process all courses within BENEFIT project will be prepared using the guide for writing and using learning outcomes [11]. This approach is also in line with international accreditation bodies as for example ASIIN accreditation.

International trends in education show a shift from the traditional teacher centred approach, to the student-centred approach. By implementing the Bologna process, all modules and programs should be defined using the results of a well-founded approach, i.e. in terms of learning outcomes. Learning outcomes are statements about what and in what context a student should know, understand and be able to demonstrate after the completion of the learning process. Learning outcomes should be observable and measurable.

Most learning outcomes describe evidence of learning in areas like knowledge, comprehension, application, analysis, synthesis and evaluation (cognitive domain) (see Figure 37). According to [14], the learning process consists of six successive levels that form a hierarchy. The lowest level of knowledge is *Knowledge*, followed by *Understanding*, *Application*, *Analysis*, *Synthesis* and the highest-level *Evaluation*. Each level depends on the student's ability to achieve goals at a lower level. For example, if a student wants to apply knowledge (Level 3), he / she needs to know (Level 1) and understand (Level 2) the necessary information.

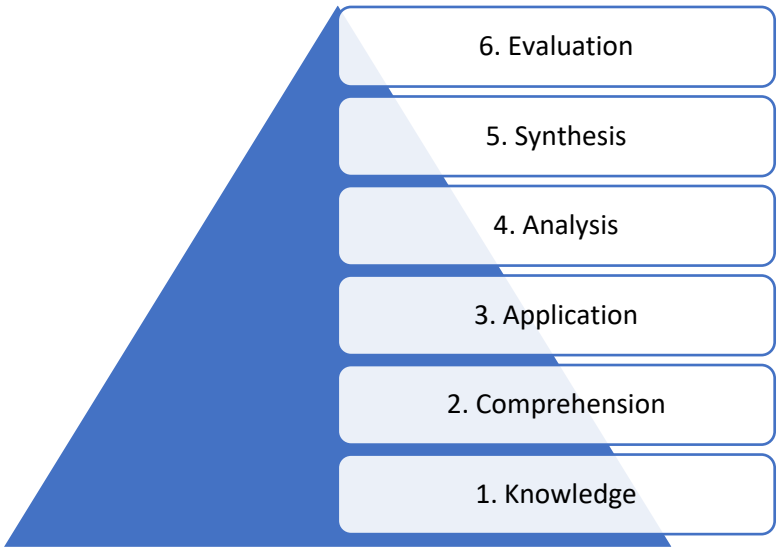


Figure 37: Six increasingly complex levels from the simple recall of facts at the lowest level to evaluation at the highest level by Bloom [5].

Some of the points relevant for BENEFIT project can be summarised as:
Provide a common language for describing learning outcomes for courses, modules and overall study program, at undergraduate and master level;
Make learning outcomes transparent, observable and measurable;
Facilitates the European Credit Transfer System (ECTS).

Learning outcomes are substituting previously used term competences as there was lack of common understanding of the term competence in the literature.

There are several definitions, where we provide two well known to later differentiate the term from competencies:

“Learning outcomes represent one of the essential building blocks for transparent higher education systems and qualifications” [15].

“Learning outcomes are statements of what a student is expected to know, understand and/or be able to demonstrate after completion of a process of learning.” [11]

The process of learning can be a lecture, a module or an entire programme.

In the remaining part of this section we will shortly describe what are the learning outcomes and collect the basic steps how to approach to transformation of writing the curriculum in the form of learning outcomes.

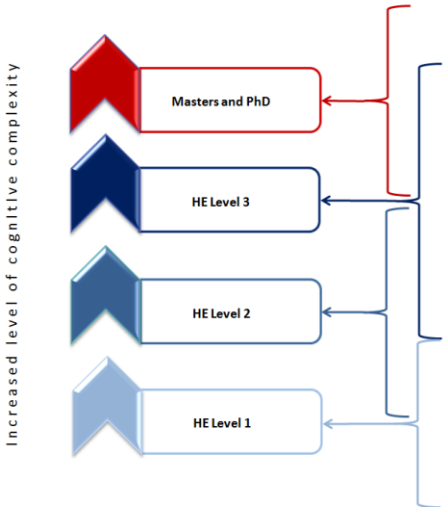
4.3.1 Writing learning outcomes

Here we provide a very short overview of writing learning outcomes. For the full description we refer to [11]. The main characteristic is that each learning outcome begins with an action verb followed by the object of that verb. For writing learning outcomes Bloom’s taxonomy is used as it provides a structure of 6 stages (levels) and list of verbs for each stage. Descriptions should be short and clear to enable later assessment of learning outcomes. Typically, 6 (and not more than 9) learning outcomes are recommended per module.

Table 4.1 provides some examples of action verbs used to assess each of the six stages of Bloom’s taxonomy serving as a quick reference. For full description we refer to [11]. Typically, learning outcomes for a module start with the line: “On successful completion of this module, students should be able to”, followed by a list of action verbs from Table 4.1.

Figure 37 presents the 6 levels, where:

- Level 1: Knowledge is defined as the ability to recall or remember facts without necessarily understanding them.
- Level 2: Comprehension is defined as the ability to understand and interpret learned information
- Level 3: Application is defined as the ability to use learned material in new situations.
- Level 4: Analysis is defined as the ability to break down information into its components.
- Level 5: Synthesis is defined as the ability to put parts together.
- Level 6: Evaluation is defined as the ability to judge the value of material for a given purpose.



Domain	Simple Definition	Example Verbs
6. Evaluation	Defend ideas or concepts	Appraise, ascertain, argue, assess, attach, choose, compare, conclude, contrast, convince, criticise, decide, defend, discriminate, explain, evaluate, grade, interpret, judge, justify, measure, predict, rate, recommend, relate, resolve, revise, score, summarise, support, validate, value.
5. Synthesis	Compile information into alternate solutions	Argue, arrange, assemble, categorise, collect, combine, compile, compose, construct, create, design, develop, devise, establish, explain, formulate, generalise, generate, integrate, invent, make, manage, modify, organise, originate, plan, prepare, propose, rearrange, reconstruct, relate, reorganise, revise, rewrite, set up, summarise.
4. Analysis	Distinguish different parts	Analyse, appraise, arrange, break down, calculate, categorise, classify, compare, connect, contrast, criticise, debate, deduce, determine, differentiate, discriminate, distinguish, divide, examine, experiment, identify, illustrate, infer, inspect, investigate, order, outline, point out, question, relate, separate, sub-divide, test.
3. Application	Use informations in new ways	Apply, assess, calculate, change, choose, complete, compute, construct, demonstrate, develop, discover, dramatise, employ, examine, experiment, find, illustrate, interpret, manipulate, modify, operate, organise, practice, predict, prepare, produce, relate, schedule, select, show, sketch, solve, transfer, use.
2. Comprehension	Explaining information	Associate, change, clarify, classify, construct, contrast, convert, decode, defend, describe, differentiate, discriminate, discuss, distinguish, estimate, explain, express, extend, generalise, identify, illustrate, indicate, infer, interpret, locate, paraphrase, predict, recognise, report, restate, rewrite, review, select, solve, translate.
1. Knowledge	Remembering information	Arrange, collect, define, describe, duplicate, enumerate, examine, find, identify, label, list, memorise, name, order, outline, present, quote, recall, recognise, recollect, record, recount, relate, repeat, reproduce, show, state, tabulate, tell.

Table 4.1: Examples of action verbs used to assess the six stages of Bloom's taxonomy [14].

To summarise the common guidelines:

1. "On successful completion of this module, students should be able to"
2. When writing out learning outcomes, we first use the verb of action, followed by an object and a phrase that establishes the context.
3. The sentences should be clear and concise.
4. For each outcome, use one sentence with a single verb.
5. Avoid unnecessary jargon.
6. Avoid unclear expressions such as understanding, learning, knowing, acquainting, being acquainted with, and being aware of. We associate these terms with learning goals and not with learning outcomes.
7. Avoid complex sentences. For more clarity, you can also use several sentences.
8. Learning outcomes must therefore be assessable, therefore, linked to verification and evaluation. They must be written so that they can be observed and measured.
9. Make sure that the learning outcomes can be validly assessed.
10. When writing a learning outcome, ask yourself whether it is realistic to expect that students will achieve learning outcomes within the available time and available resources.
11. Provide a minimum acceptable standard that allows the student to complete the module. For this reason, it is better to write a small number of important learning outcomes than a larger number of superficial ones.
12. It is recommended to provide approximately six well-written learning outcomes per module. Not more than nine.
13. Before completing the learning outcomes, ask your colleagues and possibly the former students for opinion.
14. Try to avoid overwhelming the list with learning outcomes from the bottom of Bloom's taxonomy (Level 1 and 2).
15. Encourage students to use the acquired knowledge by integrating individual learning outcomes from higher levels (use, analysis, synthesis and evaluation).

Doubtless verbs, such as knowing or understanding, are difficult to measure. You may want to replace them with verbs such as identify, define, describe, or show (see Table 4.1). Using verbs to solve, evaluate and analyse better suggests how a student can conquer required knowledge.

Some recommended replacements for verbs describing aims with verbs describing learning outcomes:

know	→	distinguish between
understand	→	choose
determine	→	assemble
appreciate	→	adjust
grasp	→	identify
become familiar	→	solve, apply, list

At the end use the control list [11] for writing learning outcomes:

- Have I focussed on outcomes not processes, i.e. have I focussed on what the students are able to demonstrate rather than on what I have done in my teaching?
- Have I begun each outcome with an active verb?
- Have I used only one active verb per learning outcome?
- Have I avoided terms like know, understand, learn, be familiar with, be exposed to, be acquainted with, and be aware of?
- Are my outcomes observable and measurable?
- Are my outcomes capable of being assessed?
- Have I included learning outcomes across the range of levels of Bloom's Taxonomy?
- Do all the outcomes fit within the aims and content of the module?
- Have I the recommended number of outcomes (maximum of nine per module)?
- Is it realistic to achieve the learning outcomes within the time and resources available?

4.4 Guidelines

4.4.1 Organization of project activities

In order to outline the guidelines for modernization of telecommunication engineering study programs by partners in WB countries we shortly summarize the organization of project activities in work packages WP2, WP3 and WP4 (see Figure 38).

Activities in the scope of WP1 provided an analysis of the current study programs in the area of telecommunication engineering at the participating universities. Study results provided the data necessary to compare current study programs in the sense of structure, aims and content. All participating universities described the expected goals of the modernized study programs as well as deficiencies in the current study programs as well as the expected goals of the modernized study programs.

Industry feedback has been obtained through a comprehensive questionnaire developed to detect the needs of companies in WB countries, expectations from future employees in the sense of their knowledge and skills and state of training process and continuity in the education of employees. The obtained results represent input data that will be taken into account in the process of modernization of the study programs, which is implemented in the development work packages WP2, WP3 and WP4.

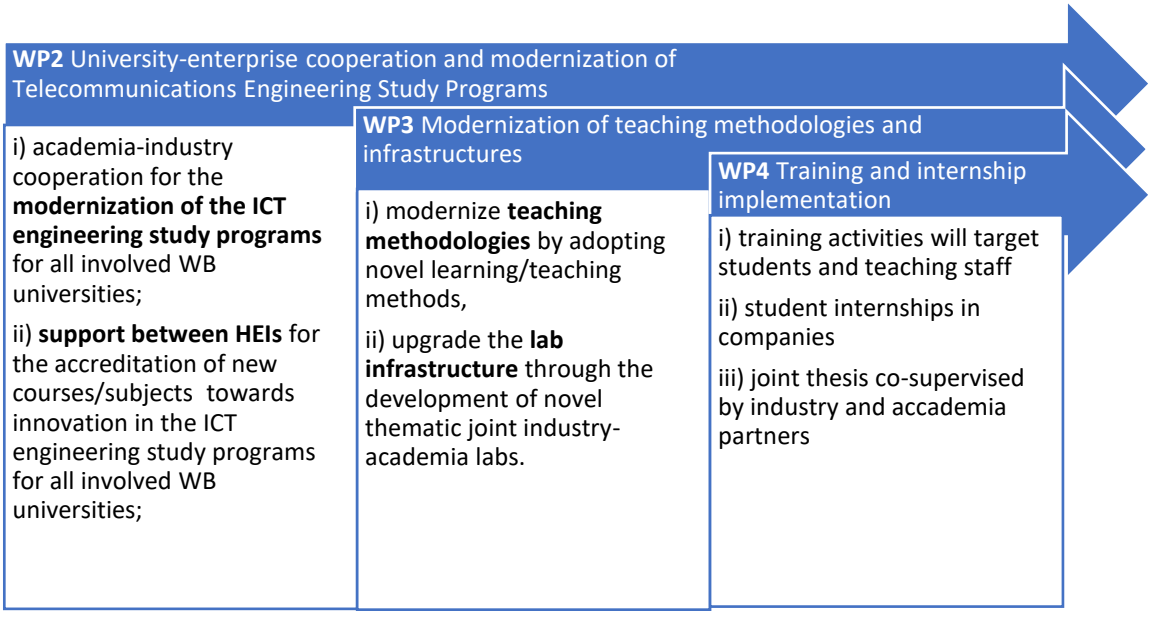


Figure 38: Plan for curriculum modernization [16]

4.4.2 Proposed procedure

Study programs modernization guidelines provide procedures and methods undertaken to improve study programs in the area of telecommunications with the goal of:

- adjusting their contents according to the identified trends in this area,
- providing learning outcomes that will meet industry activity,
- providing knowledge that will enable the graduates to continue with the next cycle of education / job.

The proposed methodology is based on contemporary documents provided by ACM and ABET, adopted to meet specificities of universities in Western Balkan countries.

The proposed procedure takes into account several inputs, collected in a series of proposed steps, organized into two phases, namely, the preparatory and development phase, and the execution and evaluation phase.

4.4.3 Preparatory & development phase

The PREPARATORY & DEVELOPMENT PHASE consists of:

a) Collect information from surveys and analyse current status and needs;
b) Analyse the study program and identify its deficiencies;
c) Analyse industry activities, needs and possible exchanges of knowledge;
d) Identify body of knowledge and knowledge areas that can modernize the selected study program by following specific guidelines, e.g. ITU, IEEE Com. Soc., IEEE Comp. Soc., ACM, ABET, etc.
e) Select courses/subjects to be modernized;
f) Identify lab equipment to modernize and new joint labs with industry;
g) Identify training activities for students and teaching staff;
h) Identify flexible mechanism for student internships;
i) Update the class content based on the identified Learning outcomes;
j) Accredit the study program at faculty, university and national levels.

4.4.3.1 Collect information from surveys and analyse current status and needs

The first action is to detect needs of graduates related to increasing their employability and overcoming potential barriers in continuing with the next cycle of education. This includes establishing the existing educational trends at universities that provide ICT programs. Such information can be obtained through independent research, organization of workshops, questionnaires and interviews.
The comparison and harmonization of similar study programs across WB countries should be carried out in order to support future student/staff mobility among universities.

4.4.3.2 Analyse the study program and identify its deficiencies

The study program exposed to modernization is analysed in the aspect of the requirements identified in the previous step. Concrete deficiencies are detected and listed. Detected deficiencies are classified according the following classification: deficiency type (e.g. not attractive courses, old teaching methodologies, obsolete laboratories), planned time scale to solve the deficiency (e.g. long-term or short-term), planned correcting actions (e.g. training programmes, joined education with industry partners).

4.4.3.3 Analyse industry activities, needs and possible exchanges of knowledge

The study program exposed to modernization has to address technological change, industry and market needs. A list and analysis of the industry and market areas in the WB region is realized. Moreover, study programs/ courses are linked to each area of knowledge defined in the aforementioned list.

4.4.3.4 Identify body of knowledge and knowledge areas that can modernize the selected study program by following specific guidelines

Modernization of study program should follow well established methodologies, such as those proposed by ACM and ABET. Body of knowledge and knowledge areas of the current study programs are extracted in the first step. This content is compared with the setup requirements, and necessary changes in knowledge bodies and knowledge areas are defined.

4.4.3.5 Select courses/subjects to be modernized

The modernization can be obtained by improving existing courses/subjects or by introducing the completely new courses/subjects. Courses/subjects for modernization are identified based on the inputs from the previous steps. Learning outcomes are defined for each modernized course/subject. In the case of the existing course/subject, the proposed level of modification should be in accordance with the local accreditation procedures. For each modernized course/subject, the components to be defined are: content, teaching methodology and type of teaching material that will be prepared (e.g. presentations, books, lab sessions, audio and/or video lectures).

4.4.3.6 Identify lab equipment to modernize and new joint labs with industry

Each of the 6 HEI partners will collaborate with local ICT industries to create joint labs in order to foster traineeship and entrepreneurial education of future graduates.

4.4.3.7 Identify training activities for students and teaching staff

Training activities will mainly target students, but specialized training targeting teaching staff will also be organized. Training for students will assume fully developed training modules (block classes/seminars, lab exercises). Training topics will vary from techno-economic, entrepreneurial and IPR related, to focused training modules in the domain of telecommunications engineering equipment, ICT services, development and programming skills, IoT and cloud technologies, machine learning and data analytics and many other tools recognized to be fundamental for future ICT engineering development.

Teacher training modules will be implemented in the domain of teaching methods, remote lab tools, teaching practices, educational trainings, training in prototyping tools, etc.

Specify training activities for students and teaching staff and describe how they fit the needs of proposed modernized courses/ subjects.

4.4.3.8 Identify flexible mechanism for student internships

A framework for support of student internships in companies, ranging from short visits where students will make group visits and receive information about the opportunities in industry, all the way to multi-month internships for individual work and thesis work as part of specific projects proposed by industrial sector in WB countries. The project's industrial partners will aim to provide internship and joint thesis co-supervision.

4.4.3.9 Update the class content based on the identified Learning outcomes

Course/subject content is determined from the learning outcomes, while considering the industry requirements and ensuring a sufficient degree of harmonization with similar study programs in the region. The following procedure will be used: teaching methodologies are described, training programmes for teaching staff is implemented and new course materials are prepared.

4.4.3.10 Accredit the study program at faculty, university and national levels

Accreditation procedure for modernized study program is initiated with regards to selected courses to be modernized (by improving existing courses/subjects or by introducing the completely new courses/subjects).

a) Collect information and analyse current status and needs;	•conduct a surveys and review the main outcomes of Academic survey •collect similarities and differences among partners •collect survey and review the main outcomes of Industry survey •develop tools to involve local and regional industry •provide surveies that are continuously monitored
b) Analyse the study program and identify its deficiencies	•identify the deficiency •classify the deficiencies
c) Analyse industry activities, needs and possible exchanges of knowledge;	•analyse industry activity and needs through surveys •analyse industry key knowledge and know-how through surveys
d) Identify body of knowledge and knowledge areas that can modernize the selected study program by following specific guidelines	•define main knowledge areas •consider what teaching/learning methodology is the most appropriate •propose specific guidelines and trends
e) Select courses/subjects to be modernized	•determine the courses/subjects to be improved by adding selected knowledge areas or topics and/or implanting new teaching methodologies •determine the new courses/subjects, with appropriate content, teaching methodology and material type •provide syllabus outline for the modernized study programme/module
f) Identify lab equipment to modernize and new joint labs with industry	•specify equipment •describe how it fits the needs of proposed modernized courses/subjects
g) Identify training activities for students and teaching staff	•specify trainig activities for students •specify training activities for teaching staff
h) Identify flexible mechanism for student internships;	•specify a new flexible mechanism for student internships
i) Update the class content based on the identified Learning outcomes	•set the appropriate level on Bloom's taxonomy •write learning outcomes •training for teaching staff •develop/learn new teaching methodologies •prepare/update courses material
j) Accredit the study program at university and national levels	•follow internal procedures for updating the existing courses/subjects and accreditation of new courses/subjects and/or study programme/module

Figure 39: Procedure for curriculum modernization: PREPARATORY & DEVELOPMENT PHASE

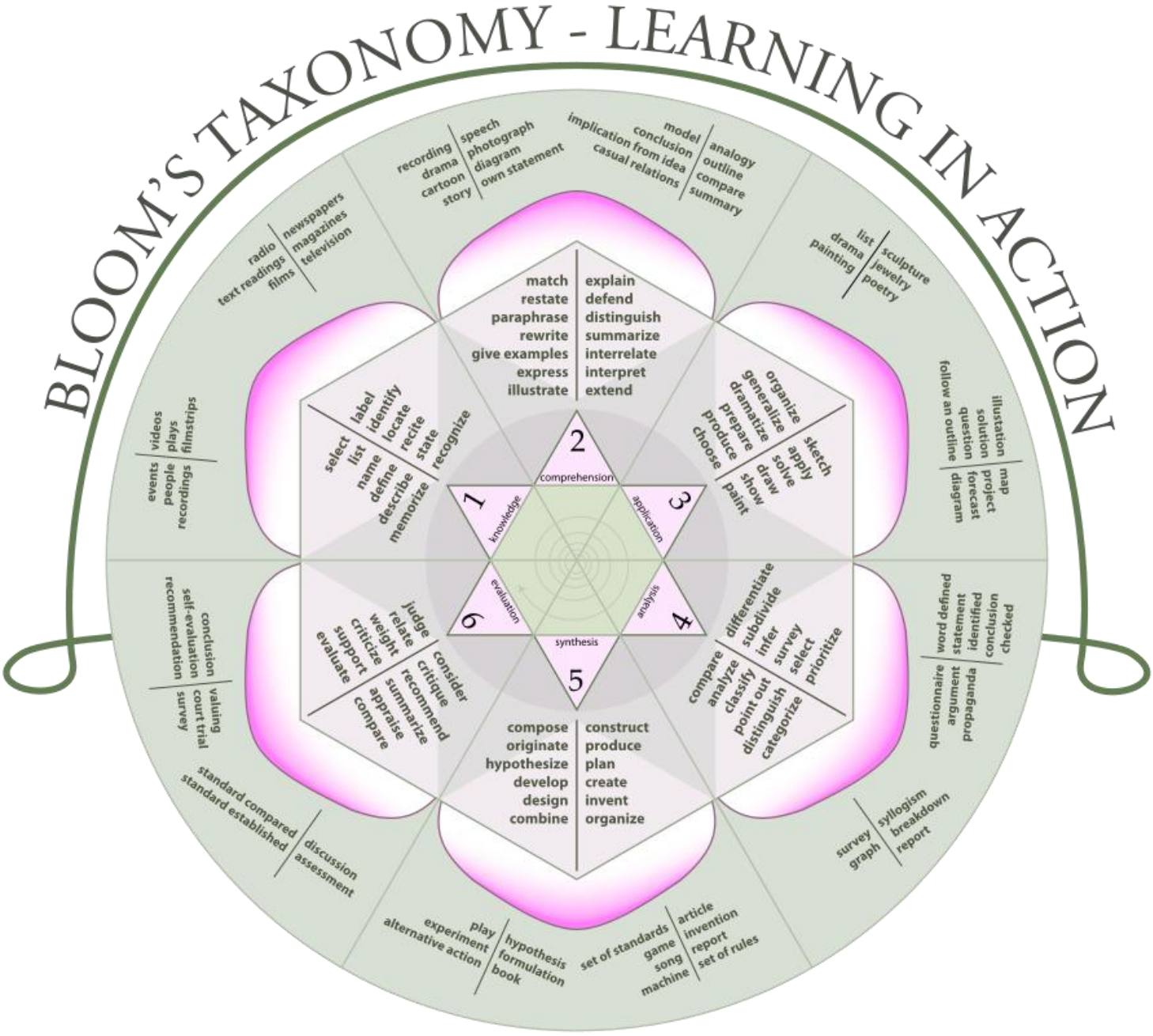


Figure 40: Bloom's taxonomy, learning in action

4.4.4 Execution & evaluation phase

After the courses/subjects are accredited the process is followed with EXECUTION & EVALUATION PHASE:

a) buy lab equipment and create new joint labs with industry;
b) deliver the courses/subjects;
c) deliver training activities for students and teaching staff;
d) deliver web platform for student internships;
e) collect feedback from students and external experts;
f) analyse data and propose further improvements;
g) disseminate lessons learned to the regional stakeholders.

4.4.4.1 Buy lab equipment and create new joint labs with industry

The laboratory material previously defined will be bought. The joint laboratories with industry will be settled.

4.4.4.2 Deliver the courses/subjects

This phase includes the delivery of modernized classes, applying new teaching methodologies and prepared course/subject materials. If possible, courses/subjects are delivered in the "experimental" phase prior to accreditation. If not, adjustments should be conducted during the first years of the course/subject delivery. A web repository will be created for class material, recorded remote classes and network of audio-libraries.

4.4.4.3 Deliver training and internships activities for students and teaching staff

Training activities for students will be delivered in the form recognized by the local law regulations (practicum, block of lab. exercises, additional semestral activities, etc.) and in cooperation with the industry partners or experts from industry.
Training activities for teachers will be delivered in the form of short courses, workshops etc. on the specific topics. These training will be organized in the cooperation with industrial partners or experts in the areas of ICT or education.
Internship opportunities will be delivered by the industrial partners.

4.4.4.4 Deliver web platform for student training and internships

Training and internship opportunities will be visible to the entire students' and teachers community of partners HEIs through the web portal developed specifically for this purpose.

4.4.4.5 Collect feedback from students and external experts

Modernized study programs are evaluated by external experts, such as professors from participating universities. After course/subject delivery, student feedback is obtained through questionnaires and evaluation sheets. It is highly encouraged to organize workshops with students and industry representatives to discuss benefits and drawbacks of modernized study programs.

4.4.4.6 Analyse data and propose further improvements

Use the feedback obtained in the previous step to propose further improvements. Improvements can include changes in the body of knowledge, knowledge areas, knowledge units, learning outcomes, as well as teaching methodologies.

4.4.4.7 Disseminate lessons learned to the regional stakeholders

The process of study program modernization and achieved outcomes are presented at the BENEFIT project webpage and corresponding university webpage. It is expected that the dissemination of results will increase the interest of students for telecommunications/ICT studies and will be used as an example of good practice in other regions.

k) Buy lab equipment and create new joint labs with industry	•buy lab equipement •settle new joint labs with industry
l) Deliver the courses/subjects	•prepare content for lectures •prepare content for labs •ad the courses/ subject material to web repository
m) Deliver training and internships activities for students and teaching staff	•deliver training activities for students and teaching staff •deliver intership activities for students
n) Deliver web platform for student training and internships	•list available training and intership activities
o) Collect feedback from students and external experts	•qualitative and quantitative analysis of lectures and labs
p) Analyse data and propose further improvements	•continously improve body of knowledge, knowledge areas, knowledge units, labs, learning outcomes, teaching methodologies •follow other classes and update the learning outcomes
q) Disseminate lessons learned to the regional stakeholders	•prepare online lectures •prepare remote labs •collaborate with HEIs in the region

Figure 41: Procedure for curriculum modernization: EXECUTION & EVALUATION PHASE

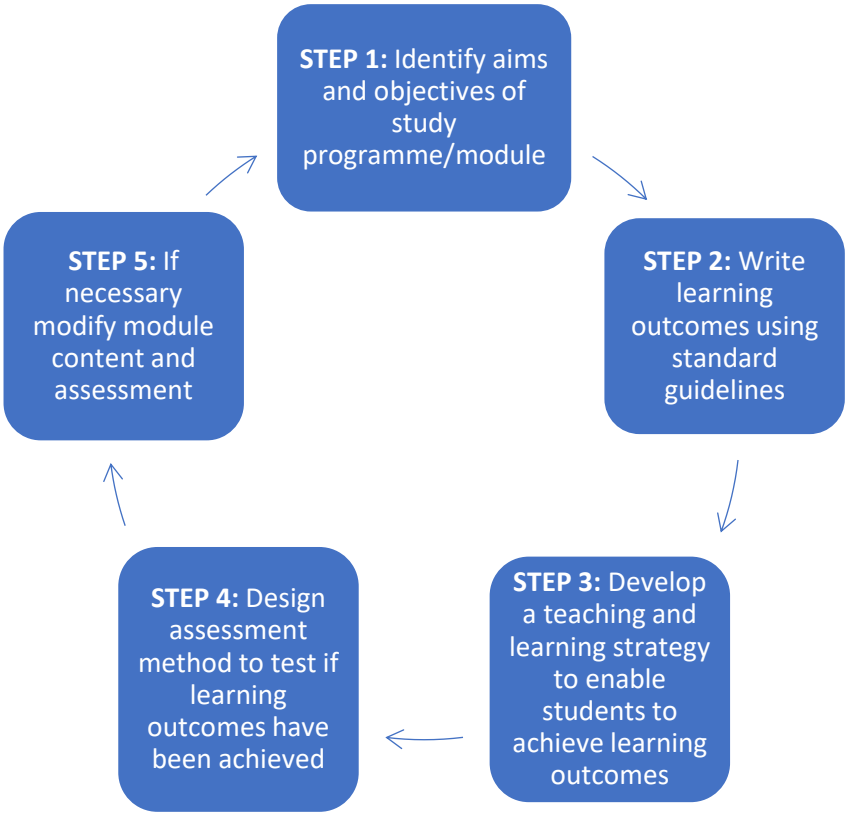


Figure 42: The iterative nature in the development of learning outcomes for the identified modules [11] p. 61

Study programs are continuously monitored and periodically improved. The quality of a study program is monitored through key performance indicators (KPI) such as rate of student employability, enrolment acceptance rate and student satisfaction. ICT domain is going through fast changes and is closely related to vibrant industry. Study programs should be dynamic, not static, requiring flexible regulation framework that will allow universities to respond to requirements and demands of such environment. In that sense, study program modernization represents a cyclic process as shown in Figure 12.

5. Conclusions

This document aims at providing necessary guidelines for the BENEFIT project activities according to industry inputs and good examples from EU.
The conducted academic survey, gives a snapshot of the present situation about the telecommunication engineering curriculum development. The analysis of the existing industry, employment status, employment perspectives, competencies and skills needed, together with the academic survey was necessary to recognise the current gap and deficiencies of study programmes.
Moreover, a survey on the existing policies, local constraints, was implemented to understand the legal procedures to upgrade the study programmes.
Guidelines and best practices were conceived to facilitate the reform of curricula.

6. References

[1] Framework Law on Higher Education in Bosnia and Herzegovina, Official Gazette of Bosnia and Herzegovina" Numbers 57/07 and 57/09, 2009.

[2] "Guidelines to the Criteria for Accreditation of Higher Education Institutions in Bosnia and Herzegovina," [Online]. Available: http://hea.gov.ba/Dokumenti/u-pripremi/Criteria%20eng.pdf .

[3] Decision on the criteria for accreditaton of higher education institutions in Bosnia and Herzegovina, 2016.

[4] "The statute of the University of Banja Luka," [Online]. Available: http://www.unibl.org/en/university/regulations/statute.

[5] "The Law on Higher Education," October 2017. [Online]. Available: http://bg.ac.rs/files/sr/univerzitet/glasnik-zakoni/Zakon-visoko-obrazovanje-2017.pdf.

[6] "Short overview of the regulations on higher education in Serbia," [Online]. Available: http://erasmusplus.rs/higher-education-in-serbia/.

[7] "The Statute of the University of Belgrade," March 2018. [Online]. Available: http://bg.ac.rs/files/sr/univerzitet/univ-propisi/Statut-UB-28.2.2018.pdf.

[8] "The Statute of the University of Novi Sad," [Online]. Available: https://www.uns.ac.rs/index.php/rs/univerzitet/dokumenti/send/6-statut/288-statut-univerziteta-u-novom-sadu-2.

[9] "The Statute of the University of Niš," [Online]. Available: https://www.ni.ac.rs/dokumenti/aktuelni-pravni-propisi-univerziteta-u-nisu/send/118-aktuelni-pravni-propisi-univerziteta-u-nisu/2373-statut-univerziteta-u-nisu-2017-glasnik-univerziteta-u-nisu-broj-82017 .

[10] K. O. a. V. Vladimir, "ICT sector skills needs analysis in Vojvodina in a VET multilevel governance perspective. EFT," 2017. [Online]. Available: http://www.etf.europa.eu/web.nsf/pages/ICT_skills_needs_analysis_Serbia.

[11] D. Kennedy, "Writing and using learning outcomes, Quality Promotion Unit," UCC, 2007.

[12] ACM, "Curricula Recommendations: Computer Engineering Guidelines," 2016. [Online]. Available: https://www.acm.org/binaries/content/assets/education/ce2016-final-report.pdf.

[13] A. E. A. Commission, "Criteria for accrediting engineering programs," 2018. [Online]. Available: http://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2018-2019/.

[14] B. Bloom, Taxonomy od Educational Objectives: Handbook 1, The Cognitive Domain, 1956.

[15] S. Adam, Using Learning Outcomes: A consideration of the nature, role, application and implications for European education of employing learning outcomes at the local, national and international levels, Report on United Kingdom Bologna Seminar, 2004.

[16] BENEFIT project proposal, 2017.

7. Annexes:

7.1 Academic survey and summary

Curriculum Assessment	- Overview of the structure of studies related with the telecommunications engineering studies

Note: *For a blue coloured cells choose an answer from the drop-down list.*
In a yellow coloured cells write an answer.

Institution

University:
Web page:

Contact Person

Name and surname:
E-mail:

STUDY STRUCTURE:

Study programme title:	
Study programme type:	
Duration of the study programme (in years):	
Number of ECTS points acquired upon study completion:	
Professional title conferred:	
Study programme web page:	

The basic objectives of the study programme are (up to 10):	•
General competences obtained through the study programme (up to 10):	•

Number of ECTS acquired for final/diploma thesis:	
Number of ECTS for professional practice:	
Duration of professional practice (in weeks):	
Number of students enrolled in the first year of study in academic 2016/2017:	
Number of students graduated in academic 2016/2017:	

Specifics of the study programme (if any):	

REGULATIONS:

		Document nr.1:	*Document nr.2:*	*Document nr.3:*	*Document nr.4:*	*Document nr.5:*
Institutional regulations:						
Strategies, recommendations and other legal documents of faculty/university related with the curriculum:	Document name:					
	The most important suggested guidelines about curriculum / learning outcomes:					
National regulations:						
Policies / laws defining high education in the country:	Document name:					
	The most important suggested guidelines about curriculum / learning outcomes:					

COOPERATION WITH INDUSTRY:

Number of realized student internships within the last 2 years:		
Number of created BSc/MSc theses with cooperation of external experts within the last 2 years:		
Number of industry experts involved in student training:		
Involvement of industry experts in shaping the study programmes:		Short description:
Number of developed joint industry-academia labs:		

PROFESSIONAL ACTIVITY:

Number of start-ups started within the last 5 years:	
Number of spin-offs started within the last 5 years:	

TEACHING METHODOLOGIES:

Classes overview:		Course title:	Type:	Category:	Group:	Teaching forms:	Number of ECTS credits:	Hours per week (total for all teaching froms):	Hours per week for practical work (lab, projects, etc.)	Usage of e-tools: y/n:
	1									
	2									
	3									
	4									
	5									
	6									
	7									
	8									
	9									
	10									
	11									
	12									
	13									
	14									
	15									
	16									
	17									
	18									
	19									
	20									
	21									
	22									
	23									
	24									
	25									

COMPETENCES Sheet
First part

COMPETENCES:									
		Mathematics	Physics	Fundamentals of electrical engineering	Measurement and instrumentation	Information theory	Electronics engineering	Radio communications	Communication networks	Communication systems
Core competences for each group of courses (up to 10):	1									
	2									
	3									
	4									
	5									
	6									
	7									
	8									

Second part

		Software engineering	Computer engineering	Information and data management	Signal processing	Other engineering courses	Multimedia	Communication and presentation skills, foreign languages	Business economics, management and organization
	1								
	2								
	3								
	4								
	5								
	6								
	7								
	8								
	9								

7.2 Competences for BSc and MSc study programmes

COMPETENCES OVERVIEW								
1st Cycle Study Programme (BSc)								
Mathematics								
UNI-KLU_BSc	UL_BSc	FERIT_BSc	UB_BSc	UBL_BSc	UNI_BSc	UNS_BSc	UNSA_BSc	UNTZ_BSc
Analysis Ia Analysis Ib Analysis I Analysis II Stochastics I Lineare Algebra für Informatik und Informationstechnik Numerical methods	number systems sequences series derivative integral matrices systems of linear equations function series ordinary differential equations linear systems of ODEs differential geometry vector analysis complex analysis	Linear algebra Analysis of functions Vector analysis Ordinary and partial differential equations Integral calculus Probability theory and statistics Functions of several variables Scalar and vector fields	Elements of mathematical logic. Algebra. Rational functions. Introduction to mathematical analysis. Integral calculus. Differential equations. Boolean algebra. Combinatorics and graphs.	Linear algebra Differential calculus Integral calculus Differential equations Using MATLAB for computations in linear algebra Complex analysis Vector analysis Probability and statistics	Linear Algebra Theory of Polynomials and Analytic Geometry Analysis of functions Series Ordinary and partial differential equations Multivariable function. Special functions Integral calculus Complex analysis	Discrete Mathematics: 1) Algebra: logic, relations, functions, Boolean algebra, groups, rings, fields, polynomials. 2) Linear algebra: complex numbers, finite fields, free vectors, analytical geometry. 3) Determinants,	Calculus: integral, differential, multivariable Linear algebra Complex numbers Fourier transform Lapalace transform Probability theory Statistics	**Mathematics I, II & II** (compulsory courses): Elementary functions and their graphs. Criteria for checking convergence in different limit processes. Differential calculus of the one real variable function; differential calculus used in solving

	integral transformations numerical methods	Functions of a complex variable Double and triple integrals Fourier series Fourier transformation Laplace transformation	Functions of more variables. Transforms applicable in Electrical engineering. Conditional probability and independence of events. Random variables and their distributions. Numerical characteristics of random variables. Laws of Large Numbers and Central Limit Theorem. Estimate of parameters and testing hypothesis.	Numerical analysis	Laplace transform. Fourier transformation. Probability theory and statistics	systems of linear equations, vector space, matrices, characteristic roots/vectors. Mathematical Analysis 1 & 2: 4) Real/complex functions of one or several variables (limits, continuity, differential calculus). 5) Ordinary differential equations of first & higher order. Linear differential equations of n-th order. 6) (In)definite integral and application, improper integral, double and curvilinear integral.		concrete problems. Techniques of finding indefinite integrals, and integral calculus application in solving typical problems. Properties of numerical sequences, numerical series, functional sequences and functional series. Solving different types of differential equations. Examining the properties of functions of several variables, calculating limit values, and examining the continuity

						7) Series (number, function, power and Laurent), singularities, residue, conformal mapping. Probability, Statistics and Stochastic Processes: 8) Conditional probability and Bayes' formula. 1D and 2D random variable, distribution functions. 9) Numeric characteristic. – (cond.) expectation, dis-person, covariance, correlation. Limit theorems. 10) Statistics – point and interval estimate, (non)-		of functions. Determination of derivations, differentials, gradient and extrema. Computing and application: multiple integrals and first and second type of line integrals. Sequences of the complex numbers. Function of complex variable and its integral. Series of the complex number and series of the complex functions. Fourier series, Fourier transformation and Laplace transformation and their applications.

						parametric hypotheses and significance testing. 11) Stochastic processes – general notions. Stochastic process transformation-derivative, integral. 12) Poisson process, white noise. Markov chains. Stationary process. Mass service systems.		

Physics								
UNI-KLU_BSc	UL_BSc	FERIT_BSc	UB_BSc	UBL_BSc	UNI_BSc	UNS_BSc	UNSA_BSc	UNTZ_BSc
Electrotechnical and Physical Fundamentals of Information Technology Electrotechnical and Physical Fundamentals of Information Technology	mechanics thermodynamics atomics optics	Mechanics Electromagnetism Thermodynamics Optics The structure of matter	Mechanics - basic concepts of kinematics and dynamics of a particle and rigid body. Introduction to wave motion. The structure of matter Basic principles of measurements and measuring devices with practical implementation. Processing measurement results and expressing uncertainty in measurements. Introduction to the fluid mechanics and	Translational and rotational kinematics Translational and rotational dynamics Special theory of relativity Oscillations Waves Thermodynamics Kinetic theory of gases Optics Basics of quantum mechanics	Mechanics Fluid mechanics Fundamentals of thermodynamics Optics Fundamentals of atomic physics Fundamentals of nuclear physics Independent laboratory work and the application of physical laws in practice Adequate usage of acoustic components and equipment	Physics: 1) Structure of matter, statistics of micro particles. Laws of thermodynamics. Kinetic properties. 2) Mechanical waves. Ultrasound and Doppler effect. Physical and physiological sound intensity. 3) Electromagnetic waves, Hertzian dipole, Bohr model of atom, photon emission, photo effect. 4) Optics, wave refraction, lens, microscope.	Mechanics Kinematics Dynamics Oscillation and waves Fluid mechanics Thermodynamics Optics Radiation Atomic and nuclear physics	**Physics I & II** (compulsory courses) Physical basis of kinematics; Newton's laws in inertial and non-inertial systems; Work, power and energy. Rotary motion of a rigid body; Gravity. Fluid statics and dynamics; Heat appearance; Thermodynamics. Oscillation and waves; Mechanical waves, standing waves; Doppler effect. Basics of Quantum and Nuclear physics.

			thermodynamics. Basics in optics - basis for optical communications systems and fiber optic sensors. Basics of quantum physics - basis for photonics and Nano electronics. Basics of nuclear physics - for the application in energetics and medicine. Computer modeling of physical phenomena (Oscillations, Optics, Heat transfer …). Fundamentals of quantum mechanics and statistical physics.			Wave optics, diffraction, dispersion, polarization. 5) Quantum Mechanics, Schrödinger equation, Heisenberg's principle. Fermi-Dirac distribution. Mechanics: 6) Units of physical measurement. Motion of a particle. Newton's law of motion and applications. 7) Work and kinetic energy. Potential energy and conservation of energy. 8) Momentum, impulse and collision. Rotational motion of rigid		

			Basics of semiconductor electronic and optoelectronic devices			bodies. Rotational dynamics. 9) Equilibrium and elasticity. Gravitation. Oscillatory movement. 10) Computer simulation of dynamic systems.		

Fundamentals of electrical engineering								
UNI-KLU_BSc	UL_BSc	FERIT_BSc	UB_BSc	UBL_BSc	UNI_BSc	UNS_BSc	UNSA_BSc	UNTZ_BSc
Design of digital Systems Microelectronics System Theory Computer Architectures Telecommunications Control Engineering Telecommunications Systems	electric charge and current electric force current field magnetic field Maxwell equations electric machines semiconductors carrier transport diode, transistor, etc. optical devices nanoelectronics	Fundamental laws in electromagnetism, units and measures of electric and magnetic fields Calculations of electric and magnetic field strength Capacitance, inductance and resistance AC and DC electrical circuits Simple magnetic circuits Three-phase system Time domain and frequency domain of electrical networks	Electrostatics. Conductors. Capacitors. Dielectrics. D.C. fields and circuits. Electric networks with capacitors. Stationary magnetic field. Ferromagnetic materials. Time-varying electromagnetic field. Faraday's law. Inductances. A.C. circuits. Frequency characteristics. Transients.	Electrostatic field analysis DC circuit analysis Electromagnetic field analysis Simple magnetic circuits AC circuit analysis Single-phase and three-phase electric power Time-domain transient analysis Frequency response of electrical circuits Two-ports Transmission lines Propagation of	Basic physical laws of electrostatics Basic physical laws of electromagnetism Analytically calculate the magnetic and electric field parameters Solve simple electric and magnetic circuits Perform DC and AC circuit analysis Apply passive elements (resistors, capacitors, inductors), Use transformers and reactors	Fundamentals of Electrical Engineering 1 & 2: 1) Electrostatics (conductors and dielectrics in electrostatic field, capacitors, voltage, energy). 2) Electric circuits of time-invariant currents (D.C.) (Current density & intensity, Ohm's law, resistors) 3) D.C. (Joule's law, Kirchhoff's laws, generators, conditions of maximum	Electrostatics. Electromagnetism Electrical circuits DC circuit analysis AC circuit analysis Stationary magnetic field. Time-varying electromagnetic field. Faraday's law. Oscillating electric circuits Transmission lines Materials in electrical engineering	Fundamentals of Electrical Engineering 1 & 2 *(compulsory courses)*: The understanding of electrical engineering concepts, laws and principles regarding electrostatics DC electrical circuits and understand underlying physical phenomena The electrical engineering concepts, laws and principles regarding electromagnetics, AC electrical circuits and

		Nonlinear and time-variant networks		electromagnetic waves	Use electromechanical components Use components in SMD technology Apply sensor components	power transmission). 4) D.C. (Methods of circuit analysis, superposition theorem, Thevenin's and Norton's theorem). 5) D.C. (Compensation theorem, reciprocity theorem, electrical circuits with capacitors). 6) Time-invariant magnetic field (magnetic flux, Biot-Savart & Ampere's law, ferromag. materials). 7) Slowly time-varying EM field (EM induction, Faraday's law, transformers,		polyphases systems The theoretical and practical basics through research and laboratory work and mathematical methods for analysis of complex problems Introduction to Energy Systems (compulsory course): Importance of energy development and security of energy supply. Ecological and technological aspects of production and consumption and energy conversion. Basic characteristics of primary energy

						energy in EM field). 8) Electric circuits of time-varying current (A.C.) (impedance, power, three-phase systems). Electromagnetics (elective course 1/2): 9) Maxwell equations and theorems of EM field. Methods for solving time constant magnetic field. 10) EM induction and application, inductance, energy and force of magnetic fields, some effects.		resources and the method of exploitation and transformation in industrial processes. Basics of renewable energy resources, possibilities and limitations of use. Theory of Electrical Circuits (compulsory course) Understanding physical processes in linear electric circuits in transient states. Interaction between the circuits components (natural, compulsory and complete

								circuit response). Methods for modeling of dynamic models of electric circuits and methods for solving circuit response. Frequency and time domain analysis of electric circuit transient response. Modeling methods and functions of four poles and filters.

Measurement and instrumentation								
UNI-KLU_BSc	UL_BSc	FERIT_BSc	UB_BSc	UBL_BSc	UNI_BSc	UNS_BSc	UNSA_BSc	UNTZ_BSc
Instrumentation, Sensors and Actuators technology	metrology systems fundamental principles measuring accuracy and uncertainty measurement quantities measurement non-electrical quantities structure of measurement instrumentation electronic measurement instruments measurement communication intergaces	Measurement with ampermetre, voltmetre, watmetre, ohmmetre, teslametre and oscilloscope. Measurement methods Measurement uncertainty Spectral analysers Logic analysers	Introduction to metrology. Measurement uncertainty. Measuring instruments (amperemeters, voltmeters RLC meters, digital multimeters, oscilloscope) Bridges. Measurement of resistance, capacitance, inductance. Power supplies. Signal sources. Signal level measurement. Frequency and time measurement. Spectrum analyzer.	Measurement standards Measurement errors Analog and digital measurement instruments Measurement of electrical quantities Measurement methods Measurement of non-electrical quantities Reliability and sensitivity of measurement instruments	Apply measurement methods and techniques Use analog and digital instruments and equipment for measurement of electrical quantities Use analog and digital measuring instruments Process the measured results Use software tools to automate the measurements Independently use	Measurement Systems in Telecommunications: 1) Getting acquainted with measurement principles in digital communications. 2) Ability to perform and analyze fundamental tests for the characterization of digital comm. systems 3) Hands-on experience in attesting and fault measurements on the first and second OSI layer.	Introduction to metrology Etalons and measurement traceability. Unit systems Measurement errors and uncertainty in measurement Reproducibility, repeatability, accuracy and precision. Technical characteristics of measurement devices Analogue electrical measurement devices Digital measurement devices	Measurements in Telecommunications (compulsory course) Understand difference between traditional electrical measurements and communication measurements. Different measurement procedures; oscilloscope, spectral analyzer and vector network analyzer; channel characteristic determination; measurements in optical and radio communication systems. Processing of measured data

					laboratory equipment and specialized software packages			and preparation of measurement visualization.

Information theory								
UNI-KLU_BSc	UL_BSc	FERIT_BSc	UB_BSc	UBL_BSc	UNI_BSc	UNS_BSc	UNSA_BSc	UNTZ_BSc
	probability stohastic processes coding and data compaction information and channel capacity analogue signal coding, audio signals speech coding audio signal coding	Entropy Shannon's theorem Bayes ' postulate nad theorem Optimum code Information source evaluation Information processing	Information theory model of telecommunication systems. Information sources - modeling and evaluation. Source coding - theorem and algorithms. Data compression. Channel capacity (Shannon's theorem) and basic models. Channel coding - theorem, coding/decoding techniques and application. Interliving.	Model of communication system Mathematical definition and properties of information Entropy Shannon's theorem Coding for discrete sources Source coding theorem Bayes ' postulate nad theorem Optimal lossless coding Noisy communication channels	Perform time-domain and frequency-domain signal analysis Apply different modulation schemes Perform continuous signal digitalization Aanalyse communication systems influenced by undesired random impairments Apply source and error correction coding Determine entropy	Introduction to Information Theory: 1) The knowledge of the basic postulates of the information theory. 2) Source coding (statistical), block code for data compression, optimal prefix code (Huffman). 3) Arithmetic coding, universal codes, Lempel-Ziv algorithms. 4) Protective coding (model of comm. channel, transinformation, equivocation, irrelevance). 5) Optimal decoding, MAP	Entropy Shannon's theorem Deterministic and random signals, spectrum and linear systems. Information sources. Coding theory Channel coding	Statistical Theory in Telecommunications (compulsory course) Basic principles of probability theory and statistics and probability distribution. Solving problems in telecommunications requiring probability. Calculation of autocorrelation function and spectral content of random signals. Computation of response of LTI systems to random signals. Information Theory and Coding (compulsory course) Basic algorithms for data compression and forward error correcting. Design of complex data compression methods

			Fundamentals of cryptography	Channel coding theorem	Determine communication channel capacity Characterize noise and interference in telecommunication systems	criterion, properties of binary symmetric channel, convolutional codes.		based on cascade connection of several fundamental methods. Implementation of channel coding methods on hardware platforms

Electronics engineering								
UNI-KLU_BSc	UL_BSc	FERIT_BSc	UB_BSc	UBL_BSc	UNI_BSc	UNS_BSc	UNSA_BSc	UNTZ_BSc
Electronic Circuits		Basics of semiconductor physics Diode, bipolar and unipolar transistors Basics of semiconductor power switches Basics of semiconductor optoelectronic components Design and implementation of amplifiers Design basic logic, combinational and sequential circuits and analog-to-	Semiconductors. PN junction. Diode circuits. Transistors. Single stage amplifiers. Operational amplifiers and basic operational amplifier circuits. Digital logic circuits. Combinational networks. Bistables and memory elements. Basic sequential networks. Basic of HDL. Digital devices. Logic circuits.	Semiconductor elements (diodes, bipolar and MOS transistors) Analysis and design of amplifiers Circuits with operational amplifiers Circuits with feedback Semiconductor switching elements Analysis and design of logic circuits Analysis and design of multivibrators Waveform generators	Characterize and apply semiconductor components (diodes, bipolar and unipolar transistors) Characterize and apply optoelectronics components Apply rectifiers and voltage regulators Characterize, design and apply amplifiers, oscillators Analyze electrical circuits and signals by using different methods and models	Introduction to Digital and Microcomputer Electronics: 1) Ability to design and simulate simple combination and sequential networks. 2) Ability to design, write source code, test & run the program in the symbolic machine language. 3) Ability to design a structure of a simple micro-computer system based on given specifications. 4) Ability to make a	Semiconductor electronics Diodes Bipolar transistors MOS-FET transistors Operational amplifiers Oscillators DA/AD converters Power supply systems in telecommunications Basic logic elements. Logic circuits Sequential circuits Arithmetic circuits Fundamentals of optoelectronics	Introduction to Electronics (compulsory course): The fundamental operation of basic electronic components and their modeling for the purpose of the design in the electronic circuits Theoretical analysis of static characteristics of semiconductor diodes and transistors. Design and analysis of circuits with semiconductor diodes, bipolar and unipolar transistors. Design and analysis of amplifiers with bipolar and unipolar transistors.

		digital converters Logic functions, logic circuits, integrated logic circuits Digital systems design PAL and GAL programming tools VHDL	Overview of basic impulse circuits. Combinational circuits. Sequential circuits. Memories. A/D and D/A converters. Digital systems. Cellular circuits and complex programmable logic devices (FPGA,CPLD).	Basics of DC-to-DC converters Analysis and design of analog integrated circuits Design of digital systems Design and synthesis of A/D and D/A converters Design and synthesis using programmable modules VHDL Analysis and design of RF integrated circuits	Apply integrated circuits Design and apply digital circuits that microcontrollers and microcomputers are made (logic, memory, programmable circuits, A/D, D/A converters)	specification of a personal computer based on given applications.		Analog Integrated Electronics (compulsory course) Analysis of electrical circuits including ideal and real models of operational amplifiers. Design of linear and nonlinear systems with analog integrated circuits. Analysis and design of waveform generators with operational amplifiers and discrete semiconductor components. Design of the active filters, voltage regulators, and the analog/digital convertors with operational amplifiers. Sequential Circuits (compulsory course) Analysis of basics combinational circuits.

								Analyses and synthesis of sequential circuits. VHDL language for digital systems design and synthesis. Architecture and operations of a simple model of microprocessor.

Radio communications								
UNI-KLU_BSc	UL_BSc	FERIT_BSc	UB_BSc	UBL_BSc	UNI_BSc	UNS_BSc	UNSA_BSc	UNTZ_BSc
		Basics of antennas Radio wave propagation mechanisms Wireless link budget calculation	Spectrum and wave propagation Wireless local area networks Radio systems Microwave engineering Radio technologies Antenna fundamentals Microwave radio links Satellite systems Public mobile systems Electromagnetic compatibility Radio positioning	Architecture of radio transmitters and radio receivers Fundamentals of RF amplifiers and mixers The noise factor and the sensitivity of the radio Spectrum analysis Modulators and demodulators Basics of antennas Wireless links and wave propagation Optimal receiver design	Use analytical and numerical methods for calculation of EM fields Apply EM wave propagation properties Antenna design and measurements Analysis and design of sensor networks Characterize and analyze the wireless communication systems (mobile, satellite, microwave links, TV distribution, WLAN)	Principles of radio communication: 1) Radio-communication concepts: system components, services, spectra. 2) Properties of electromagnetic waves. 3) Antennas: characteristics and parameters, types, antenna arrays. 4) Propagation of EM waves: free space, reflection, diffraction, attenuation, fading. 5) Multiple access (FDMA, TDMA, CDMA,	Antenna fundamentals RF circuit design Radio technologies Satellite systems Public mobile systems Wireless local area networks Microwave radio links Electromagnetic compatibility Radio positioning Microwave engineering	Radio Telecommunication Systems (compulsory course) Communication systems for RF and microwave applications. Design requirements and specifications of mobile radio microwave link systems. Noise and interference in radio systems. Basic components of the electromagnetic radiation, analysis of the antenna parameters. Solutions of common engineering applications at transmission lines and antennas. Mobile Telecommunications (compulsory course)

					Apply multiple access techniques Determine link budget Assess the risk of exposure to RF and microwave radiation Measure/control EM radiation and apply safety measures in living and working environments	SDMA) and diversity techniques. 6) Radio system overview: cellular networks (GSM/UMTS), DECT, Wi-Fi, satellite systems. Design of Radio Systems (elective course 1/4): 7) Particularities of different radio systems. Multipath feeding and unavailability. 8) Design of fixed and mobile radio links: propagation modelling and prediction of EM field level. RF and microwave		Access techniques in mobile communications. Cellular organization of mobile systems. Techniques to increase the coverage and capacity. Architecture and performance of different mobile systems. Mobility management; Traffic characteristics of mobile networks; Security. Satellite Telecommunications (compulsory course) Basic principles of satellite communications. Different communication satellite networks and systems. Analysis and simulation of satellite based telecommunication systems.

						engineering 1 & 2 (elective): 9) EM waves, components, circuits and systems above 1 GHz (Bluetooth, Wireless LAN, etc.). 10) Ability to understand principles, potentials and limitations of next-generation wireless syst.		

Communication networks								
UNI-KLU_BSc	UL_BSc	FERIT_BSc	UB_BSc	UBL_BSc	UNI_BSc	UNS_BSc	UNSA_BSc	UNTZ_BSc
	telecommunication service protocols and protocol stack communication system and protocol specification connection management flow and congestion control medium access control protocols protocol analysis	Information and traffic network characteristics Network flows and capacities. OSI reference model TCP/IP reference model Transmission media Basics of mobile networks Local area networks Industrial LANs and protocols Internet network architecture Network routing	OSI and TCP/IP reference models Communication technologies Routing protocols basics Switching protocols basics Optical networks Optical communications Network administration and programming Switching systems fundamentals Internet Routing Architecture Access networks	Models of communications Network fundamentals Packet switching networks Network topologies and architectures OSI reference model TCP/IP reference model LAN, MAN, WAN Wireless LAN and WAN Internet network architecture Network routing QoS	Design network architectures Use data layer and network layer protocols Apply TCP/IP communication model Solve engineering problems in VoIP Apply routing in telecommunication networks Recognize communication protocols, servicec and network architectures that are used to Internet access Know broadband	Communication networks - introduction: 1) Complete understanding of communication network technologies and OSI layer structures. 2) Message, packet, session, exchange, frame, synchronous transmission and transport systems. 3) PHY level - medium, modem. Data link layer - error detection, ARQ procedures; multiple access. 4) Random access; Network	OSI and TCP/IP reference models Communication technologies Routing protocols basics Switching protocols basics Optical networks Optical communications Network administration and programming Switching systems fundamentals Internet Routing Architecture Access networks VoIP	Telecommunication Protocols (compulsory course) Theoretical models of network communication and coordination. Communication protocols: Model of communication protocols; Analyses and synthesis of communication protocols. Signaling protocols; Multimedia communication protocols. Telecommunication Networks (compulsory course) Analysis of different routing algorithms, protocols and communication networks. Structure cabling.

		QoS Basics of network security	Voice over IP Communication hardware programming	Basics of network security	telecommunication network transmission and switching: Broadband subscriber line, FTTx technologies Know cable and optical network architectures Estimate potential threats and security requirements in telecommunication network	layer and path finding, QoS. Transport layer, session, security problems. IP technology: 5) TCP/IP protocol stack, routing & security in IP, UDP, TCP, IP/MPLS networks, IP services and QoS. Telecommunication networks: 6) Fiber optic transmission. Optoelectronic principles. Wavelengths division mux (WDM). 7) Digital transmission systems (PDH, SDH, OTN), softswitch, standards for wireless (3G, 4G, LTE); VPN.		Implementation of a simple client-server socket based application. Troubleshooting networking. Switching Systems (compulsory course) Performance analysis of switch. Management and configuration of switching devices. Architecture of software switching. Switching and routing in the cloud. Virtualization of the network infrastructure. Resource allocation and load balancing switching devices. Analysis of the influence of different topologies, applications and devices on the network performance.

						Wireless sensor networks: 8) Wireless sensor and ad-hoc networks; graphs, power efficiency, protocols and standards. 9) Simulation and implementation of WSNs (embedded system programming). SCADA Systems Design (elective course 1/3): 10) IoT, Industrial IoT, protocols and applications, objects automation, process automation.		

Communication systems								
UNI-KLU_BSc	UL_BSc	FERIT_BSc	UB_BSc	UBL_BSc	UNI_BSc	UNS_BSc	UNSA_BSc	UNTZ_BSc
	fundamentals of communications and telecommunications information society information resources communication channel model digital data transmission OSI TCP/IP communication systems	Spectrum analysis Noise in communication systems Modulation techniques, probability of error, spectral efficiency Wave propagation over transmission line Basics of ADSL Basics of OFDM	Model of telecommunication systems. Deterministic and random signals, spectrum and linear systems. Signal sampling and regeneration. Analog-to-digital signal conversion and applications. Fundamentals of baseband digital transmission. Passband transmission of analog and digital signals (modulation techniques, modeling and analysis).	Models for analysis of telecommunication systems Noises in telecommunication systems Models and parameters of transmission lines Characteristics of transmission lines (air, symmetrical, coaxial) and cable systems xDSL technologies Synchronous Digital Hierarchical (SDH) transmission systems Telecommunication terminals	Analyze, synthesize, and implement transmission lines in microwave devices Use Smith chart and scattering parameters in analysis / design of microwave circuit Design of passive and active microwave circuits Use specialized software tools for analysis and optimization of microwave circuits and systems	Signals and Systems: 1) Model of communication system. Linear, non-linear and combined systems. 2) Information. The amount of information. Signal definition, types, properties and analysis. 3) Signal digitization. Sampling, quantization and coding. 4) Procedures for signal transmission and processing. Analog and digital modulation.	Information networks and telecommunication systems Discrete memoryless channels. The communication process and model of the digital communication system Deterministic and random signals, spectrum and linear systems. Signal sampling and regeneration. Analog-to-digital signal conversion and applications.	Optical Telecommunications (compulsory course) Fundamental operation of components for the generation, transmission and detection of optical signals. Design optical communication system used for point to point links, with and without wavelengths division multiplexing. Basic concept of optical access networks. Digital Telecommunications (compulsory course) Digital communication system components. Properties of digital

			Advanced passband digital transmission (Spread spectrum, OFDM and UWB techniques). Channel capacity. System design and optimization. Video systems Television	Telecommunication standards and protocols The source of the message (discrete sources; amount of information; entropy; source coding; analogous sources) Transmission of signals in the basic band (channel characteristics, channel noise, channel capacity, channel encoding, decision making, distortion in transmission - linear, nonlinear, intermodulation, bandwidth impact on	Model, simulate and analyze communication systems Understand baseband digital transmission Apply M-ary digital modulation schemes Understand and apply demodulation of digitally modulated signals Understand multiple access techniques Know transmitter and receiver architectures and functions	Modelling and Simulation of Communication Systems: 5) Ability to implement each communication unit using MATLAB's Communications Toolbox. 6) Ability to present and interpret the results of a simulation of communication systems in MATLAB. Principles of Digital Communications: 7) Statistical analysis of digital signals. Scram-bling and line coding. Baseband transmission. 8) Nyquist criteria, equalization,	Fundamentals of baseband digital transmission. Passband transmission of analog and digital signals (modulation techniques, modeling and analysis). Advanced passband digital transmission (Spread spectrum, OFDM and UWB techniques). Channel capacity. System design and optimization. Video systems Television	communication techniques. Design of matched filters and equalizers. Synchronization in digital communication systems. Analysis of digital communication system performance. Fundamentals of Telecommunications (compulsory course) Introduction to analog communication techniques and digital transmission of analog messages. Application of mathematical models in analog communication system performance analysis. Analog receivers architecture. Synchronization and functioning of phase-locked loop.

				signal transmission) Real telecommunication channels (line transmission and radio transmission) Principles of multiplexing (frequency, time and code multiplexes) Synchronization (carrier synchronization, bit synchronization, code synchronization, frame synchronization) Principles of design of modern digital telecommunication systems		optimal receiver. Symbol synchronization. Digital Modulations: 9) Signal transmission in the transposed fr. range (modulations): ASK, QAM, PSK, FSK, ODFM, DS, FH. Communication Systems Design (elective 1/4): 10) Methods of communication system design (coaxial cables, optic comm. systems etc.).		

Software engineering								
UNI-KLU_BSc	UL_BSc	FERIT_BSc	UB_BSc	UBL_BSc	UNI_BSc	UNS_BSc	UNSA_BSc	UNTZ_BSc
	programming languages design, built, test computer programs HTML and CSS Web programming with JavaScript Introduction to C programming programming Arduino basic paradigm time sliding principle synchronization and arbitrage C programming multitasking time slicing	Number systems and data formats. Compilers Programming in C Complex data types Systematic approach to software development Object-oriented programming Programming in C#	Structured programming. Data types. Control structures. Program modularization, passing parameters to a procedure/function, recursion. Data input/output, files. Pointers and dynamic memory allocation and deallocation. Complexity of the algorithms. Developing complex programs in C language. Object-oriented	Programming in C Application of basic principles of software engineering Basic data structures and algorithms Understanding of structured programming Object-oriented programming Programming in C++	Use numeral systems and computer data representation Use elements of assembly language Use operating systems Apply algorithm structures and elements of software development Implement best data structures and effective algorithms for problem solving by programming languages C/C++ and Java Programming in C	Software Lab: 1) Windows Explorer, Control Panel, Int. Explorer, Outlook Express, Word, Excel, Power Point. Programming Languages and Data Structures: 2) Design programmers in C (data types, operations, sequences, cycles, jumps, modules, files). 3) Data structures: static (array, string), semi-d. (stack, line, deck, sequence), dynamic (lists, trees). Operating Systems and Competitive Programming: 4) Concepts and principles of	Introduction to programming Object oriented programming (C++) Object oriented analisys and design	Introduction to Programming (compulsory course) Algorithms. Data types. Operators and expressions. Program flow control. Functions and program structure. Recursion. Pointers, arrays and functions. User defined data types. Dynamic memory allocation. File management. Sequential and random access files. Linked list. Object Oriented Programming (compulsory course) C++ basics. Standard library.

	synchronization and arbitrage		programming in the C++ language. MATLAB. LabVIEW. Python. XHTML and CSS programming languages. JavaScript functionalities. MySQL database by the PHP code.		Apply fundamental of Object-oriented programming Apply fundamental of Web programming Apply fundamental knowledge necessary to design, implement and use databases Independently use MATLAB and LabVIEW software packages	operating systems. Structure of OS. Distributed OSs. 5) Concurrent nature of OS. Concurrent libraries. Cooperat. & synchronizat. of processes/threads. Development Tools in Telecommunications and Signal Processing 1: 6) Principles of object-oriented programming in prog. language C++ and Standard Template Library. 7) Application of OOP principles in implementation and optimization of DSP algorithms. Development Tools in Telecommunications and Signal Processing 2: 8) Introduction to Java. Classes, inheritance and		Template functions. References. Pointers. Memory management. Class and structure types. Template class types. Inheritance and dynamic binding. Data Structures (compulsory course) Basic concepts of abstract data type and fundamental data structures. Analysis of complexity and performance of different configurations in which data can be stored Identification of optimal data structure for a real problem.

						polymorphism, exceptions and intro. to generics 9) Java Class Library with focus on file system handling, GUI, network progr. and multi-threading. 10) Java Cryptography Architecture / Java Cryptography Extension.		

Computer engineering								
UNI-KLU_BSc	UL_BSc	FERIT_BSc	UB_BSc	UBL_BSc	UNI_BSc	UNS_BSc	UNSA_BSc	UNTZ_BSc
Introduction to computer science Introduction to computer science 2 introduction to Structured and Object-Oriented Programming I & II Operating Systems Computer networks C++ Programming Image processing Fundamentals of simulation techniques	number systems Boolean algebra combinational logic circuits programmable logic circuits microcontroller bus memory central processing unit peripheral interfaces multitasking	Microprocessors systems Personal computer architecture Microprocessors Systems Busses and protocols Memory organization and management Development of a software solution in an assembler language	Examples of minimization of switching functions, analysis and synthesis of combinational and sequential circuits. Design of flip-flops. Circuit analysis combining with standard modules (multiplexer, demultiplexer, priority encoder, decoder, incrementer, decrementer, comparator, and an arithmetic logic unit, adder and substractor). Design of registers,	Number systems and data formats Basic logic circuits Analysis and design of switching networks Finite automata Design of microcontroller systems Microcontroller programming	Use computer architecture Implement Computer network	Logic Design of Computer Systems 2: 1) Basics of computer systems, design of central processors, simple assembler programs. 2) Single and multiprocessor structures, functional units. Central processor design in VHDL. 3) Memory design (RAM, DRAM, FLASH, associative memory, fast memory, cache memory). 4) Input-Output subsystem (communication with CPU, peripheral units, I/O management). 5) Transmission lines between functional units (standards, ISA, PCI, etc.). Multiple functional units. 6) VHDL (microcontroller, ALU), Assembler and Macroassembler, machine-program connection.	Embedded systems design ARM processor architecture Memory system	Introduction to Computer Science (compulsory course) Different numeral systems and codes; Boolean logic in the creation and minimization of switching functions. Synthesis of the switching network (combinational and sequential). Rounding up of the basic calculation operations using IEEE arithmetic standards. Architecture basics of the microcomputer and microprocessor i8086; basics of lower-level programming languages.

			counters and memory. Computer structure. Architecture. Programming model. Data types. Instruction formats. Addressing modes. Instruction set. Devices and device controllers. Programming. Virtual memory. Cache memory.			Dedicated Computer Structure Design for Signal Processing (elective course 1/4): 7) Standards and technologies required for designing dedicated computer structures. 8) Design of multiprocessor computer structures using VHDL. Intercomputer comm. and networks. 9) Design in the field of ISDN, ATM, SDH. Design based on digital signal processors.		Microprocessor Systems in Telecommunications (compulsory course) Analysis, design and implementation of embedded telecommunication system using microcontrollers. Basic knowledge of MCU architecture, toolchain setup and programming using C/C++ languages

Information and data management								
UNI-KLU_BSc	UL_BSc	FERIT_BSc	UB_BSc	UBL_BSc	UNI_BSc	UNS_BSc	UNSA_BSc	UNTZ_BSc
	information systems structure of data, information and knowledge data storage maintaining data managing data queries data protection tools	Data bases Relational algebra Conceptual, logical and physical data modelling SQL language use Data normalisation and data management	Fundamentals and Principles of DBMS. Data Abstraction. Instances and Schemes. Data Independence. Data Models. DDL, DML. Entity-Relationship Model. Relational Data Model. Relational Algebra & Calculus, SQL. Optimization of Relational Queries. Object-Oriented Database Systems. Object-Relational Database Systems. Transaction processing. Validation techniques. Crash		Use methods and software tools for development of software and services for mobile computing/communication devices Use Databases	Pattern Recognition (elective course 1/4): 1) Understanding of the fundamental notions and methods used in pattern recognition. 2) Understanding and implementation of supervised and unsupervised learning algorithms. 3) Ability to recognize the type of problem and train an appropriate learning algorithm. 4) Understanding and implementation of dimensionality reduction algorithms. 5) Clustering, neural networks, support vector	Databases fundamentals	Tools for Technical Documentation (compulsory course) Principles of content and form separation. Concept of markup languages. The basics of HTML. Latex document preparation process. Databases (compulsory course) Basic theory of databases. Relational algebra and SQL query language. Ability to design database models of medium complexity and construction of SQL queries of medium complexity.

			recovery. Commercial Systems.			machines, hidden Markov models. Joint learning. Algorithms and Complexity (elective course 1/4): 6) Basic concepts of algorithm theory and the notion of complexity. 7) Understanding the algorithm concept, classification of problems and algorithms. 8) Methods to prove that an algorithm solves the analyzed problem and complexity assessment.		Basic database protection.

Signal processing								
UNI-KLU_BSc	UL_BSc	FERIT_BSc	UB_BSc	UBL_BSc	UNI_BSc	UNS_BSc	UNSA_BSc	UNTZ_BSc

Digital Signal Processing	human vision digital images and videos visualization and manipulation compression processing, restoration and analysis time-discrete signals sampling discrete-time systems frequency analysis digital filter design	Mathematical models of time-continuous and time-discrete signals and systems Analysis of linear systems Fourier transforms of time-continuous and time-discrete signals Frequency characteristics and filtering principles Laplace and Z-transform Stability, controllability and observability of systems Signal sampling and regeneration	Signal analysis and processing in time domain. Signal analysis and processing in spectrum domain. LTI digital systems analysis. Digital filter design and analysis. Software implementation of the DSP systems. Introduction to multirate systems. Implementation of multirate systems, decimators and interpolators. Design of digital filter banks. Wavelet analysis.	Spectral analysis Analysis of linear time-invariant systems Laplace transform Discrete signals and systems Z-transform A/D and D/A conversion Discrete Fourier transform Time-frequency signal analysis Multirate and multiresolution signal processing Implementation of algorithms on digital signal processors Design and synthesis of	Use Laplace and Z-transform Apply filters in signal processing Apply software tools in signal processing in telecommunications Use Fourier transform of continuous signal and Discrete Fourier transform Apply Digital signal processing in frequency domain Apply digital modulation schemes Apply signal sampling and regeneration	Digital Signal Processing and Digital Filters: 1) Basic algorithms of signal processing and transforms of discrete signals. 2) (In)finite Impulse response, convolution, frequency response, sampling and aliasing. 3) Basic scientific methods for digital filter design, with adequate sw tools (Matlab DSP Toolbox). 4) Ability to analyze given problem, choose the adequate class of digital filter and design method. 5) Ability to design and implement optimal digital filters, multirate and adaptive systems.	Discrete time signals and systems Continuous time signals and systems Spectral analysis FT, DTFT, DFT, Z-transforms FIR/IIR filter design Filter structures and implementations Adaptive filters Multirate signal processing Statistical signal processing	Signals and Systems (compulsory course) Basic principles of signal processing. Classification of signals and systems. Analysis of LTI systems. LTI system response calculation. Laplace transform, Fourier series and Fourier transform; application in system analysis. Sampling theory and signal reconstruction. Digital Signal Processing (compulsory course) Discrete-time systems and z-transform. Discrete Fourier Transform; Fast Fourier Transform. Digital filter design; FIR; IIR. FPGA platforms for signal processing.

			Adaptive filters, algorithms. Equalization. Speech signal processing.	analog and digital filters Digital image processing		Digital Audio Signal Processing (elective 1/3): 6) Time-frequency analysis, enhancement, coding and transmission of audio and speech signals. 7) Audio signal processing and standards (Dolby, AAC, MPEG; RDS; GSM, VoIP, DAB). Biomedical signal processing (elective course 1/4): 8) 1D signals: ECG, SBP, DBP, HR, EEG, EMG, ultra-sound, statistical analysis, artifact recognition. 9) 2D signals: ART, SIRT, SART, Radon transform, image reconstruction, X-ray tomography, MRI.		

Multimedia								
UNI-KLU_BSc	UL_BSc	FERIT_BSc	UB_BSc	UBL_BSc	UNI_BSc	UNS_BSc	UNSA_BSc	UNTZ_BSc
	Internet and Web client-server communication web server administration server side technologies client side technologies mobile web analogue and digital forms of multimedia elements compression and media formats multimedia systems multimedia services interface and interactivity		Image processing. Video and audio digitalization and compression. Audio systems. Human perception of sound. Characteristics of audio systems. Audio signals: types, dynamic characteristics, measurements. Input acoustic environment and microphone concept. Spatial information and stereo.	Properties and perception of multimedia signals Formats and standards for storing multimedia data Algorithms for multimedia data compression Basics of multimedia signal processing Principles of multimedia information retrieval Basics of machine learning Analysis and classification of	Know architecture and parameters of digital TV transmission Know digital TV signal receiver architecture Know basic principles of TV studio production Know quality of service and measurement of TV signal parameters Use audio and video equipment and appropriate software Design of audio and video systems Apply coding and	Digital Image Processing: 1) Understanding of the basic principles and algorithms used in digital image processing. 2) Implementation of the algorithms for image enhancement, restauration and compression. 3) Ability to design and implement image processing systems. Audio and Video Technologies: 4) Sound waves generation and propagation, and psychophysiologic	Image processing. Video and audio digitalization and compression.	Multimedia Systems and Communications (compulsory course) Audio and video encoding schemes, multimedia production, integration and applications, and multimedia communications and protocols. Use applications for production and analyses of various media types. Ability to examine and compare various multimedia communication architectures and protocols.

			Audio devices: types and functions, connecting and power supply. Sound reproduction, sound reinforcement. Acoustic design of input and output acoustic environment. TV facility, studio and production equipment. Motion capture. Audio signal processing.	multimedia contents Multimedia communications Digital television Protocols for multimedia Multimedia applications	compression of audio, speech and video signals Know audio and video signal quality measures Understand audio-video synchronization Analyze of production, transmission and processing of audio and video signals in communication systems	al sound perception. 5) Audio recording, processing and reproduction, ability to evaluate the acoustic environment. 6) Ability to analyze complex acoustic-mechanical systems by equivalent electrical circuits. 7) Concept of digitizing, compression and transmission of audio and video signals. 8) Principles of operation and connections of video mixers, cameras, monitors and projectors. Television and Image Processing		

						Software 1 (elective 1/4): 9) Modulation methods in digital television. 10) Basic design techniques, testing architecture and TV signal receivers.		

Other engineering courses								
UNI-KLU_BSc	UL_BSc	FERIT_BSc	UB_BSc	UBL_BSc	UNI_BSc	UNS_BSc	UNSA_BSc	UNTZ_BSc
	introduction to robotics optoelectronics fundamentals of mechatronics low-voltage electrical installations programmable control systems	Technical Drawing AutoCAD graphical design tools IEC regulations Project documentation Technical System Designing Project types Standards applied in electrical engineering systems Regulatory rules about realization of electrical engineering projects.	DC motor modeling. Position and speed servomechanisms. System characterization in transition and steady state. State space models. State controllability and observability. State and output feedback. Observer design. Stability of continuous and discrete systems. Analysis and compensation of systems using Bode plots. Tuning PID, Dahlin and dead-beat controllers.		Model automatic control systems Implement automatic control systems in industry	Monitoring and Noise Protection (elective 1/4): 1) Noise and its impact on people (dB(A) and the normative line of acceptable noise - N-curves). 2) The regulations on permissible noise level in the working and living environments. 3) Measurement devices and techniques (sound level meters, filters, dosimeters, software tools). 4) Monitoring of noise, noise control, sound insulation, methods of protection from noise.	Control theory	Design of Telecommunication Networks (compulsory course) Design, implementation, analysis, and evaluation of large-scale networked systems. Project management and project documentation. Testing, optimizing and documenting network.

Communication and presentation skills, foreign languages								
UNI-KLU_BSc	UL_BSc	FERIT_BSc	UB_BSc	UBL_BSc	UNI_BSc	UNS_BSc	UNSA_BSc	UNTZ_BSc
Introduction to Engineering: writing and presenting		English Language Communication skills	Science and scientific laws. Development of thought about society. Social groups. Family. Class. The state. Political parties. Social norms and regulations. Environmental issues and environmental crisis. At least two courses in foreign languages, English, French, Russian or German.	Fundamentals of human communication Basic communication skills and techniques Oral and written communication in English	Use English Language for electro technology Use communication ability in business relations Apply norms of strategies for the protection of environment and sustainable development	Sociology of Technics: 1) Ability to understand social functions and creators of technical knowledge. 2) Understand impact of the nature of social systems on technical development and vice versa. 3) Impact of technology on globalization process, nature destruction and creation of risky society. 4) Impact of mass media on people's lives, education, culture and democracy. English Language (Elementary, Pre-Int., Int., Upper Intermediate) and English in Engineering 1: 5) Students are able to use spoken and written English knowledge and skills in different levels.		

						Academic Written and Spoken Communication in the Serbian Language: 6) Recognition of functional style register in Serbian and perception of its context conditioning. 7) Ability of involvement in a scientific functional style discourse.		

Business economics, management and organization								
UNI-KLU_BSc	UL_BSc	FERIT_BSc	UB_BSc	UBL_BSc	UNI_BSc	UNS_BSc	UNSA_BSc	UNTZ_BSc
	project objective and phases time management resource management decision management EU environment for innovation development processes and organizations product planning product specification industrial design prototyping entrepreneurship	Basics of business economics Cost and investment calculation Economic performance measurement metrics Entrepreneurship and entrepreneur	Basic theory of management. Work and personality of the manager. Social, business and corporate responsibility. Motives and motivation. Leadership and conflict. Organizational structures and management types.	Analysis of business idea Creation of business plan Protection of intellectual property Project management Using project management software		Entrepreneurship in ICT: 1) Ability to make a successful business plan. 2) Ability to successfully establish and manage a personally owned business.		

COMPETENCES OVERVIEW:								
2nd Cycle Study Programme (MSc)								
UNI-KLU_MSc	UL_MSc	FERIT_MSc	UB_MSc	UBL_MSc	UNI_MSc	UNS_MSc	UNSA_MSc	UNTZ_MSc
Mathematics								
	Basic concepts of probability Random variables Numerical characteristics Statistic design Numerical methods for solving systems of linear algebraic equations and nonlinear algebraic equations The optimization procedures Formulation of partial differential equations The basics of cellular automata and Monte Carlo methods	Only on Module Communication Technologies: Calculation of errors in numerical problems Numerical methods for solving linear and nonlinear equations Approximation of functions. The least squares problem. Numerical integration Solving ordinary differential equations	Random variables - application in Telecommunications. Distributions and transformations of random variables. Moments. Characteristic function. Random processes, ansamble. Stationarity, ergodicity, correlation function. Wiener-Khinchine theorem.		Apply iterative methods for solving nonlinear equations Know Newton-Kantorovic's method Apply approximation and interpolation functions Ability to numerically differentiate and integrate Approximate solution of differential equations Know wavelet transformation and time-frequency analysis		Random variables, distribution and Random processes Queuing theory	

Physics								
UNI-KLU_MSc	UL_MSc	FERIT_MSc	UB_MSc	UBL_MSc	UNI_MSc	UNS_MSc	UNSA_MSc	UNTZ_MSc
	light and Maxwell Photonic components Photonic integrated circuits Fiber sensors Nanophotonic structures in photovoltaics principles of quantum mechanics statistical thermodynamics Energy bands in crystals, semiconductors, dielectric properties of solids, liquids and gases Magnetic properties of materials. Superconductivity				Know wave propagation in optical fibers Know optical solitons			

Fundamentals of electrical engineering								
UNI-KLU_MSc	UL_MSc	FERIT_MSc	UB_MSc	UBL_MSc	UNI_MSc	UNS_MSc	UNSA_MSc	UNTZ_MSc
Control of Autonomous Systems Smart Grids Robust Design and Reliability Digital Signal Processors Modeling and Simulation of Energy Systems Traffic Telematics	Classification of materials in electrical engineering Fundamentals of crystallography Selected crystal structures of metals. Synthesis and properties of alloys Thermoelectric effects of metal junctions, electrical contacts electrochemistry, batteries and fuel cells Magnetic anisotropy, technology of soft and permanent magnet materials and their applications							

Measurement and instrumentation								
UNI-KLU_MSc	UL_MSc	FERIT_MSc	UB_MSc	UBL_MSc	UNI_MSc	UNS_MSc	UNSA_MSc	UNTZ_MSc
Measurement Signal Processing					Understand and design analog and digital telemetry systems Test telemetry systems Know telemetry standards		Symmetric and asymmetric key algorithms Data Encryption Standard, International Data Encryption Algorithm, Advanced Encryption Standard, RSA	

Information theory								
UNI-KLU_MSc	UL_MSc	FERIT_MSc	UB_MSc	UBL_MSc	UNI_MSc	UNS_MSc	UNSA_MSc	UNTZ_MSc
Information Theory	Intelligent systems in data-mining, classification and fault detection methods of local nonlinear optimization used in intelligent systems and global nonlinear optimization methods for model identification Unsupervised learning methods. Principle component analysis. PCA in identification, data filtering, control and fault detection. Data clustering. Methods of clustering: fuzzy c-means, Gustafon-Kessel fuzzy c-means, possibilistic c-means clustering, method of regression clustering. Predictive control based on nonlinear		Communiction system model. Random variables - distributions transformation, moments, characteristic function. Discrete and continual random processes - Stationarity, ergodicity, correlation. Wiener-Khinchine theorem. Introduction to filtering, correlation and detection theory. Detection of signal in noise. Introduction to modern telecommunication technologies and system design. Selected topics in contemporary communications. Global communication systems structure. Trends in future developments of		Understand stochastic processes Know detection theory - hypothesis testing Understand estimation theory Know discrete stochastic processes Analyse and design of optimum receiver	Information and Communication Theory 1) Channel codes on graphs and iterative decoding techniques (Turbo codes, LDPC codes). 2) Models of wireless channels (AWGN, Rayleigh / Rice fading) and OFDM. 3) Modulation codes (trellis coded modulation, multilevel codes). 4) Advanced topics in modern coding theory (fountain coding, network coding). 5) Calculation of channel capacity. 6) Methods of simulation of	Data compression Lossless data compression Lossy data compression Source coding	

	model and optimization. Adaptive control and online adaptation		modern communications.			communication systems. 7) Rate-distortion theory, and practical procedures for lossy coding of sources with / without memory.		

Electronics engineering								
UNI-KLU_MSc	UL_MSc	FERIT_MSc	UB_MSc	UBL_MSc	UNI_MSc	UNS_MSc	UNSA_MSc	UNTZ_MSc
Robotics Sensors and Actuators CAE of Mechatronics Systems	Integration of electrical and mechanical components/systems, computer aided design, prototyping Mechanism design Simulations of mechanisms Prototyping of mechanical systems, Prototyping of electrical systems Design of electric circuits: Analog components of electronic communications circuits and manufacturing technologies Digital components of electronic communications systems Consumer electronics and embedded systems	Only on Module Communications Technologies: Oscillators High frequency power amplifiers Modulator and demodulator structure (ASK, PSK, FSK) Characteristics of radio receivers Digital radio receivers Design principles of complex microelectronic analogue and digital circuits Application of microcontroller systems Biomedical electronics		Architecture, application areas and types of specialized microcomputer systems Systems on the chip (SoC) PLD and ASIC structures Organization of I / O transfer and interface. Methods of design and development Specialized multi-microprocessor systems Standard integrated circuits for specific purposes VHDL - language for the description of physical architecture Standard Integrated Circuits Specific Purposes - SASIC (SPLD, CPLD and FPGA)	Know semiconductor lasers and their applications in telecommunications Understand Quantum optoelectronics Know sources and transmissions of light Understand complex optical and electro-structures of telecommunication systems Design and analysis of linear power supplies Know power supply systems Understand Uninterruptible power supplies (UPS) Know Batteries and accumulators			Electronic System Design (compulsory course) The integration of sensors, actuators and communication modules with microcontrollers using analogue signal processing Design of electronic systems using software tools for simulation of electronic circuits. Design printed circuit boards that includes signal integrity and impedance matching Understanding the technology of programmable FPGA circuits. Programming and development of electronic sustems with FPGAs.

Radio communications								
UNI-KLU_MSc	UL_MSc	FERIT_MSc	UB_MSc	UBL_MSc	UNI_MSc	UNS_MSc	UNSA_MSc	UNTZ_MSc
Mobile Communications Advanced Wireless Communications	Half-wave dipole, implementation of a directional antenna Parabolic mirror, computation of its focal point, selection of the section, mirror illumination, illumination efficiency, multiple-reflector antennas Thermal noise, antenna noise temperature, natural noise sources Fresnel zones, propagation of radio waves in the presence of natural obstacles Propagation of electromagnetic waves in the Earth's atmosphere Fundamentals of celestial mechanics Properties of radio links Earth-satellite, satellite-satellite and satellite-Earth, Doppler shift in	Theory and application of Maxwell's equations Plane wave characteristics, reflection and dispersion, dispersion modes, energy density, polarization Analyses of linear dipole antenna radiation Radio signal propagation in mobile communication systems Cellular system features Antenna base station components Concepts and architecture of	Wireless networks Sensor networks Microwave radio links Cognitive radio Radio positioning Radio technologies Satellite systems Public mobile systems Radio positioning	Spread spectrum transmission techniques; DS-SS and FH-SS Code synchronization CDMA system capacity OFDMA and MIMO technologies Estimation of radio channel parameters RAKE receiver Radio communication networks Radar systems Radio-location and navigation szstems	Know Finite difference time domain and the corresponding division of space Know numerical stability and dispersion of the finite difference time domain Apply near-far transformation in time and frequency domain Solve numerical problems on the border of two domains Solve EMC problems by using electromagnetic simulations on computer and perform EMC measurements Know techniques of signal transmission using MIMO systems	Mobile Communications 1) Advanced techniques of signal transmission and processing in a mobile radio environment. 2) Selective fading and multiple propagation. 3) LTV radio-channel model. 4) The concept of RAKE receivers. 5) Combining of diversity signals. Smart antennas and MIMO systems. 6) Estimation & equalization of radio-channels. 7) Space-time coding.	Wireless networks Sensor networks, WiFi, Bluetooth, WiMax Smart antennas and MIMO systems Radio channel estimation and equalization Radio network architectures Estimation of signal-interference ratio and power management in the channel Computation of channel capacity Technique of transmitter	

	satellite communications Design of satellite telecommunications equipment for point-to-point links, broadcasting, mobile telephony, satellite telecommand and telemetry mobile networks 2G, 3G, 4G Critical communications infrastructure Wireless local area networks WiFi Short range wireless sensor networks Internet of things applications and services	2G, 3G and 4G networks Only on Module Communication technologies: Radio-reley systems (equipment, link design, propagation characteristics) Mobile satellite systems Radio diffusion and communication satellites			Develop realistic wireless sensor network applications under operating system such as TinyOS. Implement various network architectures for the wireless Internet access Know basic principles of radar systems and radiolocation Apply adaptive antenna in practice	8) Elements of the software radio. Multiuser Detection (elective course 2/9): 9) Limitations of MIMO comm. systems; capacity of channel models; simultaneous usage of resources. 10) CDMA; multiuser detection: optimal, linear without correlation, decision based, correlational.	diversity: open loop and closed loop	

Communication systems								
UNI-KLU_MSc	UL_MSc	FERIT_MSc	UB_MSc	UBL_MSc	UNI_MSc	UNS_MSc	UNSA_MSc	UNTZ_MSc
	Design, planning, modelling, control and management of telecommunication systems. Traffic theory and queuing theory. Design and planning of packet switched networks. Network traffic characterization and measurements, performance evaluation and conformance testing. Network simulation and emulation: tools and approaches. Quality of Service concepts QoS mechanisms and protocols in contemporary networks. User perceived quality. Quality of	**Module Communication Technologies:** Light propagation in fibres and power loss Subsystems of optoelectronic communication systems Modulation and multiplexing of optical signals Architecture of optoelectronic networks			Work in a modern software packages for design, analysis and optimization of microwave circuits Know the procedures for design of RF and microwave passive and active circuits Perform calculations related to multiple access techniques, modulation formats and error correction codes in satellite systems Know signalling protocols for packet-based multimedia communication systems Solve practical problems in the area of signal synchronization Design and analyse appropriate circuits which are required for reference carrier extraction and detection of phase modulated signals	Coding Techniques: 1) Ability to use up-to-date error protection coding methods in applications. 2) Trellis codes (binary & non-binary signals, signal constelations, grids, set partition, turbo codes). 3) Trellis codes, Ungerback code (Trellis Code Modu-lation), practical realization of modern modems. 4) Block codes: minimal polynomials,		

	Experience evaluation and measurements. Availability and accessibility of system, redundancy. Management and control of telecommunication networks and systems. Management models, protocols and information models. Accounting and Billing.				Simulate and designe MIMO and MU-MIMO systems Create communication chain based on USRP platform Know Cable distribution system architecture	polynomial mani-pulation, linear error protection, CRC. 5) Block codes (linear error protection, BCH & RS codes and their decoding, LDPC codes).		

Software engineering								
UNI-KLU_MSc	UL_MSc	FERIT_MSc	UB_MSc	UBL_MSc	UNI_MSc	UNS_MSc	UNSA_MSc	UNTZ_MSc
Mobile Applications with Android	Operating systems Processes, threads, scheduling Input-output devices and drivers Data storage, files, file systems Inter-process communication and synchronization Memory and memory management Databases and transactions Software development approaches in telecommunications object-oriented programming software design and development in the field of	Advanced programming in C Technologies for developing mobile applications Developing a complex mobile application and programming a user interface Principles of object-oriented programming Programming in C# and Phyton Advanced Web programming HTML JavaScript functionalities CGI, PHP, SQL	XHTML and CSS programming languages. JavaScript functionalities. MySQL database by the PHP code. Telecommunication Systems Modeling and Simulation		Understand business strategies, models and processes Understand and use XML Web technologies Use servers, platforms and middleware in e-business systems Use Web services and service-oriented architectures in e-business Know e-business protocols and standards Develop web-based e-business application using J2EE platform Apply Web service for e-	Telecommunication System Software (elect. 2/9): 1) Ability to design telecommunication system software and put it in use. 2) Languages of telecommunication system specification: MSC, SDL. 3) UML language - examples of specification of telecommunication software. 4) Specification of software according to ISO OSI model. 5) HDLC communication operator. 6) Digital swithcboard software: user signalling, regional processors, call management.	Telecommunication Systems Modeling and Simulations. Network simmulations Advanced programming topic in telecommunication systems and services Object oriented programming Uniform Modeling Language Specification and Description Language	Telecommunication System Programming (compulsory course) The analysis, design and implementation of embedded telecommunication system using RF System on Chip The knowledge of RF SoC architecture, toolchain setup and programming using C/C++ languages

	telecommunications documentation, modular application design through, testing, using version tracking mechanisms				business system integration	7) The mobile network software and the intelligent network software. 8) The software for network virtualization technology (VLAN, VXLAN, multilayer VPN).	HTML, XML, C++, PHP, SIP CGI, CPL	

Computer engineering								
UNI-KLU_MSc	UL_MSc	FERIT_MSc	UB_MSc	UBL_MSc	UNI_MSc	UNS_MSc	UNSA_MSc	UNTZ_MSc
Multimedia Systems Vision and INS Based Navigation Pattern Recognition in Intelligent Cehicles Machine Vision in Intelligent Transportation Systems System Science and Neurocomputing Fundamentals of Image Processing Artificial Intelligence Systems Security Pervasive Computing	Man-machine communication Human perception and information processing Properties of terminal equipment Operation of terminal equipment The design of human-machine interaction Design, development and evaluation of user interfaces Specific user interfaces and interaction styles	Elective courses: Architecture of DTV receiver hardware and software Development of digital TV software Green computing Computer network design				Distributed Computer System Application (el. 2/9): 1) Ability to apply the concepts of distributed computer applications. 2) The features of distributed computer systems. 3) Operating systems in distributed computer systems and their maintenance. 4) The architecture of distributed computer applications and tools for their development.		

						5) Examples of distributed computer system applications.		

Information and data management								
UNI-KLU_MSc	UL_MSc	FERIT_MSc	UB_MSc	UBL_MSc	UNI_MSc	UNS_MSc	UNSA_MSc	UNTZ_MSc
	Artificial intelligent systems: artificial perception, artificial intelligence, soft computing, machine learning, Intelligent problem solving Expert systems, Knowledge representation Basics statistic methods, Algorithm and numerical analysis Graph theory, The finite fields Introduction to operational research and optimization Network analysis, Nonlinear optimization, Decision theory Aspects of security Protection of communication and information systems Symmetric key encryption Key management Evolution of the information and communication technologies Cybersecurity on the application and user levels Regulatory aspects, data protection and SLA.	Optimal coding Losless source coding Error control coding	Intelligent objects, definition and applications. M2M communications and applications. Integration of M2M intelligent objects with mobile communication systems. M2M platforms analysis. Operating systems. Overview of communication protocols for interaction and cooperation with intelligent objects.			Cryptography System for Data Protection (el. 2/9): 1) Symmetric cryptography: stream ciphers, block ciphers, hash functions. 2) Public key cryptography. RSA, elliptic curve cryptography, digital signatures. 3) Blockchain and other distributed ledger technologies.	Symmetric and asymmetric key algorithms Data Encryption Standard, International Data Encryption Algorithm, Advanced Encryption Standard, RSA Crypography and security	

Signal processing								
UNI-KLU_MSc	UL_MSc	FERIT_MSc	UB_MSc	UBL_MSc	UNI_MSc	UNS_MSc	UNSA_MSc	UNTZ_MSc
Signal Processing for Communications Power Line Communications State Estimation of Robotics Systems	Sound waves Psychoacoustics Localization of sound Spatial acoustics Electroacoustics and transduction Acoustics in human-machine interaction Capturing, sampling and reconstruction of images Colours and colour spaces Image transformation Edge detection and segmentation. Image recognition. Imaging object classification.	Digital signal processing	Adaptive filters, algorithms. Equalization. Image processing. Introduction to theory of antenna arrays. Mathematical models of wideband and narow band signals on antenna array. Algorithms for narrow band and widband spatial beamforming. Algorithms for direction of arrival estimation. Adaptive antenna arrays. Principles of space-time communications.	Electroacoustic design Audio coding Noise measurement and protection Automatic speech recognition Modern digital image processing and analysis techniques Acquisition and analysis of biomedical signals Pattern recognition techniques and machine learning Spectral density estimation, signal modeling Optimal and adaptive filtering	Programme the DSP processors in assembly language and higher programming language Audio and video signal processing using DSP processors Apply spatial operations in image processing Implement video compression using motion compensation Apply space-time codes Generate basic signals using FPGA-based platforms	Medical Image Processing (elective course 2/9): 1) Ability to understand basic principles and up-to-date methods of medical digital image processing. 2) X-ray systems. Computed tomography. Magnetic resonance. 3) Ultrasound image. Medical image segmentation and registration. Geometrical image transformation. Nonlinear Biomedical Signal Processing (elect. 2/9): 4) 1D sequence analysis: combined simbol, fractal, correlation dimension, entropic analysis. 5) Surrogate data. Transformation methods. Deterministic chaos analysis methods.	Frequency response, amplitude and phase characteristics, group delay. FIR/IIR filter design Filter structures and implementations Adaptive filters and applications Multirate signal processing Statistical signal processing Image processing	

	Quality evaluation of images and video. Image perception. Quality of imaging and video communication services.					6) Signal decomposition and repeated analysis. Detection and Estimation (elective course 2/9): 7) Understanding the methods of signal detection and estimation in a noisy environment. 8) Signal paremeter estimation & hypothesis testing in Gauss noise on a single/multi-chan. observation. 9) PLL as an estimator of the phase and frequency. Parameter estimation with a finite num. of states.		

Other engineering courses								
UNI-KLU_MSc	UL_MSc	FERIT_MSc	UB_MSc	UBL_MSc	UNI_MSc	UNS_MSc	UNSA_MSc	UNTZ_MSc
	Modelling and simulation of mechatronic systems Mechatronics in transport systems (industrial, road, tracks) design of new products, innovation process, product development cycle, technology market development phases Basics of reliability theory of electronic systems, probability distribution functions, environmental influences Standardization system. Safety and electromagnetic compatibility (EMC) regulations. Visual effects of light, Non-visual effects of light, Basic physics of light	Only on Module Network Technologies: Interent of Things technologies and arhitectures Collecting, storing, processing and visualising the data in accordance with the Internet of Things paradigm	Basics of remote sensing and its importance. Basics of solar radiation and infrared radiation of objects on Earth. Optical sensors and detectors. Remote sensing platforms. Geometric and radiometric characteristics and image formats. Basic principles of simulation and application of software tools in analysis of remote sensing systems. Practical estimation of remote sensing data. Modern remote sensing systems - hardware and software solutions for remote sensing systems.		Apply basic theoretical, scientific, and technical knowledge on practical problems Participate in writing research papers in the specific scientific field Carry out certain experiments in the laboratory Conduct research in order to find solutions for the assigned task			

	Light and colour, Photometry, Light sources, Luminaires Lighting with artificial light, Daylight, Lighting design, Quality of road lighting Total quality management System reliability and maintenance human-robot interaction Haptic robots human movements and their effects on the body. sensory systems for measuring the motion and loading parameters in human usable in clinical or sport environments		Primary and secondary optics, detectors, cooler and electronics. Detectors in infrared spectral range, space and thermal resolution.					

Multimedia								
UNI-KLU_MSc	UL_MSc	FERIT_MSc	UB_MSc	UBL_MSc	UNI_MSc	UNS_MSc	UNSA_MSc	UNTZ_MSc
		Compression methods Image coding standards Video coding standards Algorithms and standards for speech compression Audio encoding Multimedia transmission over broadband networks Multimedia in mobile communications Communication protocols for multimedia Digital television systems Application of video coding standard in digital television		Modern approaches for multimedia signal processing Multimedia signal analysis Feature extraction Multimedia information retrieval and management Multimedia classification Modern techniques in multimedia communications Wireless multimedia communications	Understan the technical details and functioning of receiving equipment in TV system Analyse production, processing and transmission of multimedia content in communication systems Know audio effects and their application In-depth knowledge of three-dimensional sound Know digital TV systems and standards Know architecture of	Computer Vision (Digital Image Processing 2) (elective course 2/9): 1) Types of tasks in computer vision and algorithm performance evaluation. 2) Sensors and image: radiation and illumination, optics, radiometry, sensors, geometric callibration. 3) Probability models in computer vision, fuzzy signal processing, neural networks in signal proc. 4) Projects: object recognition using intelligent cameras, topological maps of microstructures. 5) Projects: fast 3D object mapping, 3D plane recon. from the	Multimedia sources. Authoring description, organization, user settings). Requirements for adaptation and trans-coding of the source multimedia information and formats. User interface. Modeling of the multimedia interaction. interactive services. Preparation of the media for multimedia interactive services: MPEG-4; MPEG-7, MPEG-21. Methods of media delivery: unicast, broadcast and multicast. Standards for multimedia communication-	Multimedia Communication Systems and Services (compulsory course) Identify, categorize and compare various multimedia transmission methods Identify, categorize and compare various multimedia systems Explore and compare various multimedia communication standards and protocols Allocate, analyze and

					satellite, cable and terrestrial TV system Know IPTV	image sequence, movement mapping. Speech Technologies (elective course 2/9): 6) Modeling of speech producation and perception. Speech signal features, analysis and visualization. 7) Speech modeling: acoustic, lexical and linguistic. Approaches to ASR (DTW, HMM, DNN). 8) ASR algorithms: training (GMM, B-W, ML) and decoding (Viterbi, Token passing, N-best, VTN). 9) Text-to-speech synthesis (TTS): language proces-sing, synthesis (concatenative and parametric). 10) Recognition of speakers & emotions in speech. Natural language processing,	MHEG/MHP, DAVIC, EPG. Podcasting of audio and video, broadcasting of TV programs, EPG, VOD. Generic system configuration of multimedia communications; Real-time and non real-time systems. Management and surveillance, traffic planning; IP multicast technology support. Examples of networks for multimedia communications: IPTV-3 play, DVB reference model of the interactive TV. Configuration of multimedia portals for interactive TV, mobile TV, IP datacasting, IP video-web conferences. Multimedia Peer-To-Peer communication. Telemedicine, Distance learning.	use multimedia services.

						dialogue systems, SLU.	Multimedia system security. Digital rights managements in network multimedia communication system.	

Communication and presentation skills, foreign languages								
UNI-KLU_MSc	UL_MSc	FERIT_MSc	UB_MSc	UBL_MSc	UNI_MSc	UNS_MSc	UNSA_MSc	UNTZ_MSc
Team and leadership skills English Language Courses Feminist Science / Gender Studies: Gender and Technology	Public speaking, time constraints and the audience. Collection and selection of data and information, determination of the main message Selecting of evidence, preparation of presentation and handouts, speech preparation. Performance and critical evaluation of the presentation, poster as a form of communication, Structure of an article and basic rules of writing articles, illustrations in scientific and technical literature. Rules and guidelines for writing a diploma and preparing a defense.	Team work Collaboration in designing Presentation of project plan and project results German lenguage (elective)	English, French, Russian or German.				Literature review technical writing Time menagement and planning Presentation skills	

Business economics, management and organization								
UNI-KLU_MSc	UL_MSc	FERIT_MSc	UB_MSc	UBL_MSc	UNI_MSc	UNS_MSc	UNSA_MSc	UNTZ_MSc
Value Based Management Operational Management and Logistics Energy Economics: Theory and Policy Entrepeneurship & Innovation Management Operational Management & Supply Chain Management Energy and Environmental Economics	Directives and legislation Standardization Accreditation Metrology Conformity assessment Assessment and quality management system certification European technical legislation in different fields	Enterprise management Decision making Strategic project management Selection and recruitment of personnel Business intelligence Techniques and tools for project management. Techniques of project planning. Development of project documentation	Ten principles of economy. Basic of economy category. Manufacturing and reproducing. Capital market, work market, company business. Economy politic, globalization, transitioning. Introduction to Business Planning. Operational plan. Marketing Plan. The financial plan. How to reach innovation? Creating a business plan. Management of business risks. Establishment of innovative enterprises. Introduction to the use of intellectual property. The use of patents by the "spin-off" companies. Placing intellectual property on the market.		Work within the project team during the planning of the project Organize the project team Organize interaction with users Organize schedules and budgets Ability of risk management		Operator business. Net values and incomes. Network and service business. Determining the prices and charging for services. Investments and operations. Cash flow models.	

7.3 Industry survey

Survey for employers

BENEFIT Boosting the telecommunications engineering profile to meet modern society and industry needs

BENEFIT is an ERASMUS+ KA2 project that focuses on three main pillars:

1) the cooperation between Higher Education Institutions (HEIs) and industry to modernize the study program in telecommunication engineering in the Western Balkans region;
2) the adoption of modern teaching methodologies and tools, the upgrade of the infrastructure, and the creation of several joint university-industry labs;
3) the training of both teachers and students.

This survey has been prepared to collect information on job market/needs and to map skills and knowledge areas required from ICT engineers and specialists in the ICT sector so that study programs in telecommunications engineering can be modernized.

More information on the project can be found at: https://www.project-benefit.eu

Privacy and data consent

Information presented in this questionnaire is strictly confidential. Please check the boxes below, you do not have to tick all of them, we will protect your personal information according to your choices below, then sign and date the form where shown.

Checking the boxes, I confirm:

☐ I have been informed about the objective of the project and my role and involvement in it. I understand that my participation is voluntary.

☐ I agree to take part in the above research study.

☐ I understand that relevant sections of any of the information I am providing, may be looked at by responsible individuals and under the supervision of the principal investigator of this study or for contributing to the understanding of the matter.

☐ I agree that my data gathered in this study may be shared by the partners of the Erasmus+ project 585716-EPP-1-2017-1-AT-EPPKA2-CBHE-JP and the European Commission.

☐ I agree that the name of the company can be mentioned in the acknowledgements of the project at the project website, in reports and in publications.

☐ I agree that I agree that my data gathered in this study may be stored (after they have been anonymized) in a specialist data centre and may be used for future research.

☐ I agree to the use of anonymized quotes in publications.

☐ I wish to be contacted again by the research team to be informed about the state of development of the project.

Region, municipality:

Business entity (Company):

Representative of the business entity: (name, surname)

Function:

Contact telephone/e-mail:

Signature: _____

Date:

A. General data

A.1. Full name of the business entity				
A.2. Register code of the business entity				
A.3. Registration date				
A.4. Juridical address				
A.5. City and country				
A.6. Telephone/fax/e-mail				
A.7. Organizational type	☐ Limited liability company	☐ Stock company	☐ Other _____	
A.8. Ownership	☐ Private	☐ Public	☐ Other _____	
A.9. Origin of capital	☐ Domestic	☐ Foreign	☐ Mixed	☐ Other _____
A.10. Type of core business activity	Market sector		Core business	
	☐ Energy		[software and services in ICT domain] _____	
	☐ Materials			
	☐ Industrials and manufacture			
	☐ Consumer			
	☐ Healthcare			
	☐ Financial			
	☐ Information technology			
	☐ Telecommunication services			
	☐ Utilities			
	☐ Real estate			
A.11. Business model	☐ Internal product/ service development	☐ Outsourcing	☐ Other _____	
A.12. Size by number of employees	☐ Micro (up to 9 employees)	☐ Small (10-49)	☐ Medium (50-249)	☐ Large (250 plus)

B. Self-assessment of the skills of those currently employed

B.1. Does your company have problems with ensuring adequate skills of employees? [Mark appropriate selection with X]

Yes	No

B.2. Has your company experienced difficulties in filling vacancies in the last 12 months? [Mark appropriate selection with X]

Yes	No

B.3. According to your experience what are the obstacles which cause difficulties in filling vacancies for each of the following occupational groups? [Mark appropriate selection with X. Multiple answers are allowed]

Difficulties in filling vacancies	ICT specialists, developers, researchers	Managers	Marketing and sales	Other (please specify) _____
Insufficient supply of qualified candidates who poses adequate skills				
Candidates do not have work experience				
Candidates do not possess positive attitudes towards learning, working hard and career development				
Candidates do not favour occasional/short-term jobs				
Wages are not high enough to attract qualified candidates				
Do not know				
There are no difficulties in filling vacancies for this type of profession				

B.4. What are your expectations regarding the changes in the number of employees in the next 12 months? [Please mark with X only ONE answer for each occupational group]

Occupations	Increase	Remain unchanged	Reduce	Do not know
ICT specialists				
Managers				
Marketing and sales				
Other				

B.5. Please list the professionals (up to 10) which your company currently lacks. [Please insert level of education from 1-5 in the first column and a number of professionals needed in the second column. Please write-in other occupations not specified in the list.]

List occupations [Job title]	Level of education (1 – any level of education 2 – VET secondary 3 – general secondary 4 – post secondary 5 - tertiary) [Please insert the code]	Number of professionals
ICT specialists		
Developers		
Researchers		
Marketing and sales		
Other [please write-in below]:		

* VET (vocational education and training)

B.6. Indicate the sources for the recruitment of professionals used by your company. [Mark appropriate selection with X or write-in. Multiple answers are allowed]

National employment job matching services	
Private employment agencies, etc.	
Announcement on the company's website	
Collaboration with secondary vocational schools and universities	
Recruiting employees from other companies	
Word of mouth	
Other sources [please specify] _____	

B.7. Which skills are the most important for your employees to fulfil their assignments but are currently insufficient? [Mark appropriate selection with X or write-in. Multiple answers are allowed]

Skills	ICT specialists, developers, researchers	Managers	Marketing and sales	Other
Professional (technical) skills, according to the job description				
Knowledge of foreign languages				
Possession of professional ethics				
Skills in organizing and managing a team				
Communication and team spirit				
Ability to work with clients				
Ability to identify and solve problems				
Passion for new knowledge, ambition to learn and excel				
Other specific technical skills				

_____				
There is no lack of skills				

B.8 Which professional skills are most important for your company in reference to the ICT specialists? [Mark appropriate selection with X or write-in. Multiple answers are allowed]

Skill\job title	Software specialist	Hardware specialist	System and security specialist	Quality, test and certification specialist	Operations and maintenance specialist	Project management
Hardware components						
Hardware integration						
Firmware						
Middleware						
Software and Applications						
Other specific technical skills _____						

B.9 Which professional skills does your company currently lack in reference to the ICT specialists? [Mark appropriate selection with X or write-in. Multiple answers are allowed]

Skill\job title	Software specialist	Hardware specialist	System and security specialist	Quality, test and certification specialist	Operations and maintenance specialist	Project management
Hardware components						
Hardware integration						
Firmware						
Middleware						
Software and Applications						
Other specific technical skills _____						

B.10 The table below reports a list of macro knowledge areas covered by study programs in telecommunications engineering. Please grade the importance of each of them for the ICT specialists in your company. [Mark appropriate selection with X. 1 – Not important, 2 – Slightly important, 3 – Moderately important, 4 – Important, 5 – Very important. Write-in additional information.]

Knowledge areas [see below for descriptions]	1 Not important	2 Slightly important	3 Moderately important	4 Important	5 Very important
Mathematics					
Physics					
Fundamentals of electrical engineering					
Measuring and instrumentation					
Electronics engineering					
Radio communications					
Information theory					
Communication networks					
Communication systems					
Signal processing					
Software engineering					
Computer engineering					
Information and data management					
Other engineering courses					
Multimedia					
Communication and presentation skills, foreign languages					
Business economics, management and organization					
Applications of telecommunications (e.g., in energy, health, robotics, automotive, etc): [please specify] _____					
Other knowledge areas: [please specify] _____					

Description of Knowledge Areas

1. **Mathematics**: number systems, matrices, linear algebra, analysis of continuous functions, differential equations, probability, statistics, etc.
2. **Physics:** mechanics, thermodynamics, atomics, optics fluid statics and dynamics, thermodynamics, nuclear physics, etc.
3. **Fundamentals of electrical engineering:** circuit analysis, semiconductors, frequency and time domain, Maxwell equations, transmission lines.
4. **Measuring and instrumentation**: metrology, measuring accuracy and uncertainty, instrumentation, standards, etc.
5. **Electronics engineering**: microelectronics, operational amplifiers, integrated circuits, combinational and sequential circuits, etc.
6. **Radio communications**: radio-communication concepts, propagation of EM waves, radio systems design, antennas and propagation, etc.
7. **Information theory:** source coding, channel coding, statistical theory in telecommunications.
8. **Communication networks**: communication network technologies, OSI layers, TCP/IP, protocols, network management, network security, etc.
9. **Communication systems**: analog and digital data transmission, communication theory, channel modelling, multiple access schemes, etc.
10. **Signal processing**: signal analysis, s-domain, z-domain, digital signal processing, audio processing, transforms, Fourier analysis, filters.
11. **Software engineering**: programming principles, programming languages, object-oriented programming, operating systems.
12. **Computer engineering**: computer system architecture, microprocessor, memory, input-outputs, embedded systems.
13. **Information and data management**: information and knowledge, data storage, maintaining data, markup languages, etc.
14. **Other engineering courses**: courses from other departments not directly related to telecommunications.
15. **Multimedia:** Multimedia systems and services, image processing, audio and video technologies, multimedia production, etc.

B.11. In your opinion, what are the reasons that cause the lack of skills, observed by the occupational groups? [Mark appropriate selection with X or write-in. Multiple answers are allowed]

Reason	ICT specialists, developers, researchers	Managers	Marketing and sales	Other
High fluctuation of employees				
Market requirements				
Lack of newly employed				
Technological change				
No possibility to organize in-company training				
No financial resources for off-site training				
Lack of time due to project deadlines				
Other causes: [please specify] _____				
There are no problems				

B.12. Does your company collaborate with secondary vocational schools and universities (in terms of hiring graduates, providing work experience, scholarships, internships, and so on)? [Mark appropriate selection with X]

	Secondary schools	Universities/faculties
Yes		
No		
Do not know		

B.13. To what extent are you satisfied with the skills and competences acquired during the process of formal education? [Mark appropriate selection with X]

	Secondary schools	Universities/faculties
Very satisfied		
Somewhat satisfied		
Neither satisfied nor dissatisfied		
Somewhat dissatisfied		
Very dissatisfied		

B.14. Do you know the qualifications offered by the national education and training system? [Mark appropriate selection with X]

Yes	No	Partly, depends on the profile

B.15. In your opinion, what changes are necessary in the vocational education and higher education institutions in order for the skills and competences of the graduates to meet the job requirements of your company? [Mark appropriate selection with X or write-in. Multiple answers are allowed]

Readiness to review and change curricula in order to align them with technological change	
Openness to new methodologies of teaching	
Focus on practical training, organisation of practice, internships at the company, etc.	
Joint projects between companies and education institutions	
Define and update educational profiles in line with labour market needs	
Involve the representatives of the social partners (employers, trade unions, public employment service, other public and non-public relevant actors) in planning and developing the educational profiles	
Create the skills and competences that will be applicable in the company without more time being spent on additional trainings	
Introduce additional foreign language courses (professional language)	
Provide career guidance services to future graduates	
Harmonise the training programmed with international standards in order to improve the supply of ICT and other professionals	
Other [please specify] _____	
Do not know	
Nothing	

C. Assessment of the continuing training process of employees

C.1. Does your company practice continuing training and development of employees in order to meet the job requirements? [Mark appropriate selection with X. If the answer is NO or DO NOT KNOW go to question C.7]

Yes	No	Do not know

C.2. If YES, please indicate what specialists (up to 10) were trained at your company in the last 12 months. [Please insert occupations/professional profiles and number]

List occupations [Job title]	Number of specialists

C.3. Please specify the most common training topics by specialists trained. [Please insert occupations, training topics and number]

List occupations [Job title]	Specialized training	
	Topics	Number of specialists

C.4. Does your company evaluate the impact of training on the efficiency of employees who attended? [Mark appropriate selection with X]

Yes	No	Rarely	Do not know

C.5. Who are the providers of training for your company? [Mark appropriate selection with X or write-in. Multiple answers are allowed]

Your company	
ICT Cluster Academy	
National Employment Service	
State educational or training institutions	
Private educational or training institutions	
The manufacturer of equipment	
Other [please specify] _____	
Do not know	

C.6. To what extent are you satisfied with the current level of training available for your employees? [Mark appropriate selection with X]

Very satisfied	
Somewhat satisfied	
Neither satisfied nor dissatisfied	
Somewhat dissatisfied	
Very dissatisfied	

C.7. Does your company plan to hold or pay for training for your employees in the next 12 months? [Mark appropriate selection with X]

Yes	No	Do not know

D. Education and business cooperation

D.1. Is information on needed skills communicated to the education trainings in the ICT sector? [Mark appropriate selection with X]

Yes	No	Do not know

D.2. If YES, through [Mark appropriate selection with X or write-in. Multiple answers are allowed]

Communication between the ICT companies and education/training institutions locally	
Communication between the ICT sector and the education/training authorities at local level	
Communication between the ICT sector and the education/training authorities at provincial level	
Communication between the sector and the education/training authorities at national level	
Other [please specify] _____	

D.3. If NO, why? [Mark appropriate selection with X or write-in. Multiple answers are allowed]

There is no mechanism that functions at present	
Other [please specify] _____	