# Designing information technology curriculum through international standardization and ACM/IEEE recommendations

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**Abstract:** This paper explores the process of designing an Information Technology (IT) curriculum in accordance with ISO/IEC standards and Association for Computing Machinery/ Institute of Electrical and Electronics Engineers (ACM/IEEE) guidelines. By aligning educational programs with internationally recognized standards and recommendations, institutions can ensure the relevance and quality of their IT education. This study outlines key considerations in curriculum development, including the integration of core competencies, the incorporation of emerging technologies, and fostering industry-relevant skills. Through a systematic approach to curriculum design, educators can prepare students for meeting the demands of the rapidly evolving IT landscape and effectively contribute to the global digital economy. A comparative analysis of the coverage of the International Classification for Standards – ICS2 subsegments (within ICS = 35) by educational subjects, across essential and supplemental IT domains, is conducted and presented in the form of a three-dimensional model. Quality, relevance, and international alignment of the study program are provided through comparative analysis with the Information Technology Curricula 2017 (IT2017), as well as compliance with the international programs of other universities in the European Union (EU). The main results of the study are presented through an implementation within the refined curriculum framework, indicating comprehensive coverage and adaptability to innovations.

**Keywords**: curriculum framework, IT domains, standardization.

## 1. Introduction

In today's rapidly evolving technological landscape, the design of an effective Information Technology (IT) curriculum demands a sophisticated approach that integrates international standards and best practices endorsed by well-known professional bodies such as the Association for Computing Machinery (ACM) and the Institute of Electrical and Electronics Engineers (IEEE). As the demand for skilled IT professionals continues to surge globally, it becomes imperative for educational institutions to develop curricula that not only cater to the industry's current needs but also anticipate its future requirements.

The incorporation of international standards into IT curricula serves multiple purposes. Firstly, it provides a benchmark against which educational outcomes can be measured, enabling institutions to assess the effectiveness of their programs and identify areas for improvement. Secondly, adherence to standards enhances the credibility of educational credentials, instils confidence in employers, and promotes the mobility of graduates in the global job market. Finally, it promotes consistency and comparability in IT education, facilitating the transfer of credits and qualifications between institutions and countries.

The competency framework (encompassing areas, units, scope, and competencies) establishes the cornerstone of any IT curriculum, with the aim to achieve a balance between the skills demanded by the industry [1] and the skills sought by the faculty community [2]. According to Curriculum Guidelines for Undergraduate Degree Programs in Information Technology from 2008, the "core components" were programming, networking, human-computer interaction, databases, and web systems [3]. ACM and IEEE Computer Society (IEEE-CS), and various other organizations have recognized not just the lack of dynamic visualizations but also the necessity to shift computing curricula from a knowledge-centric learning model to a competency-driven (performance-oriented) approach [4]. Competencies provide a shared framework for academic programs and employers to articulate the expected achievements of graduates upon finishing their studies, as well as the abilities that new hires should demonstrate in their new roles within the computing profession [5]. In order to achieve these competencies, incorporating new teaching tools, like intelligent tutoring systems, is essential. These tools aim to enhance the teaching process by addressing the unique needs of individual students [6].

Initial course units from various curriculum recommendation reports, categorized according to specific fields such as Computer Engineering (CE), Computer Science (CS), Information Systems (IS), Software Engineering (SE), and IT are presented in [7]. The possibilities for incorporating at least one fundamental course on sustainability into the curriculum for undergraduate and graduate programs in SE, as an additional option, were studied and the assessment of key competencies in sustainability with respect to the proposed units in SE curriculum was conducted [8].

The enhanced model of the continuous improvement cycle that incorporates the Body of Knowledge (BoK) as a mandatory reference for course and curriculum was proposed. The BoK served as a source for fundamental knowledge areas, topics, and learning outcomes, and provides a framework for creating coherent and accurate curricula and its content was stored in a database [9]. The framework was created by combining curriculum models from existing literature on the design of curriculum frameworks in various fields. This combined model was then refined by incorporating ACM/IEEE recommendations [10].

The main focus is modeling IT study programs that provide the students with a solid foundation in contemporary concepts and skills. Designing a curriculum for a range of related IT professional degrees today is not the only problem. The brief lifespan of technical knowledge, which is increasingly shortened in today's world, leads to the need for preparing graduates to continually acquire new technologies. Furthermore, the IT market exhibits an innovation model that significantly differs from the research model commonly found in academies of applied studies and universities.

The proposed three-year IT curriculum with 180 ECTS credits has originated through the modernization of the accredited study program in Information Technology, which has been realized since 2017 at the Academy of Applied Studies Šumadija. The aim of the curriculum is to promote the development of highly skilled professional engineers specialized in computer engineering, aligned with societal and individual demands.

The alignment of the proposed curriculum with international and regional curriculum standards is examined through a comparative analysis of the curriculum content covered in three-year undergraduate applied studies within study programs of computer science and informatics, IT, applied IT, and information systems engineering. The proposed model presents very good compliance with the compared programs, and is aligned with the recommendations for developing curricula for undergraduate studies in Information Technology Curricula 2017 (IT2017). It also ensures good coverage of standardized subdomains.

## 2. Curriculum modeling for achieving objectivities and competencies

The studies are implemented through mandatory and elective courses, two professional internships, and the completion of a professional-research and final thesis [11]. The courses are categorized into academic educational, professional, and professional applicative, in accordance with accreditation standard 5 [12].

The objectives of the study program are clearly and unambiguously formulated. They are aligned with the requirements of the labor market and economic development, and also with societal development. The developed curriculum for IT studies is designed to ensure knowledge, skills, abilities, and attitudes aligned with the National Qualifications Framework (NQF, qualification level 6.1 S), such as:

Enabling students to integrate and apply a wide range of knowledge in the field of information technology;

Gaining proficiency in IT and its associated domains;

Enabling students to utilize information technology principles to address practical challenges and optimize IT resources;

Attainment of professional capabilities in IT and the development of skilled professionals;

Understanding current trends in IT and leveraging professional resources and modern IT tools to gain expertise and enhance independent learning in IT and related domains;

Fostering students' recognition of the importance of continuous learning, considering the rapid pace of evolution within the information technology domain, with simultaneous preparation of students for further education (specialist and master professional studies).

This applied undergraduate study program in IT provides students with the opportunity to acquire a broad spectrum of knowledge and skills for choosing and deploying hardware systems; deploying software solutions in business and industrial systems administration; developing software applications; creating, executing, and managing information systems; crafting, setting up, and managing computer networks; creating and overseeing databases; developing graphical and web applications; fulfilling user needs in practical scenarios.

## 3. International and regional curriculum compliance

All courses have been compared with recommendations for developing the curriculum for undergraduate Information Technology studies (IT2017), focusing on standardized segments/fields of IT (ICS1 = 35), and subsegments of ICS2 in the field of information technology, aiming to demonstrate the coverage of all ICS2 subsegments by subjects proposed in the curriculum (from 35.020 to 35.260 according to ISO classification). In this process, comparability with the essential domains from IT2017 was considered, as well as with support domains [13]. Covering essential domains that ensure minimum competencies, while the choice of support domains reflects the purpose and objectives of the study program.

The subject of the proposed IT study program can be classified into 10 essential domain clusters and five supplemental domain clusters. The essential domain clusters are: Software Fundamentals (ITE-SWF), Platform Technologies (ITE-PFT), Global Professional Practice (ITE-GPP), Integrated Systems Technology (ITE-IST), Networking (ITE-NET), User Experience Design (ITE-UXD), Web and Mobile Systems (ITE-WMS), Information Management (ITE-IMA), Cybersecurity Principles (ITE-CSP), and System Paradigms (ITE-SPA). The supplemental domain clusters are: Social Responsibility (ITS-SRE), Data Scalability and Analytics (ITS-DSA), Cloud Computing (ITS-CCO), Mobile Applications (ITS-MAP), and Internet of Things (ITS-IoT). Mathematics is represented partly through discrete structures

(ITM-DSC), as well as through content aligned with the level of applied studies (probability, statistics, data analysis, linear algebra, and differential and integral calculus). Sciences related to IT are also present. Classification of compulsory (C) and elective (E) subjects into essential and support domain clusters and their subdomains, categorized through ICS2, is presented in Table 1. Each subdomain has a proper level as an indicator of learning engagement (L1, L2, or L3), and should be used only as a rough estimator. Within a subdomain, Level L1 (L1) signifies a basic level of involvement linked with mastering the foundational concepts. Levels 2 (L2) and 3 (L3) within the same subdomain denote moderate and extensive levels of engagement respectively, involving the application and transfer of knowledge to intricate scenarios [13].

**Table 1 (a).** Contemporaneity and international alignment of the study program - analysis through ICS2 (35.xy0) and essential and support domain clusters and its subdomains

| ICS 2 35.xy0 subareas [a] | Subject and status (Compulsory – C, Elective - E) | Domains and subdomains in IT2017 | Subjects in more than one IT subarea |
|---|---|---|---|
| 35.020 | Internet of things (C) | ITS-IOT-01 Perspectives and impact (L1); ITS-IOT-02 IoT architectures (L2); ITS-IOT-03 Sensor and actuator interfacing (L1); ITS-IOT-04 Data acquisition (L1); ITS-IOT-05 Wireless sensor networks (L2); ITS-IOT-06 Ad hoc networks (L1); ITS-IOT-07 Automatic control (L2); ITS-IOT-08 Intelligent information processing (L2); ITS-IOT-09 IoT application and design (L2) | Fundamentals of ICT (C)<br>Operating systems (C) - ITE-PFT-02 Operating systems (L3)<br>Web design (C)- ITE-UXD-03 Effective interfaces (L2); ITE-UXD-04 Application domain aspects (L1); ITE-WMS-02 Technologies (L2); ITS-MAP-07 Interface implementations (L2) |
| 35.030<br>35.040 | Information system security (E) | ITE-CSP-02 Policy goals and mechanisms (L1); ITE-CSP-03 Security services, mechanisms, and countermeasures (L2); ITE-CSP-11 Mitigation and recovery (L1); ITE-CSP-12 Personal information (L1); ITE-CSP-13 Operational issues (L2) | |
| 35.040 | Introduction to programming (C) | ITE-IST-04 Integrative programming (L2); ITE-SWF-04 Program development (L3) | |
| | Object-oriented programming (C) | ITE-IST-04 Integrative programming (L2); ITE-SWF-04 Program development (L3) | |
| | Fundamentals of visual programming (C)<br>Java programming language (C)<br>Web programming (C)<br>Fundamentals of PHP programming (E)<br>Introduction to engineering programming (E)<br>Python programming language (E) | ITE-IST-04 Integrative programming (L2); ITE-SWF-04 Program development (L3); ITE-IST-05 Scripting techniques (L2) | |
| 35.080 | Algorithms and data structures (C) | ITE-SWF-05 Fundamental data structures (L2); ITE-SWF-06 Algorithm principles and development (L2) | |
| | Mobile application development (E) | ITE-SWF-07 Modern app programming practices (L1); ITS-MAP-02 Architectures (L1); ITS-MAP-03 Multiplatform mobile application development (L2); ITS-MAP-04 Servers and notifications (L1); ITS-MAP-05 Performance issues (L1) | |

**Table 1 (b).**

| | | |
|---|---|---|
| | Information Systems Design (C) | ITE-GPP-12 Information systems principles (L1), ITE-SWF-02 Concepts and techniques (L2); ITE-SPA-02 Requirements (L2); ITE-SPA-03 System architecture (L1); ITE-SPA-06 Integration and deployment (L2); ITS-SDM-01 Process models and activities (L2); ITS-SDM-02 Platform-based development (L1); ITS-SDM-03 Tools and services (L2); ITS-SDM-04 Management (L2); ITS-SDM-05 Deployment, operations, maintenance (L2) |
| | Software testing (E) | ITE-SPA-05 Testing and quality assurance (L2); ITE-SPA-10 Performance analysis (L1) |
| 35.100<br>35.110 | Computer networks (C) | ITE-NET-01 Perspectives and impact (L1); ITE-NET-02 Foundations of networking (L1); ITE-NET-03 Physical layer (L2); ITE-NET-04 Networking and interconnectivity (L3); ITE-NET-05 Routing, switching, and internetworking (L2); ITE-NET-06 Application networking services (L2); ITE-NET-07 Network management (L3) |
| 35.140 | Multimedia and graphic applications (E) | ITS-MAP-08 Camera, state, and documents interaction (L1); ITS-MAP-09 2D graphic and animation (L1) |
| 35.160<br>35.180<br>35.200<br>35.220 | Computer architecture (C) | ITE-PFT-04 Architecture and organization (L1); ITE-PFT-03 Computing infrastructures (L1); ITE-SPA-03 System architecture (L1) |
| | Cloud computing (E) | ITS-CCO-01 Perspectives and impact (L1); ITS-CCO-02 Concepts and fundamentals (L2); ITS-CCO-03 Security and data considerations (L2); ITS-CCO-04 Using cloud computing applications (L2); ITS-CCO-05 Architecture (L2); ITS-CCO-06 Development in the cloud (L2); ITS-CCO-07 Cloud infrastructure and data (L2) |
| | Electronic business (E) | ITE-GPP-11 Employability skills and careers in IT (L1) |
| 35.210 | Databases (C)<br>Application programming with databases (C) | ITE-IMA-02 Data-information concepts (L2); ITE-IMA-03 Data modeling (L3); ITE-IMA-04 Database query languages (L3); ITE-IMA-05 Data organization architecture (L3); ITE-IMA-07 Managing the database environment (L2) |
| | Internet marketing (E) | ITE-WMS-03 Digital media (L2); ITE-WMS-07 Social software (L1) |
| | Decision support systems (E) | ITE-GPP-03 IT governance and resource management (L1); ITE-SWF-03 Problem-solving strategies (L1) |

a See Fig.1 for ISC2 subareas names.

Bearing in mind that the level indicators offer a comparative measure, by comparing the levels of engagement we can conclude that some subjects like Operating systems, Databases, or Application programming with databases require three times the level of engagement compared to the subjects like Internet of things, Mobile application development, etc. Consequently, a higher number of ECTS credits should be allocated to these subjects. Subjects that are not classified according to ICS2 are shown in Table 2. Their affiliation according to IT2017 with the respective subdomains and levels of engagement is also presented. These subjects require a minimal level of student learning engagement, which can be considered as an adequate solution.

**Table 2.** Analysis of non-classified subjects according to ICS2 through essential and support domain clusters and its subdomains

| Subject and status (Compulsory – C, Elective - E) | Domains and subdomains in IT2017 |
|---|---|
| Business communication and presentations (C) | ITE-GPP-09 Communications (L1); ITE-GPP-11 Employability skills and careers in IT (L1) |
| Entrepreneurship (C) | ITE-GPP-03 IT governance and resource management (L1); ITE-GPP-04 Risk identification and evaluation (L1); ITE-GPP-08 Project management principles (L1); ITS-SRE-04 Global challenges and approaches (L1); ITS-SRE-05 Risk management (L1) |
| Sustainable development (C) | ITE-GPP-05 Environmental issues (L1) |
| Statistical and numerical methods (E) | ITM-DSC-09 Combinatorics (L1); ITM-DSC-10 Iteration and recursion (L1); ITM-DSC-12 Discrete information technology applications (L1) |
| Electrical engineering (C) | *Related Science* |
| Integrated circuits (C) | *Related Science* |
| Technical mathematics (C) | *Related Mathematics* |

A comparative analysis of the coverage of ICS2 subareas (2nd dimension) by course subjects (1st dimension), through essential and support domains (3rd dimension), is presented graphically in Figure 1 in the form of a three-dimensional (3D) curriculum model.

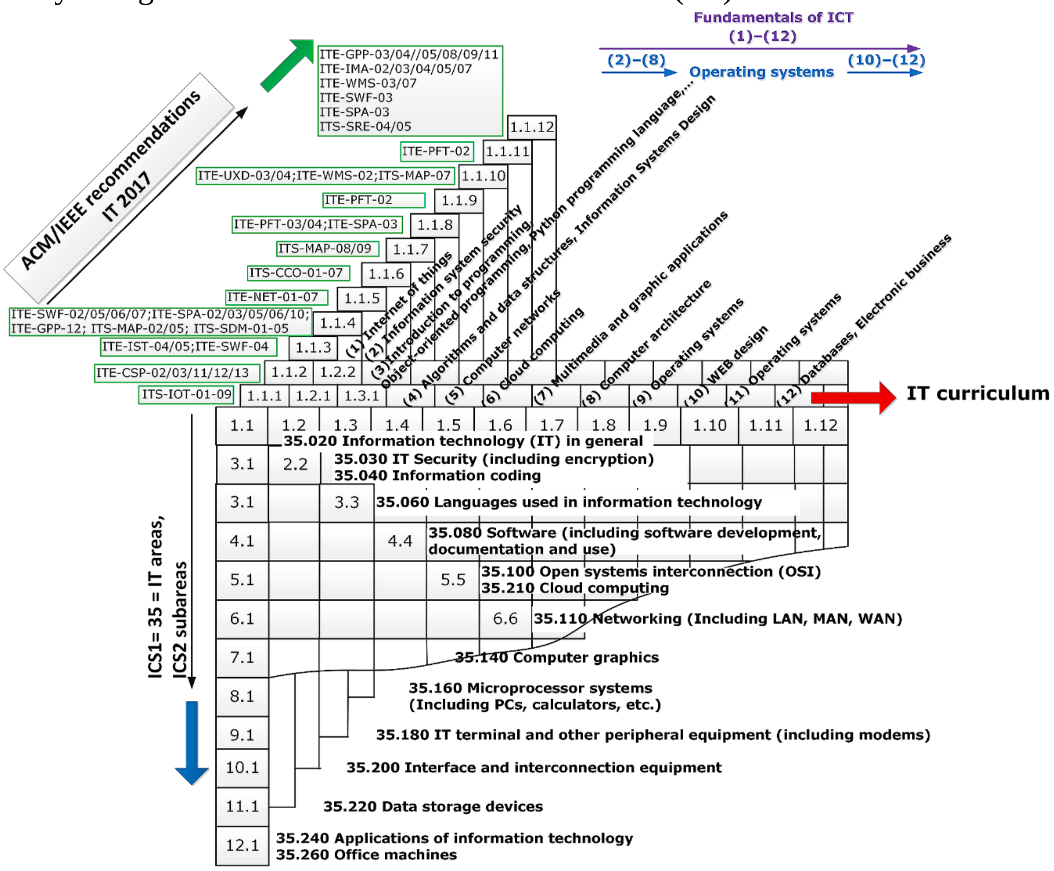


**Figure 1**. 3D curriculum model with IT domain clusters through ICS2 (adapted from [14])

## 4. Results and discussion

The proposed 3D curriculum model presented in Figure 1 indicates the fact that the developed curriculum is aligned with international standards (on one side) and with ACM/IEEE recommendations (on the other side). This is due to the fact that ACM/IEEE in their Curriculum guidelines for baccalaureate degree programs in IT do not explicitly reference international standardization.

An additional analysis is conducted by cross-referencing the number of ECTS credits for the compulsory and elective subjects and the levels of engagements presented in Table 1. Mandatory subjects (89 ECTS credits) include all levels of engagement (L1, L2, L3) as well as their respective combinations (L1+L2, L2+L3, L1+L2+L3). On the other hand, elective subjects (30 ECTS credits) assume only one level of engagement (L1), along with some optional combinations (L1+L2, L2+L3). No elective subject includes all three levels of engagement.

ECTS credits distribution by levels of engagement for mandatory subjects in percentages is shown in Figure 2. The largest quantity of ECTS credits is allocated to the combination of L2 and L3 levels of engagement, taking up 33.7% of the total ECTS credits for all mandatory subjects. The combination of L1 and L2 levels of engagement comes second with 25.83%. Equal amount of ECTS is given to L1 and L3 separately, with each taking up 13.48% of total ECTS. Lastly, the combination of all three levels of engagement as well as L2 separately are each given 6.74% of total ECTS credits assigned to mandatory subjects.

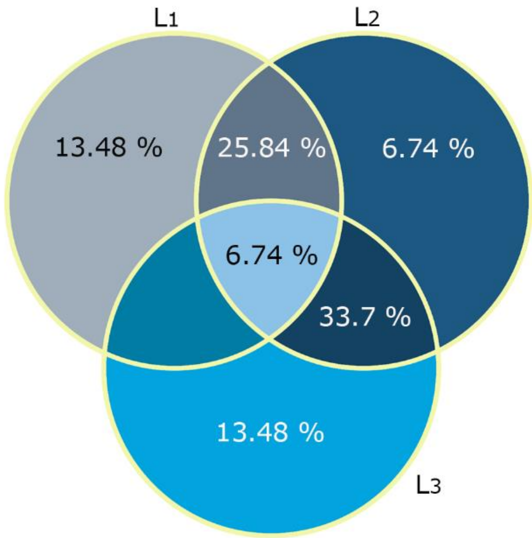


**Figure 2.** ECTS credits distribution by levels of engagement

Several programs have been deliberated in order to verify the compliance of the innovated IT curriculum model. Bearing in mind the fact that IT studies in Serbia are classified into Interdisciplinary, Multidisciplinary and Transdisciplinary studies (IMT studies), the following representative examples have been chosen:

1) Computer science and informatics (professional higher education first-cycle study program), implemented at the Faculty of Computer and Information Science, University in Ljubljana, Slovenia [15];

2) Information technologies (bachelor's study program), implemented at the Faculty of Information Technology, Brno, Czech Republic [16];

3) Undergraduate applied IT studies, implemented at The College for Information Technologies – VSITE, Zagreb, Croatia [17];

4) Bachelor in applied IT, implemented at Faculty of Science, Technology and Medicine (FSTM), University of Luxembourg, Belval Campus, Esch-sur-Alzette, Luxembourg [18];

5) Information systems engineering (professional bachelor degree program), implemented at PI Utenos kolegija, Utena, Lithuania [19].

Serbian law of higher education prohibits the transfer of ECTS credits between different study programs with the sole exception being the transfer between the same type of studies and degree level. Therefore, students in professional undergraduate programs do not have the opportunity of direct transition to academic studies, and vice versa, which marks the importance of this distinction.

All the aforementioned study programs last three years and carry 180 ECTS credits. Subjects, expressed by its ECTS credits, are aligned with the subjects in the proposed IT study program. The compliance is expressed in percentages and presented in Figure 3.

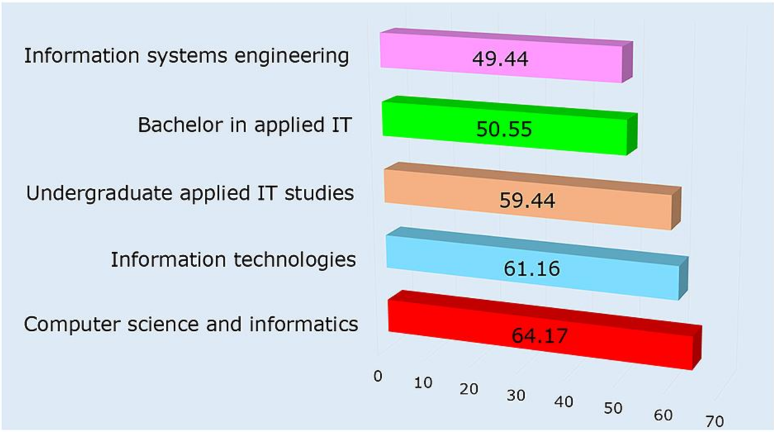


**Figure 3.** Compliance of IT curriculum model

The alignment of the study program with similar programs from the European Higher Education Area is at a satisfactory level. It ranges from 49.44% to 64.17%. The percentage representation of essential and support domain clusters, mathematics (through discrete structures and content aligned with the level of applied studies), as well as sciences related to IT in the proposed curriculum structure (in relation to 180 ECTS credits) is presented in Figure 4.

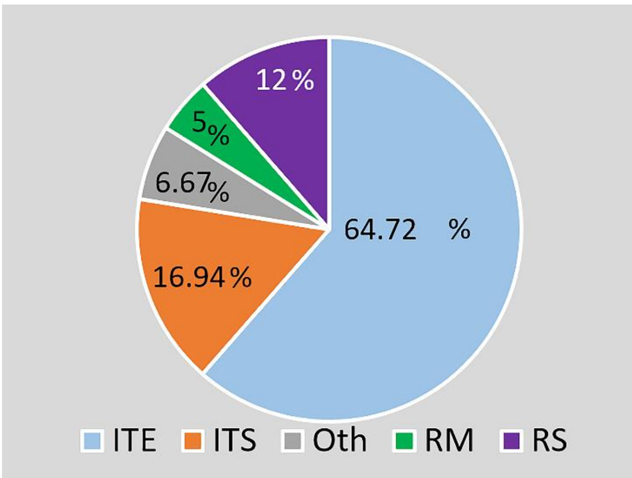


**Figure 4.** The percentage representation of subjects in the curriculum structure by domain clusters: ITE – Essential; ITS – Support; Oth – Other; RM – Related Mathematics; RS – Related Science

## 4. Conclusion

This paper proposes a framework for designing an IT curriculum that integrates international standardization principles with ACM and IEEE recommendations. The proposed framework aims to balance academic expertness and industry relevance which would prepare the graduates to excel in their future careers in IT. Through a detailed analysis of international standards and ACM/IEEE recommendations, this paper seeks to provide educators and curriculum developers with actionable insights to enhance the quality and effectiveness of IT education programs worldwide. By aligning educational objectives with industry standards and best practices, institutions can ensure that their graduates possess the requisite competencies to thrive in an increasingly competitive and dynamic IT landscape.

The proposed IT curriculum is aligned with contemporary global scientific trends and the state of the art in the field, and is comparable to similar programs at foreign higher education institutions, especially within the European Higher Education Area. It provides the proper representation of the essential and support domain clusters, as well as mathematics, and sciences related to IT.

Given that IT is a broad discipline which incorporates both theoretical knowledge and practical expertise, the presented curriculum offers a blend of theory and practical application across various domains within IMT studies. Since IT is an ever-expanding area constant fine-tuning is necessary in order for the curriculum to be up-to-date and stay relevant. With the rise of artificial intelligence (AI), it is highly beneficial to slowly introduce subjects related to the application of AI, all while keeping in mind the balance between different levels of students' engagement.

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