05

Subject-Specific Criteria of the Technical Committee 05 – Materials Science, Physical Technologies

for the accreditation of bachelor's and master's degree programmes in materials science, physical technologies and related interdisciplinary subjects

(adopted: 18 March 2022)

The following specifications complement the "ASIIN General Criteria for the Accreditation of Degree Programmes".

1 Preliminary Note

1.1 Context and Function

The Subject-Specific Criteria (henceforth "SSC") of the Technical Committee 05 – Materials Science, Physical Technologies (henceforth "TC 05") were developed in coordination with the relevant professional communities. Thus, the SSC align with current national and international standards and contribute to the creation of comparable quality assurance procedures. The SSC address the demand to formulate subject-specific and discipline-oriented learning outcomes as one of the most important quality criteria towards promoting academic and professional mobility in Europe. The SSC take into account the diverse preparatory work that has been done within the framework of European projects and professional networks. They are the result of the continuous assessment of TC 05, summarising what is considered good practice by academia and the professional community and what is required by the labour market in terms of forward-looking educational quality. The expectations outlined in the SSC for the achievement of programme objectives, learning outcomes and competence profiles are therefore not to be understood as a static scheme. Rather, they should be viewed as a basis for discussions between experts, higher education institutions and the ASIIN committees. They include the most important abilities, skills and competencies that are typically considered „state of the art" within the subject area but that are modified in accordance with the profile and strategic objectives of the higher education institution.

The SSC of TC 05 are intended to support higher education institutions in formulating their self-assessment reports for the purpose of accreditation processes. The applying institutions are responsible for defining the intended learning outcomes and profiles of their degree programme. These definitions will then serve as the main standard for the evaluation of the respective curricula by ASIIN. Institutions are not restricted in the development and testing of innovative degree programmes. Within the degree programme objectives and profiles as defined by the institution, deviations from the abilities, skills and competences as defined in the SSC are possible. With the help of the SSC, applying institutions are requested to critically reflect on the interaction between the intended learning outcomes, curricula, teaching and learning methods and the associated quality expectations of their degree programmes.

1.2 Responsibilities and collaboration between technical committees

The TC 05 is responsible for the evaluation of bachelor’s and master’s degree programmes in materials science and physical technologies. Furthermore, the competence of TC 05 encompasses heavily interdisciplinary programmes within this field that are situated between science and technology. Degree programmes with a heavy content in physical technologies, material science and technology as well as process related content are typically within the responsibility of TC 05. In case of interdisciplinary degree programmes with a marginal amount of content from the mentioned fields, TC 05 is jointly responsible together with the participating disciplines or will only provide experts for the accreditation procedure.

The following paragraphs elaborate the fields and terms within the responsibility of TC 05.

1.2.1 Materials science and engineering

Bachelor’s and master’s degree programmes that focus on materials science, materials engineering as well as related technologies and applications are classified under the field „Material Science and Engineering“. They cover a wide range of scientific fundamentals of material properties, from production and processing up to application and failure of materials. They also combine the fundamental principles of experimental and theoretical materials science with physical-chemical fundamentals as well as with engineering topics.

Typical specialisations in the area of materials science and engineering are, among others, the scientific understanding of different classes of materials such as metals, polymers, ceramics, natural materials and compound materials as well as their interplay ranging to innovative composite materials. Furthermore, important subjects are functional materials with magnetic, electric, optical, mechanical or biological properties, bio-based or biodegradable materials, nano materials, and powdered or sintered materials. Further subject specifics are the associated materials technologies, microstructural-analytical, mechanical-static and mechanical-dynamic characterisations as well as damage diagnostics for complex load collectives.

1.2.2 Physical technologies

The field „Physical Technologies“ contains bachelor’s and master’s degree programmes that combine an extensive mathematical and physical fundamentals with other appropriate engineering or scientific focus areas (e.g. mechanical engineering, micro systems technology, electrical engineering, computer engineering, optical technologies, medical technology, etc.) within a complete degree programme. Within this term, degree programmes that present an extensive cross-sectional nature, which makes it impossible to classify these under only one discipline, are also included. Generally, this makes the mathematical and natural science portion of the study programme larger than it is for instance in more classic degree programmes like electrical engineering and mechanical engineering. The relevance and value of degree programmes in Physical Technology lies within their special role as a bridge between physical research, technological development and industrial application. Graduates of these programmes are often employed in key positions at the link between science and technology.

Examples of specialisations within physical technologies are optical technologies, micro systems technology, nano technology, surface technology, medical technology, bio technology or measurement/sensor technology.

1.2.3 Collaboration of the technical committees

Moreover, TC 05 assumes responsibility of coordinating accreditation procedures for bachelor's and master's degree programmes which touch the fields described in 1.2.1 and 1.2.2 but which are heavily interdisciplinary and therefore do not easily correspond to the field of one of the other Technical Committees. Examples include: metallurgy, metallurgical technologies, biological and chemical process technologies, environmental technology, sustainability technologies, recycling and repair technologies.

2 Educational objectives and learning outcomes

The educational objectives that graduates need in the professional field or in further studies, i.e. knowledge, abilities and competencies, are clarified in a short and concise description. These educational objectives are developed according to various objectives of bachelor's and master's degree programmes regarding scope and depth.

In terms of freedom of career choice, it is a particular challenge to design undergraduate bachelor's degree programmes in such a way that students acquire sufficient general fundamentals and, at the same time, sufficient occupation-specific aspects and competences to ensure them good opportunities for successful further development even in a changing professional environment. Irrespective of the respective specification in detail, it appears just as important that the undergraduate degree programmes impart a sufficient degree of scientific and technical fundamentals in order to prepare students for specialised master's curricula, but also to offer professional perspectives. Master's degree programmes are aimed more at specialising programmes that, on the one hand, should lead into the professional world in a research-related way or, on the other hand, prepare students for special fields of application in connection with leadership activities.

In addition to a certain continuity of the study programme design, new and innovative scientific and technical fields of study and specialisations within the study programme are particularly advocated. In this context, not only the contents of the core competences of the college/university are important, but also the teaching of competences that meet the global challenges such as climate protection, cost and resource efficiency, digitalisation of processes (Industry 4.0, "digital twins").

In the following, the qualification profiles of bachelor's and master's graduates are described in a general way. Depending on the study profile and the subject orientation, these qualifications and competences can be more or less pronounced.

2.1 Requirements for bachelor's degree programmes

A bachelor's degree aims at facilitating an early entry into a professional career (professional qualification) on the one hand, and on the other it should qualify graduates for advanced scientific degree programmes within the fields of TC 05 or an additional scientific degree programme in a different area of study.

The clear statements about the practical orientation and professional qualification of a degree programme, which are required of the higher education institution by ASIIN's General Criteria for Degree Programmes, are of particular importance against the background of the complexity and heterogeneity of academic education.

Completion of a Bachelor Degree programme should lead to the following objectives or learning outcomes:

2.1.1 Subject-specific competences

Knowledge, comprehension and application

Being in command of the fundamental knowledge and comprehension of science, mathematics and engineering forms the basic competences to achieve further educational objectives. The graduates are able to apply the knowledge and the competences that they have obtained to develop new products, processes or methods. Ethical, social, health, safety, ecological and economic factors must be taken into account.

Graduates:

- know and comprehend the principles of natural sciences, engineering, technology and mathematics that are the basis of the subject area of their focal studies,
- have a systematic comprehension of the central elements and concepts of the subject area of their focal studies,
- possess interdisciplinary (coherent) knowledge on the subject areas of their focal studies,
- have knowledge of additional aspects of subject related sciences,
- are able to apply their knowledge and comprehension to conduct developments according to predefined and specific requirements, to realise results and do this in collaboration with a team of engineers, scientists and representatives of other subject areas,
- have learned fundamental development and planning methods and possess the competency to apply these systematically,
- know the relationship between their discipline and the general expectations of society.

Research, analysis, problem solving and evaluation

The ability to conduct systematic and structured research is the basic precondition for formulating the motivation and objectives of challenging tasks. The analysis should encompass the identification of a problem, clarification of a specification, reviewing possible solutions, selection of the most suitable methods and their implementation. In order to perform these different analytical processes with high quality and achieve good and sustainable learning outcomes, knowledge and command of proven scientifically based methods is necessary. The fundamental principles of relevant methods must be known and understood. They must be mastered by the graduates.

The graduates:

- are capable of carrying out literature and data research and use databases and other sources of information,
- have a solid command of methods and procedure to document research results,
- are able to conduct a comparative analysis between their own findings and results from theory and relevant literature, and to draw conclusions relevant to their interest,
- possess the necessary knowledge and comprehension to identify, formulate and to solve problems, including aspects outside of their area of specialisation, by means of established or newly developed methods,
- are able to transform generally formulated tasks into feature-oriented requirement profiles and conduct a scientifically based analysis by applying learned methods,
- are able to apply their knowledge and competences to analyse developments (material characteristics, products, processes, methods), advance these developments and communicate these to others,
- are in a position to apply various methods – mathematical analysis, computer-aided designs or systematic experimental research – to conduct task-specific analyses and/or independently resolve issues of development tasks,
- are able to select and apply suitable analysis and modelling techniques.

Application

Successful practice requires a solid competence in knowledge and methodology, combined with practical experience in completing typical research tasks. Only this will lead to the effective and efficient development of solutions. A critical additional element is a profound knowledge of the fundamentals of natural science including sufficient theoretical knowledge. Only this will ensure targeted expansion of existing knowledge or be transferred onto new tasks. Furthermore, the cross-sectional character of the respective disciplines requires that experts of this subject area also possess fundamental knowledge of other engineering or applied sciences. Part of the professional profile is the ability to transfer independently acquired ‚know-how‘ to other areas (technology transfer).

This includes practical knowledge and experience of:

- the applicability of technologies, the usability of materials and innovative materials, the applicability of processes as well as their possible limitations,
- a careful evaluation and parameter-controlled choice of materials,
- specific technologies, processes and procedures,

- data processing, measurement engineering and experimental procedures, as well as the design of models,
- technologies, processes and procedures, devices and tools that correspond to the specific focal points of the respective study areas,
- practices in the production facility,
- professionally and methodologically relevant literature and other sources of information.

Graduates:

- are able to combine theory and practice to solve problems related to a setting of Physical Technology, Material Science or Material Engineering,
- are able to initiate respective developments and justify their necessity,
- are in a position to select and apply the necessary and suitable devices, tools (hard and software) and methods,
- have developed an understanding of applicable techniques and methods and their limitations,
- are able to evaluate economic viability,
- apply safety technology.

2.1.2 General and social competences

Graduates:

- are able to work in teams and are able to constructively contribute as an individual and as a team member,
- are able to apply various methods to communicate effectively with the engineering or scientific community and with any community in general,
- are aware of the health, safety and legal implications and responsibilities of the engineering practice, as well as the implications resulting from technical-scientific solutions within a social and natural environment. Graduates also commit to appropriately act according to professional ethics, accountability and norms set by the technical-scientific practice,
- are aware of the methods and limitations of project management and business practice, such as risk and change management,
- acknowledge the need and have the ability for independent and lifelong further learning.

2.2 Requirements for master's degree programmes

Building on an initial higher professional qualification, the master's degree programme leads towards acquiring in-depth analytical, methodological and above all scientific competences. At the same time, the acquired competencies from the first professional qualification programme are being expanded and broadened. This should be ensured through a suitable curricular structure and it should support the relevant research and development activities of the responsible faculty. A master's degree programme can have an application orientation as well as a research orientation. Master's graduates should reach a level of knowledge and competence that in principle qualifies them for a doctoral degree in their area of specialisation.

2.2.1 Subject-specific competences

Graduates of master's degree programmes should have obtained the following objectives.

Knowledge, comprehension and application

Being in command of in-depth knowledge and comprehension of science, mathematics as well as the technological fundamentals and of professional practice in the field are features of a master's degree programme and are necessary to achieve further educational results.

Graduates:

- possess profound knowledge and in-depth comprehension of the subject-specific fundamentals of the main focus of their degree programme (theory and practice),
- have advanced knowledge of related subject areas,
- have developed a critical awareness of new insights in their discipline,
- have mastered the current state of the art of their subject area.

Research, analysis, problem solving and evaluation

The ability to conduct systematic research and analyse increasingly complex tasks is the basic precondition for scientifically formulating and solving problems. In addition to elaborating the motivation and objective of an endeavour, an expedient approach must be demonstrated including the review of possible solutions and the selection of the most suitable ones and their implementation. In order to perform these different analytical processes with high quality and achieve good and sustainable learning outcomes, knowledge and command of proven scientifically based methods is necessary. The fundamental principles of relevant methods must be known and understood. They must be mastered by the graduates.

The analysis can include the identification of a problem, clarification of a specification, the consideration of possible solutions, the selection of the most suitable methods and their implementation. In order to execute these processes with the highest quality and to get results that are sufficient for further requirements, e.g. regarding the development status or a leadership position, scientifically based methods for executing these processes are broadly known. In a broader scope, they can be applied and if needed further developed according to problem specific requirements.

Innovative development activities can refer to devices, processes, methods, models and materials. Beyond scientific and technological aspects, the specifications can involve the consideration of social, health and safety, ecological and economical requirements.

Graduates:

- are able to conduct independent scientific work,
- possess the ability to independently identify and analyse complex problems,
- are able to determine independently and using suitable methods the state of the art related to a certain problem, to clearly define an objective and to create a solution matrix,
- can independently develop a solution for a proposal or test a hypothesis, present and discuss results, come to conclusions and summarise them in an understandable way,
- are able to expand their knowledge and skills independently and methodically,
- are able to critically reflect, discuss and evaluate research concepts and results,
- are in a position to use innovative methods to solve technological problems and to develop new methods where necessary,
- are able to formulate and to solve problems in new or emerging areas within their field of specialisation,
- are able to solve scientific and technical problems in accordance with their level of knowledge and understanding and in collaboration with representatives of other disciplines,
- can use their creativity to develop new and original ideas,
- are able to further develop their skills and competences during their professional career and to make use of them accordingly.

Application

Successful practical work requires practical skills and experience in dealing with typical challenges in order to develop and implement targeted solutions, to evaluate the results and to optimise the solutions iteratively.

Graduates possess practical skills to solve problems. These include practical knowledge of:

- engineering and/or scientific processes, devices and tools,
- the application of materials and methods,
- models and simulations,
- the practice in research, development and production,
- the state of the art in research and technology.

Graduates:

- are able to combine theory and practice in order to solve scientific and/or technological problems

- are able to combine knowledge and learning from various areas and to cope with complex issues,
- have comprehensive knowledge of applicable technologies and methods and their limitations,
- know the non-technological implications of the work of engineers and scientists, particularly the safety, social and ethical consequences as well as the general social context of their activities.

2.2.2 General and social competences

Graduates:

- meet all the requirements that are placed on graduates of a master's degree regarding key qualifications,
- are able to lead a cooperative and well-connected team,
- are able to effectively work and communicate in a national and international context,
- are in a position to recognise and evaluate the social, ethical, ecological and economic preconditions and implications of their projects,
- are in a position to evaluate their projects regarding occupational safety and work conditions and take adequate precautions to prevent accidents,
- are able to situate their professional activities within a broader societal context and to take on current social challenges.

3 Curriculum

The learning objectives for a given degree programme should be attained by means of an adequate content structure of the programme. Only through this kind of goal-oriented curriculum planning is it possible to realise the most important characteristics of bachelor's and master's degree programmes. A critical feature of bachelor's degree programmes is to achieve a professional qualification in the respective field. Master's degree programmes, by contrast, focus on the ability to independently carry out engineering and/or scientific work.

The interdisciplinary character and the general profile of programmes in materials science and engineering and physical technologies requires a certain amount of content in the following broadly specified subject areas in order to achieve the intended learning outcomes of these programmes.

The specific curriculum must be structured in such a way as to allow students to achieve the learning outcomes as defined by the institution.

3.1 Bachelor's degree programmes in materials science and engineering

Subject-specific competences	Examples of curricular content
Sound mathematical and scientific foundations	Mathematics, physics (especially solid-state physics), chemistry, computer science
Basic subject-specific knowledge and methodological skills	Fundamentals of materials science (crystallography, solid-state physics, state diagrams, microstructure analysis, structure-property correlation), design theory, applied thermodynamics, manufacturing processes
Basic application skills	Materials engineering (materials classification, materials in application, nomenclature), thermal and thermo-chemical treatment processes, materials testing (mechanical-static and mechanical-dynamic testing, chemical/physical testing), functionalisation of materials, system properties (wear, corrosion), materials selection, damage diagnostics, simulation/modelling
Deeper knowledge in a field of specialisation	Deepening of knowledge and skills in one or several specialisations
General and social competences	**Examples of curricular content**
Basic knowledge on economic and ecological implications	Interdisciplinary teaching content, e.g. economics subjects, non-technical, non-scientific electives
Ability to work in a team at national/international level	Time and project management, team development, communication skills, languages
Methodological competences	**Examples of curricular content**
Knowledge/skills for independent scientific work on an assignment and for presenting and discussing the results of the	Project, final thesis

work	
Skill to independently work on a task	internship

3.2 Master's degree programmes in materials science and engineering

Master's degree programmes can focus on research or on application, which has to be reflected in the curriculum. Depending on the higher education institution's profile, the focus of materials science may differ. This makes it possible for advanced subjects in a practically oriented programme, for instance related to materials engineering, to ensure the achievement of the intended learning outcomes. Equally, advanced subjects of a research oriented degree programme that focus strongly on research and fundamentals, can ensure that the intended learning outcomes, for instance regarding scientific analysis, are achieved to a larger extent.

Subject-specific competences	**Examples of curricular content**
Advanced mathematical, scientific and engineering skills for solving complex problems	Consolidation of mathematical, natural and engineering fundamentals: mathematical methods, higher mechanics, heat and mass transfer, technical informatics, higher design theory, technical physics, modules for digitalisation processes
In-depth subject-specific knowledge, skills and methodological competence for the deepening or broadening of topics in materials science	Advanced knowledge of materials science (crystallography, solid-state physics, thermodynamic systems, microstructure analysis, materials characterisation, process-structure-property correlation), materials-specific design theory, applied thermodynamics, manufacturing processes, joining processes, metallurgical processes, machining and processing processes, laboratory practicals
Specific skills in application-oriented materials engineering	Materials engineering, innovative materials (composite materials, material composites, hybrid systems, functional materials) and associated technologies, in-depth knowledge of thermal and thermo-chemical treatment processes, materials testing (mechanical-static and mechanical-dynamic testing, chemical/physical testing), functionalisation of materials, system properties (wear, corrosion), data and computer-aided material selection, damage diagnostics, simulation/modelling.
Deeper knowledge in a field of specialisation	Deepening of knowledge and skills in one or several specialisations

General and social competences	**Examples of curricular content**
Skill to evaluate engineering practice and its implications	Interdisciplinary teaching content, e.g. economics subjects, non-technical, non-scientific electives
Ability to work in a team at national/international level	Project management, team development, leadership and moderation, communication skills, languages, stay abroad
Methodological competences	**Examples of curricular content**
Knowledge/skills for independent work in research and development including documentation, analysis, discussion, conclusion and societal contextualisation	Project, final thesis
Skill to independently work on a complex and demanding task	Final thesis

3.3 Bachelor's degree programmes in physical technologies

Subject-specific competences	**Examples of curricular content**
Sound mathematical and scientific foundations	Mathematics: analysis, algebra, differential equations, complex numbers, vector algebra, statistics, computer algebra; Physics: mechanics, thermodynamics, optics, electricity; Chemistry
Basic application skills	Computer science, electronics, design/CAD, materials science/materials engineering, measurement and control technology, microprocessor technology, digital signal processing
Basic knowledge in physical technologies	Nuclear and molecular physics, solid-state physics, optics, laser technology, simulation, modelling, physical chemistry, plasma technology, vacuum and cryogenics, methods of artificial intelligence
Deeper knowledge in a field of specialisation	Photonics, laser development and application, microsystems technology, nanotechnology, regenerative energy technology, environmental technology, technical optics, technical acoustics, medical physics, biophysics
General and social competences	**Examples of curricular content**
Basic knowledge on economic and ecological implications	Interdisciplinary teaching content, e.g. economics subjects, non-technical, non-scientific electives
Ability to work in a team at national/international level	Time and project management, team development, communication skills, languages
Methodological competences	**Examples of curricular content**
Methodological competences to deepen and expand on physical-technical topics	Student research project, final thesis, seminar
Skill to independently work on a challenging task within the subject area	Internship, project, final thesis

3.4 Master's degree programmes in physical technologies

Master's degree programmes can focus on research or on application, which has to be reflected in the curriculum. Research-oriented degree programmes encompass a subject-specific specialisation in the area of mathematics and natural sciences. The subjects depend on the exact focus of the programme. A programme that focusses on application should include advanced courses in this area.

Depending on the institution's profile, different specialisations are possible. These specialisations can be freely elected by the students. By offering suitable electives, it is possible for an application-oriented programme to ensure that the relevant specialisation subjects, e.g. in engineering, lead to the achievement of the corresponding learning outcomes. Similarly, specialisation subjects in a research-oriented programme with a strong focus on research and fundamentals should ensure the achievement of relevant learning outcomes, e.g. regarding scientific analysis and research methodology.

Subject-specific competences	**Examples of curricular content**
Advanced mathematical, scientific and engineering skills for solving complex problems	Theoretical physics, statistical physics, quantum physics, theoretical optics, quantum technology, modelling in optical design
In-depth subject-specific knowledge, skills and methodological competence for the deepening or broadening of topics in physical technologies	Mathematical methods of physics, simulation, methods of AI, complex sensor systems, deepening of manufacturing technologies
Deeper knowledge in a field of specialisation	Deepening of knowledge and skills in one or several specialisations

General and social competences	Examples of curricular content
Skill to evaluate engineering practice and its implications	Specific competences in physical technologies
Ability to work in a team at national/international level	Project management, team development, leadership and moderation, communication skills, languages, stay abroad
Methodological competences	**Examples of curricular content**
Knowledge/skills for independent work in research and development including documentation, analysis, discussion, conclusion and societal contextualisation	Student research project, final thesis, colloquium
Skill to independently work on a complex and demanding task	Final thesis

4 Types of Courses

The learning outcomes are not limited to professional knowledge and skills, but also include a significant proportion of methodological competences such as social and interdisciplinary competences.

As a rule, these cannot be achieved solely by the necessary courses with classical methods (lectures, exercises, tutorials, etc.), but additionally require a result-oriented, consistent course structure. Thus, general and social competences should be integrated into subject-related courses. For this purpose, traditional course types should be adapted. It is desirable to include innovative learning methods such as blended learning. This relies on a continuous professional development of the teaching staff. Furthermore, a high degree of flexibility is necessary to live up to and anticipate societal expectations (e.g. digitalisation of teaching, use of online tools, virtual examinations etc.)

5 Concluding remark

The contents and learning outcomes listed above are only an overview and are subject to constant change in line with legal expectations and scientific progress. FA 05 closely cooperates with other technical committees to do justice to interdisciplinary degree programmes.