Fachausschuss
Phys.Technologien,
Werkstoffe und Verfahren

ASIIN

SUBJECT-SPECIFIC CRITERIA

For the Accreditation of Bachelor's and Master's degree programmes in physical technologies, materials, and processes

(09 December 2011)

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

1. Preliminary Note

1.1 Function and context

The Subject-specific Criteria (SSC) of the Technical Comittee for Physical Technologies, Materials and Processes have the premise that the intended learning outcomes framed by Higher Education Institutions in their own responsibility and according to their academic profile concerning the programmes submitted for accreditation build the main scale for their curricular review.

Above this the Subject-Specific Criteria of all ASIIN Technical Committees meet a number of important functions:

The SSC are the result of an assessment, regularly performed by ASIIN Technical Committees, which summarize what is considered as good practice by a professional community formed equally by academics and professional practitioners in higher education and is required as future-oriented quality of training in the labour market. The expectations outlined in the SSC for the achievement of study objectives, learning outcomes and competency profiles are not developed statically. They are rather subject to constant review in close cooperation with organizations of the professional community, such as associations of faculties and university departments, professional societies and federations relating professional practice. Applicant universities are asked to study critically the interaction between the intended learning outcomes they strive for, the curricula and their relating quality expectations by using SSC and to position themselves in the light of their own higher education goals.

In their role in the accreditation process the SSC also provide a professionally elaborated basis for discussion among experts, Higher Education Institutions and bodies of ASIIN. By this they make an important contribution to the comparability of national and international accreditation procedures, since it should not be left to chance of the characters of the individual evaluators which technical parameters find their way into discussion and individual assessment. Simultaneously the SSC enumerate those abilities, skills and competencies which may typically be considered as state of the art of a discipline, but which can always be exceeded and varied, and also should be in accordance with the objectives of the university.

For inter- and multidisciplinary studies the SSC of ASIIN can provide orientation for presentation and evaluation. However, they are basically aligned on the core subjects of particular disciplines.

The SSC of the ASIIN are positioned and coordinated internationally and thus contribute to the achievement of the unified European Higher Education Area. They act on requirements of the "Bologna 2020" European strategy to formulate subject specialized, discipline-oriented learning outcomes as one of the most important means for the promotion of academic and professional mobility in Europe as quality requirement. The SSC consider, among others, the many preparations in the context of European projects (e.g. "Tuning") and professional networks.

1.2 Area of competency

The term "physical technologies" subsumes Bachelor's and Master's degree programmes combining comprehensive mathematical-physical fundamentals and principles with suitable focal issues of engineering sciences (above all mechanical engineering, electrical engineering, computer engineering) to form one complete degree programme. In addition, such degree programmes are comprised under this designation showing a distinct cross-section character, so that it is impossible to clearly allocate them to only one discipline of civil engineering. The scope of the share of mathematics and natural sciences is, as a rule, larger then it is the case with classic degree programmes in electrical and mechanical engineering. The relevance and its benefits are in the special bridge function between physical research, technical development, and industrial application.

Typical focal points of studies in the field or under participation of physical technologies are among others **photonics**, **laser technology**, **micro-system technology, nanotechnology**, **surface technology**, **audiology**, **medical technology** or measurement engineering/**sensor technology**.

As today decisive innovations in civil engineering govern the area of materials, degree programmes in materials science and materials/materials technology combine the fundamental principles of experimental and theoretical materials science with physical-chemical fundamentals as well as focal issues in civil engineering (above all mechanical engineering, electrical engineering, computer engineering) and form a new type of study programme. Also in this respect the cross-section character of the programme orientation is to be observed.

Typical focal points of studies in the area of or under participation of materials science are among others **solid state physics, nanotechnology**, **surface technology**, **plastics engineering**, physical metallurgy, **analytical chemistry of materials**, **materials technology**, **failure investigations** or **medical technology**.

An essential aspect of the focal contents of physical technologies and materials science/technology are process aspects. This applies to both the area of development and analysis and the application of corresponding process technologies or the manufacture of special/new materials.
Degree programmes in the field of process engineering accordingly combine fundamentals of mathematics and natural science with those of process engineering and manufacturing engineering as well as with focal contents of the aforementioned fields of focal and engineering studies.

Typical focal points of studies in the area or under participation of the subject group process engineering are laser technology, micro-technology, manufacturing and production engineering, materials technology, foundry technology, joining technology, materials exploration and refinement.

1.3 Collaboration of the Technical Committees

The Technical Committee Physical Technologies, Materials, and Processes works together with the other Technical Committees of ASIIN, mostly to give consideration to the requirements of interdisciplinary study programmes. The universities are called upon to submit their assessment of the assignment of one or several Technical Committees in the course of the application for an accreditation procedure.

Degree programmes with a proportion of more than 50 percent of physical-technological, materials science or process-related contents are overseen by the Technical Committee Physical Technologies, Materials, and Processes who is, as a rule, in charge of the accreditation procedure and seek advice of auditors from other areas, if needed. When it comes to interdisciplinary study programmes with a weighted share of physical-technological, materials science-related contents (below and up to and including 50%) the Technical Committee Physical Technologies, Materials, and Processes and the disciplines involved are jointly responsible or simply provide auditors.

2. Educational objectives – Learning Outcomes

The educational objectives are outlined by the description of the learning outcomes required by the graduates for practising their profession or for post-graduate studies. The outcomes vary in extent and intensity in accordance with the differing objectives of Bachelor's and Master's programmes.

2.1 Requirements on Bachelor's Degree Programmes

Bachelor's degrees are to facilitate early professional careers (professional qualification) in the area of physical technologies, materials science or processes as well as qualify the graduates for advanced scientific degree programmes or additional degree programmes other than in the first cycle degree programme.

Accordingly, Bachelor's degree programmes in the field of physical technologies, materials and processes serve the achievement of the following objectives and learning outcomes:

Knowledge and Understanding

A solid command of fundamental knowledge and an understanding of natural sciences, mathematics, and engineering fundamentals form the basic competence for the achievement of advanced educational objectives.

Graduates:

- know and understand the principles of natural sciences and mathematics forming the basis of the technological-scientific topic area of their focal studies;
- have a systematic understanding of the central elements and concepts of the technological-scientific topic area of their focal studies;

- have a coherent knowledge of the technological-scientific topic area of their focal studies, also comprising knowledge of the latest findings in their discipline;
- are aware of and have knowledge in additional multidisciplinary aspects of thematically-related sciences (informatics, EDP, control engineering, …).

Engineering Analysis

Analysis can comprise the identification of a problem, clarification of a specification, consideration of possible solution methods, the choice of a most suitable method and its implementation. To conduct the various processes with a high degree of quality and to achieve results securely meeting the requirements and in their consistency answering to the purpose of sustainability, scientifically founded methods are necessary the fundamentals of which are known and applied.

Graduates:

- have the required knowledge and understanding to identify, formulate, and by way of established methods, solve problems in the field of civil engineering (which may contain aspects outside the area of their specialisation);
- are qualified to translate generally formulated tasks/requirements into feature-oriented requirement profiles through the application of learned methods and conduct scientific-methodically founded analyses
- are in a position to use their knowledge and understanding to analyse engineering products, processes, and methods;
- are able to apply various methods – such as mathematical analysis, computer-aided design or practical experiments – to the conduction of specific problem analysis and/or the independent solving of methodical questions in the framework of development tasks;
- are able to choose and apply suitable analysis and modelling techniques.

Engineering Design

Developments can relate to devices, processes, methods, or artefacts and the specifications can require consideration of social, health and safety, ecological, and economic framework conditions exceeding the area of technical aspects.

Graduates:

- are qualified to use their knowledge and understanding to conduct developments (products, processes, methods) in accordance with predefined and specified requirements, realise the results, and work with engineers and non-engineers in teams;
- have learned the fundamentals of engineering design methodology and have the competence to apply them systematically.

Investigations and Assessment

Investigations may involve literature, patent and data research, designing and the conduction of experiments, data interpretation, and computer simulation. The consulting of databases, guidelines (codes of good practice), and safety regulations can be necessary to this end.

Graduates:

- are qualified to carry out literature, patent, and data research and to use databases and other sources of information;

- have a sound command of corresponding methods and procedures needed for the documentation of research findings, i. a. list of references, creation of reports, …;
- are able to plan and conduct respectively suitable experiments, interpret the derived data, and draw conclusions;
- can conduct a comparing analysis of their findings with findings stemming from theory / literature and draw the necessary conclusions as to their field of specialisation;
- have the competences required in respect of working in workshops and laboratories.

Engineering Practice

Engineering activities require corresponding methodical competence and practical experience with typical problems in order to develop targeted solutions. Moreover, sound knowledge in the fundamentals of natural sciences, including theory, is an essential element for experts on physical technologies, materials, and processes. This is the only way to safeguard that existing knowledge can be advanced or transferred to new tasks in a targeted manner. Furthermore, the cross-section character of the respective disciplines requires that experts on this topical field also have fundamental knowledge in other engineering or applied sciences.

Therefore, graduates have practical and methodical skills authoritative for the solution of problems as well as a comprehensive fundamental knowledge of natural and applied sciences for the transfer of their know-how to other disciplines. This comprises practical knowledge of:

- the applicability of technologies, the usability of materials, and the applicability of processes and possible limitations;
- programme-specific technologies, processes, and procedures;
- computer-aided data processing, measurement engineering and experiment conduction, and computer-aided design of models;
- technologies, procedures, processes, devices, and tools corresponding to their programme specialisation and related fields;
- workshop practice;
- technically and methodically relevant literature and information sources.

Graduates:

- can combine theory and practice to solve problems with physical-technical background or relating to materials science and processes;
- are qualified to initiate respective developments and substantiate their necessity;
- are in a position to select and apply suitable devices, tools, and methods;
- have developed an understanding of applicable techniques and methods and their limitations;
- are aware of the non-technical consequences of practical engineering activities.

Social Competences

Graduates:

- are able to work and function efficiently on their own and as team members;
- can apply various methods to communicate with the engineering community and society as a whole;
- show an understanding for the health and safety and legal consequences of engineering practice;

- are aware of the responsibility for the consequences of engineering solutions in a societal and ecological environment;
- feel obligated to act in accordance with professional ethics and the responsibilities and standards of engineering practice;
- are aware of the methods used in project management and business practice such as risk and change management and their limitations;
- recognise the necessity of independent life long learning and are qualified to pursue it.

2.2 Requirements on Master's Degree Programmes

As a continuation of an initial university degree, Master's degree programmes lead to the acquisition of advanced analytic-methodical competences. At the same time, the technical competences attained in the first cycle are deepened and advanced.

Knowledge and Understanding

A sound command of advanced knowledge and understanding of the fundamentals of natural sciences, mathematics, and engineering sciences is characteristic to achieve the Master's level educational objectives.

Graduates:

- have a profound knowledge and advanced understanding of the technical fundamentals of the focal subjects of their degree programmes (theory & practice);
- have advanced knowledge in technically related subjects;
- have developed a critical awareness of the latest findings in their discipline;
- are informed about the current status of the findings in their field of expertise.

Engineering Analysis

Analysis can comprise the identification of a problem, clarification of a specification, consideration of possible solution methods, the selection of a most suitable method and its implementation. To conduct the various processes with a high degree of quality and to achieve results meeting the advanced requirements, e.g. with a view to the development status or leading positions, scientifically founded methods applied to the conduction of such processes are known to a comprehensive degree and can be securely applied to an advanced scope and can be developed with a focus on specific tasks.

Graduates:

- have the ability to identify, analyse, and solve problems independently which are incompletely defined or unusual and show competing specifications;
- are qualified to abstract and formulate complex problems arising from a new or emerging field of their specialised discipline;
- are able to apply their knowledge and understanding to the development of engineering models, systems, and processes;
- are able to apply various methods – such as mathematical analysis, computer-aided design, or practical experiments;
- are in a position to recognise the relevance of ecological and economic framework conditions related to social, health and safety issues;
- are qualified to apply innovative methods to problem solutions.

Engineering Design

Developments can relate to devices, processes, methods, or artefacts and the specifications can require consideration of social, health and safety, ecological, and economic framework conditions exceeding the area of technical aspects.

Graduates:
- are qualified to realise engineering designs in accordance with the level of their knowledge and understanding and collaborate with engineers and non-engineers in teams;
- are able to apply their knowledge and understanding to the development of solutions for unusual problems also integrating other disciplines;
- can use their creativity to develop new and inventive ideas and methods;
- can use their ability as engineers to judge in order to structure, process, and/or complete complex, technically demanding, and/or incomplete information in such a way that utilisation under consideration of scientific aspects is safeguarded;
- are in a position to develop and/or optimise systems, processes, and methods on the basis of the learned (degree programme) findings, ideas, products, processes, and methods;
- have been enabled by their studies to develop the level of their knowledge and understanding independently also with a view to later professional practice and to apply such knowledge accordingly.

Investigations and Assessment

Investigations may involve literature, patent and data research, designing and the conduction of experiments, data interpretation, and computer simulation. The consulting of databases, guidelines (codes of good practice), and safety regulations can be necessary to this end.

Graduates:
- are able to apply suitable methods to pursue investigations or detailed research as to technical problems. Should the need arise, they are in a position to advance the level of their knowledge and understanding methodically and independently to the required degree;
- are qualified to identify, locate, and procure required information;
- can define and conduct investigations using the means of analysis, modelling, and experimenting;
- can evaluate data critically and draw conclusions;
- are able to investigate the application of new emerging technologies to their engineering discipline.

Engineering Practice

Engineering activities require practical experience with typical problems in order to develop or reengineer targeted solutions.

Graduates have practical skills in problem solving. They comprise practical knowledge of:
- the usability and limitations of materials;
- computer-aided design;
- engineering processes, devices, and tools;
- workshop practice;
- technical literature and sources of information.

Graduates:

- can combine theory and practice to solve engineering problems;
- can combine knowledge in different fields and handle complex issues;
- are able to consider systematic aspects in problem solutions and implementation (holistic approach);
- have a comprehensive understanding of applicable techniques and methods and their boundaries;
- are familiar with the non-technical consequences of practical engineering.

Social Competences

Graduates:
- fulfil all requirements made on graduates of Bachelor's degree programmes with a view to key qualifications on the higher level of Master's degree programmes;
- can analyse, adjust to external conditions, or reengineer existing organisational units and processes (not only technical);
- can establish and lead organisational units (personnel, processes, infrastructure, technology) responsibly;
- can work effectively as leaders of teams consisting of members of different disciplines and levels;
- are able to lead and moderate discussions in groups or teams with a result-oriented approach;
- can work and communicate effectively in national and international contexts.

3. Curriculum

The intended learning outcomes defined for a particular degree programme are to be achieved by way of a corresponding structure of the contents of the relevant degree programmes. Only through such an outcome-oriented curriculum planning the characteristics such as professional qualification, with a view to corresponding Bachelor's degree programmes or qualification for scientific working in respect of Master's degree programmes, are achieved.

Having the character of a cross section and the orientation of the contents of the degree programmes in physical technologies, materials, and processes therefore require a minimum of the scope of the generally described contents outlined in the following with a view to the outcomes described. The designing of the concrete curriculum has to be defined on the basis of the programme outcomes by the Higher Education Institution.

3.1 Bachelor's Degree Programmes in Physical Technologies

Mathematical Fundamentals including Informatics

These include, inter alia, Algebra, analysis, vector calculus, differential and integral calculus, functions of several variables, linear equation systems, mathematical methods of physics, introduction to informatics, applied informatics and electronic (measuring) data processing.

Fundamentals of Natural Sciences

These include, inter alia, *Experimental physics* (e. g.: mechanics, vibrations and waves, acoustics, thermodynamics, atom and nuclear physics, solid state physics, statistical physics) and

Fundamentals of chemistry and materials science (related to the creation of a focal point of studies).

Subject-specific fundamentals

The contents of engineering fundamentals form the basis of an understanding, a design in compliance with the engineering sciences, and the development of the advanced subjects.

For instance, subjects like construction theory fundamentals, measurement and control engineering, sensor technology, application of micro-controllers, and process engineering etc. are of crucial importance.

The subjects taught in engineering fundamentals are ideally each related to the orientation of the focal studies in the respective degree programme.

Also subject-specific fundamental subjects in natural sciences are orientated on the theme focus of the respective degree programme. This complex can, for instance, comprise subjects such as laser physics, technical optics or acoustics, fundamentals of ophthalmology, medical and orthopaedic technology, materials science, vacuum technology, surface and thin film technology. Together with the courses to be allocated to the advanced subjects in focal studies, these subjects then form the structure of the contents of a degree programme.

Advanced Subjects in Focal Studies

The elected focal point of studies should form a degree programme of necessary scope based on fundamentals of mathematics and natural sciences and in connection with the subject-specific fundamentals in order to accomplish sustainable acceptance on the labour market.

The subjects offered in a field advance or deepen the technological aspects in the area of subject-specific fundamentals. This may comprise courses such as laser technology, laser measurement engineering, laser material processing, laser systems engineering, plasma technology, high-performance materials, manufacture and treatment of ceramics, plastics engineering, fibre-reinforced composites, and image processing.

Non-technical Subjects

These include, inter alia, Foreign languages, business economics, rhetoric, personnel management, soft skills etc.

Industrial placement

Industrial placements are typically completed in a company (in Germany or abroad) which assists engineering practice.

3.2 Master’s Degree Programmes in Physical Technologies

As to **research-oriented** Master’s degree programmes in physical technologies, advanced subjects should concentrate on areas to be allocated to mathematics and natural sciences. The subject-specific offer is oriented on the programme’s focal points.

Examples are special fields of mathematics, system theory, quantum mechanics, statistical physics and solid state physics.

For the education in a **practice-oriented** Master's degree programme in physical technologies advanced modules are, for example, in the subjects engineering mathematics, software applications, e. g. mathematical programmes for the analysis of measuring results or the depiction of theoretical correlations (e.g.: MATHEMATICA, MathCad, …) and in supplements to physics.

Depending on the university profile, different focal studies, e.g. laser technology, nanotechnology or medical technology may be offered and freely elected by the students.

The orientation of Master's degree programmes (application or research-oriented) is reflected in the curricular structure. For instance, with regard to a practice-oriented programme advanced and correspondingly orientated subjects, e.g. from the field engineering sciences, facilitate theachievement of the relevant outcomes, e. g. concerning development competence. Accordingly, advanced subjects with a strong orientation on research and fundamentals in a more research-oriented programme can ensure the achievement of relevant learning outcomes, e. g. concerning scientific analysis and working methodology, to a larger extent.

3.3 Bachelor's Degree Programmes in Materials Science

Fundamentals of Mathematics and Natural Sciences

These include, inter alia, Engineering mathematics (algebra, differential and integral calculus, analytical geometry, vector calculus, Fourier series, Laplace transformation), physics (acoustics, thermodynamics, vibrations and waves), and chemistry (organic and inorganic).

Subject-specific Fundamentals

The contents of engineering fundamentals form the basis of an understanding, a design in compliance with the engineering sciences, and development of the advanced subjects.

For instance, subjects like construction theory fundamentals, applied thermodynamics, processing technology, and materials science and examination etc. are of crucial importance.

The subjects taught in engineering fundamentals are each related to the orientation of the focal studies in the respective degree programme.

Subject-specific fundamental subjects in natural sciences are orientated on the theme focus of the respective degree programme. This complex can, for instance, comprise subjects such as fundamentals of materials science, solid state physics, polymer chemistry, materials used in electrical engineering, surface chemistry and surface physics.

Together with the courses to be allocated to the advanced subjects in focal studies, these subjects form the structure of the contents of a degree programme.

Advanced Subjects in Focal Studies

The elected focal point of studies should form a degree programme of necessary scope based on fundamentals of mathematics and natural sciences and in connection with the subject-specific fundamentals in order to accomplish sustainable acceptance on the labour market.

The subjects offered in this field advance or deepen the technological aspects in the area of subject-specific fundamentals. This may comprise courses such as structural analysis, solid state analysis, semi-conductor or metal physics, manufacture and treatment of ceramics, plastics engineering, composite materials, joining and coating processes, corrosion and wear control, choice of materials, heat treatment, failure investigation, and simulation. Plasma technology, high-performance materials, image processing.

Non-technical Subjects

These include, inter alia, foreign languages, business economics, rhetoric, personnel management, soft skills etc.

Industrial placement

Industrial placements are typically completed in a company (in Germany or abroad) which assists engineering practice.

3.4 Master's Degree Programmes in Materials Sciences

Both **research-oriented** and **practice-oriented** Master's degree programmes have a basis in advanced knowledge in mathematics and engineering sciences in the fields of engineering mathematics, experimental physics, statistical physics and solid state physics, chemistry, and applied mechanics.

Moreover, depending on the orientation of the degree programmes, increased implementation of modules relating to software applications in natural sciences, e. g. mathematic programmes for the analysis of measuring results or depiction of theoretical correlations (for instance: MATHEMATICA, MathCad, …) is sensible.

Depending on the universities' profiles, different focal subjects are offered in materials science, for instance, in the field of materials engineering (metallurgical processes, treatment and processing, application and choice of materials), characterisation and examination of materials, development of materials or the orientation on individual main groups of materials (ferrous metals, non-ferrous metals, polymers, ceramic materials).

The orientation of Master's degree programmes (application or research-oriented) is reflected in the curricular structure. For instance, advanced and correspondingly orientated subjects, e.g. from the field of engineering sciences, could be chosen with regard to a practice-oriented course to ensure achievement of the relevant outcomes, e. g. concerning development competence. Accordingly, advanced subjects with a strong orientation on research and fundamentals may be offered in more research-oriented programmes to achieve relevant outcomes, e. g. concerning scientific analysis and working methodology, to a larger extent.

3.5 Bachelor's and Master's Degree Programmes in Processes Engineering

If degree programmes relating to the above topics are orientated on process engineering contents to an increasing degree this is typically considered in the corresponding fields of subject-specific fundamentals and technical consolidation.

These degree programmes can be allocated to the two above-mentioned topical complexes, so that the above mentioned is transferable.

4. Types of Courses

The learning outcomes outlined in paragraph 2 are not limited to technical knowledge and skills but comprise a considerable share of methodical, social, or cross-subject competences.

As a rule, they cannot be achieved solely by way of courses using classic methods but require an adequately outcome-oriented and consistent form of teaching. Therefore, the achievement of non-technical competences might be sensibly integrated into courses, provided that teaching methods are used which are adjusted in this sense.

Examples of such methods are laboratories (scientific work, teamwork, documentation), seminars focusing on natural sciences or technical subjects (scientific work, investigation, presentation, rhetoric, possibly languages), project work (development, scientific work, investigation, teamwork, documentation).