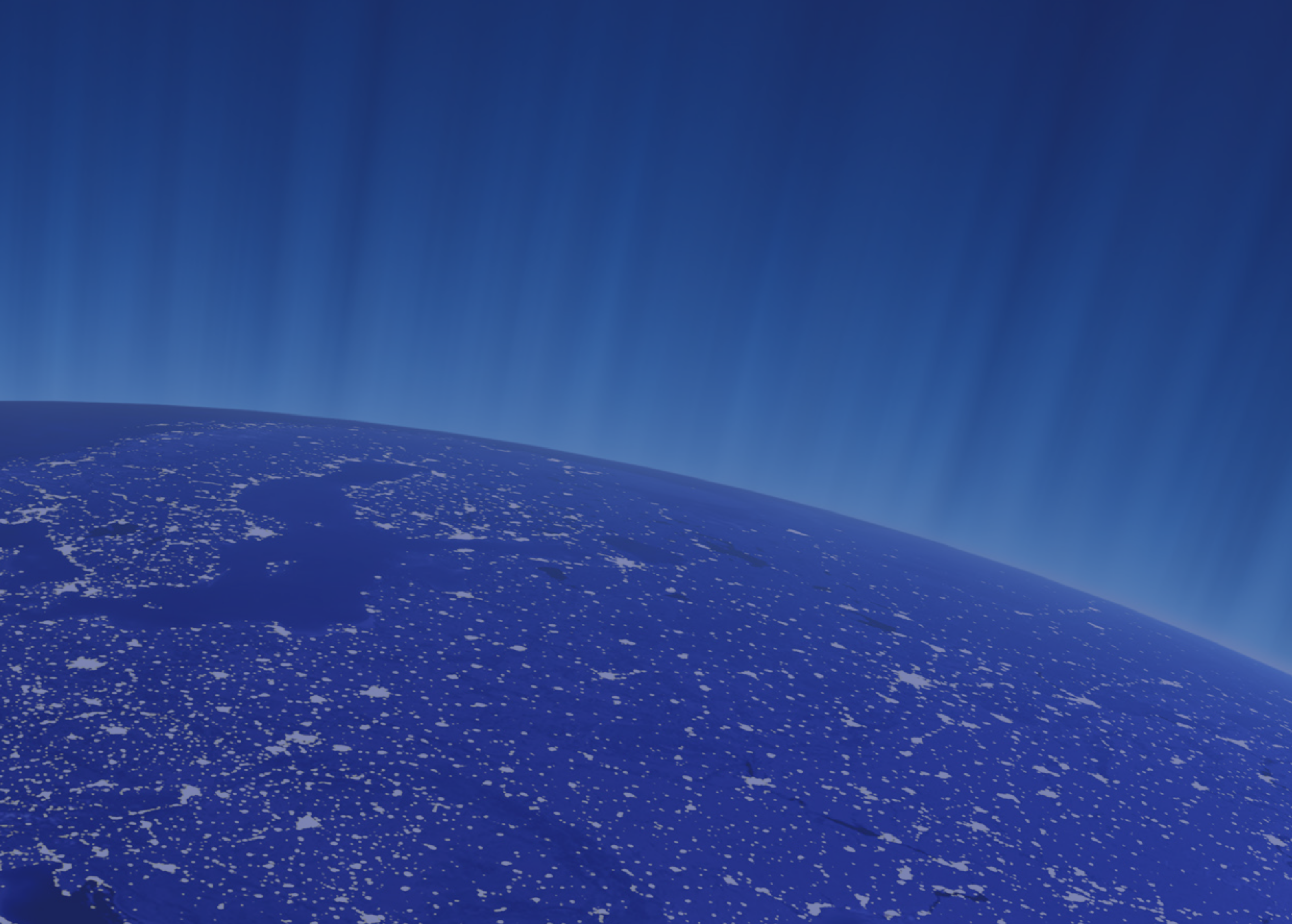
EFCE Bologna Recommendations 2020

European Federation of Chemical Engineering

Europäische Föderation für Chemie-Ingenieur-Wesen

Fédération Européenne de Génie Chimique



EFCE

Tempora aptari decet

Foreword by the EFCE President

Education is one of the prime pillars of wellbeing and prosperity in Europe. In 1999 the European Union started a large modernization project of its higher education systems with the adoption of the Bologna Declaration. Considering the ease at which today's students move between countries, one of the two main goals of the "Bologna Process" has certainly been achieved - at least to a large extent. The second Bologna goal, ensuring the quality of higher education across Europe, has proven to be much more difficult to achieve. Since the beginning of the Bologna Process, many new subjects have been introduced into the academic curricula, new institutions - public and private - joined the education field, the balance between various types of higher education has shifted and new modes of delivery forced their way into the higher education landscape. One can expect that the use of online teaching in particular will see an unprecedented rise due to the 2020 Covid-19 pandemic and the subsequent demand for social distancing whilst nevertheless keeping teaching alive. All of these changes require diligent consideration when trying to accommodate them while ensuring quality education programmes for the next generation.

Since the beginning of the Bologna Process the European Federation of Chemical Engineering (EFCE) has contributed to the developments in the field of Chemical Engineering science and application. In 2005 it published one of the first sets of recommendations for first and second cycle degrees in engineering aligned with the Bologna Process. The document became a well-received and much used guide for shaping chemical engineering degree programmes. In 2010 the recommendations were updated in order to strengthen the outcome orientation and to include the third cycle (PhD degrees). Since then, the harmonization and accreditation of higher education degrees have seen many changes and therefore an update of the EFCE's recommendations is required to remain a point of reference when assessing the quality of a degree programme or developing new provisions in chemical engineering.

The main purpose of the EFCE's recommendations is to ensure that graduates who have completed a chemical engineering degree possess the skills required for chemical engineering practice. This includes not only knowledge of the fundamentals, such as thermodynamics, reaction engineering or separation technology, but also competences beyond engineering science, e.g. for working in teams and across borders. Higher education teachers and programme designers are challenged to accommodate new knowledge (e.g. digitalization) in the curriculum while ensuring enough time and energy is devoted to students achieving the competence levels required to practice chemical engineering. Therefore, the EFCE recommends that chemical engineering programmes include international experience and industrial practice, which complement classroom and laboratory work, digital exercises and (group) projects at the university or other higher education institutions.

The European Federation of Chemical Engineering has no mandate and no desire to enforce any ready-made teaching programmes on the institutions of higher learning, or to hinder the development of new concepts of study. Tables of course content and credits are given as exemplars, not requirements, and in any case, they only amount to two-thirds of the study time. However, the EFCE does not believe there is much that could be omitted from this core without bringing into question the validity of the course as a chemical engineering qualification. Similarly, a proper second cycle degree in chemical engineering, which has become the standard in many countries in Europe, cannot be achieved with much less than 300 ECTS credits spent on relevant subjects. In this respect, this document may also serve as a reference for students wishing to transfer from cognate disciplines to Chemical Engineering to indicate knowledge and skills they may be missing from their previous studies.

Tempora aptari decet: times change and the need to adapt is as great as ever. With globalization, digitalization and the effects of the pandemic, the need for change in our education system may never have been so urgent since the foundation of the European Union. It is hoped that these revised EFCE recommendations will help higher education institutions to educate young chemical engineers in all three cycles to ensure they are capable of solving the problems we face in Europe today and in the future.

Frankfurt, 2020-05-04

Dr. Hermann J. Feise
(EFCE President)

Introduction

According to the 2001 and 2003 communiqués of the Bologna Follow-up Conferences of the Ministers responsible for Higher Education[1] , "first and second cycle degrees should have different orientations and various profiles in order to accommodate a diversity of individual, academic and labour market needs". Broadly speaking two types of higher education provision in chemical engineering are seen in a number of countries: "more research-oriented" first cycle ("bachelor") programmes and more "application-oriented" first cycle programmes. Both types of programmes cover a study of three or four academic years each of 60 ECTS credits (total 180-240 ECTS credits). The length of the programmes may depend on the length of pre-university education. After completion of the undergraduate, first cycle ("bachelor") curriculum, students can continue their study with a second cycle ("master") programme, typically in chemical engineering; this extends to a further 90-120 ECTS credits (1½ - 2 academic years).

The Bologna Declaration recommended the introduction of internationally comparable credit system ECTS (European Credit Transfer and Accumulation System), which provides the required volume of student work per year (about 1500-1800 hours) corresponding to 60 credit points. It follows that one credit point represents a study load of approximately 25-30 hours. The study load includes both physical contact hours (e.g. lectures labs) and self-study. Specific assignment of credits to courses, modules, and other parts of the study is under the authority of a higher education institution, and the introduction of ECTS is at the consideration of each signatory country.

The qualifications framework is primarily aimed at parties responsible for planning degree courses at Universities or Higher Education Institutions. It is intended to aid the development of new courses and the expansion of existing courses. This especially applies to the planning of new, related engineering courses whose students must acquire fundamental key skills in engineering.

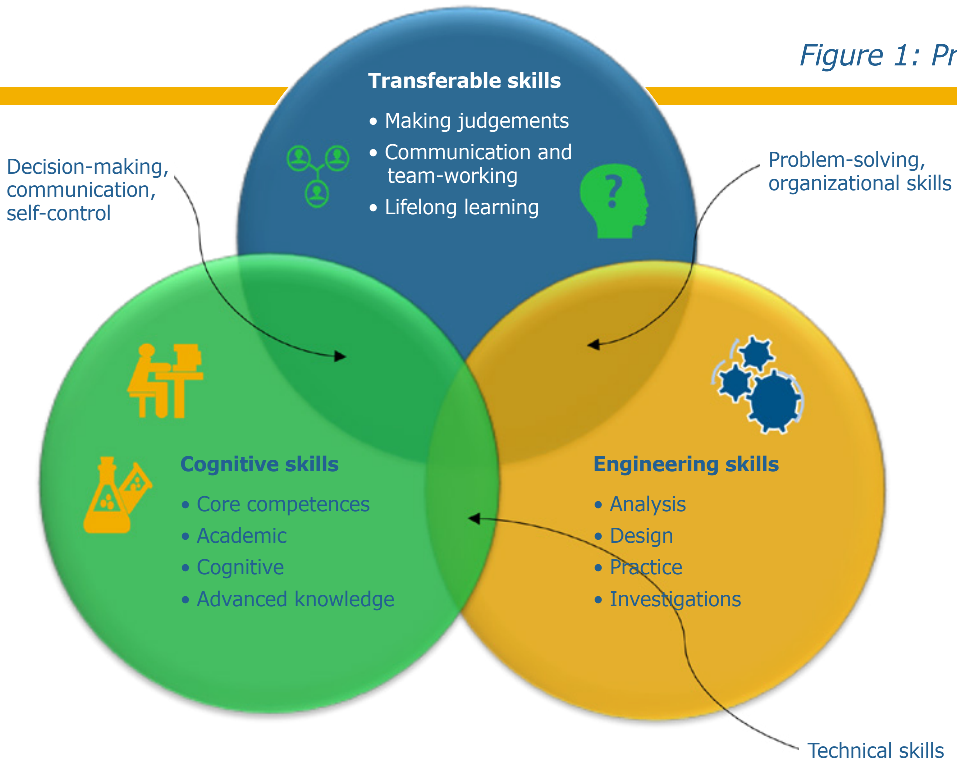
The Accreditation Council, accreditation agencies, and experts working with accreditation processes constitute a second target audience. The latter are tasked with evaluating the relevance of individual degree courses on the basis of the present qualifications framework. Overall, the WPE recommends that the practicality of degree courses is externally evaluated even for system-accredited universities.

The present recommendations for the first and the second cycle adopt the EUR-ACE® Framework Standards and Guidelines (EAFSG) for accreditation of engineering programmes published in 2015, by ENAEE (European Network for Engineering Accreditation), which are grouped into the following Programme Outcomes:

---

[1] A Framework for Qualifications of the European Higher Education Area, Bologna Working Group on Qualifications Frameworks, February 2005

Figure 1: Programme Outcomes



- Knowledge and Understanding;
- Engineering Analysis;
- Engineering Design;
- Investigations;
- Engineering Practice;
- Making Judgements;
- Communication and Team-working;
- Lifelong Learning.

The EAFSG document is a second version of the EAFS document, and according to ENAEE the aim of this revised version was not to alter the fundamental standards which remained unchanged, but to take into account the feedback of ENAEE stakeholders (students, higher education institutions, employers, professional organisations and accreditation agencies), to clarify and simplify the presentation[2]. The most significant change was the replacement of transferrable skills programme outcomes with the three explicitly stated outcome categories relating to these skills. Whilst the EFCE recommendations retain these as separate outcome categories, it is important to note that it is expected that graduates demonstrate their achievement in the context of the remaining knowledge and skill outcomes stated above.

The recommendations accommodate the outcomes of both "more research-oriented" and "more application-oriented" chemical engineering programmes, with the former tending to show more scientific depth and the latter more practical competencies.

[2] EUR-ACE Framework Standards and Guidelines, Edition March 31, 2015

NOTE: throughout these recommendations, and as in the EAFS document, the term "chemical engineering graduate" (or simply "graduate") is used to describe someone who successfully completes an accredited degree programme in chemical engineering. The term "chemical engineer" has been avoided because of the confusion that could arise from its widely different interpretations throughout Europe (and also worldwide), including specific regulatory meanings in some countries.

The programme outcomes are formulated in a general way, to emphasise what should be common to chemical engineering education. The core curriculum proposed here with additional appropriate topics in science, in chemical and other engineering, and in non-technical areas will exemplify the general outcomes through a variety of concrete examples. Thus, different chemical engineers will be able to handle the demands of different industries and tasks: e.g. oil refining, bulk and fine chemicals, paper, polymers, food, cosmetics, pharmaceuticals, environmental issues. Particularly second cycle graduates will be able to perform research tasks and go on to doctoral studies.

A large percentage of chemical engineers are now engaged in making various specialty products (formulated products), and relatively fewer in making traditional commodity chemicals. While all chemical engineers still need many of the traditional chemical engineering skills, the EFCE feels there is now a need to include the knowledge of "product engineering" more extensively in the common core in order to reflect the increasing importance of modern materials science. The changes in the profession, activity sectors, teaching methods, the evolution of learners, the growing importance of international collaboration, sustainability and digital methods and tools require updates within university curricula.

It is currently anticipated that the digital transformation will introduce considerable challenges and changes to the entire education sector and its institutions. This will especially be due to the increasing pace, at which knowledge is produced, the manifold ways of accessing it and the forthcoming changes to the labour market.

The WPE believes that the academic and multidisciplinary qualifications outlined in the present qualification's framework will remain fully valid in an increasingly digital world. Universities and HEI (Higher Education Institutions) lecturers are encouraged to explore new teaching methods that will allow them to convey these qualifications more effectively and increase compatibility with the current generation of students, who are increasingly "digital native.

In addition to professional expertise and non-technical skills (key qualifications), students must internalise their social and political responsibility and the significance of ethical, responsible conduct in the field of engineering

Further, these recommendations give the higher education institutions the opportunity to introduce their own "flavour" and/or innovative concepts into their programmes. For this reason, core curricula are proposed which cover only two thirds of a first cycle ("bachelor") programme and the framework of a second cycle ("master's") degree.

Programme outcomes

In line with recommendations/requirements from other bodies (including accreditation bodies), EFCE has formulated its recommendations first and foremost as programme outcomes, i.e. what the students should know or be able to do immediately after graduation. As set in the EAFSG2, "Programme Outcomes describe the knowledge, understanding, skills and abilities which an accredited (chemical) engineering degree programme must enable a graduate to demonstrate." In addition, such standards describe the Programme Outcomes that accredited programmes must meet, but do not prescribe how they are realised. Higher education institutions retain the freedom to (re) formulate programmes with an individual emphasis and character and to prescribe conditions for entry into each programme.

In order to describe appropriate learning or programme outcomes, the use of a taxonomy is recommended. One of the most frequently used taxonomies is the Bloom´s taxonomy (named after Benjamin Bloom, 1913-1999)[3], a system of terms that facilitate the qualitative evaluation of study outcomes. It distinguishes between six levels of competence, where each level includes all subordinate levels. Throughout this document Bloom's taxonomy (see appendix) is used to indicate the level of competence or proficiency and applied to e.g. module descriptions and competence-based examinations.

[3] Bloom, B. S., Engelhart, M. D., Furst, E. J., Hill, W. H., Krathwohl, D. R. (1956), Taxonomy of educational objectives: The classification of educational goals. Handbook I: Cognitive domain. New York: McKay

First Cycle ('Bachelor') Chemical Engineering programme outcomes

A first cycle degree graduate should meet the following criteria:

- **Knowledge and Understanding**

  The graduates have the ability to:
  - describe and explain basic knowledge of mathematics, physics, chemistry and biology which enables them to achieve the other programme outcomes and understand the phenomena which occur in the field of chemical engineering;
  - explain and interpret the fundamental principles of chemical engineering for the modelling and simulation of chemical reactions and bio molecular processes, of energy, mass and momentum transport processes, and of separation processes;
  - describe the basic principles of measurement techniques and control and to transfer these principles into practical applications;
  - recognize the wider multidisciplinary context of chemical engineering.
- **Engineering Analysis**

  The graduates have the ability to:
  - identify problems of different complexity in their subject and to abstract, formulate and solve them holistically using fundamental principles;
  - consider, analyse and evaluate products, processes and methods of their subject on a system engineering base; to correctly interpret the outcomes of such analyses;
  - select and apply suitable methods of analysis, including experimentation, modelling, simulation and optimisation.
- **Engineering Design**

  The graduates have the ability to:
  - develop a basic design for products and processes according to specified requirements, which can include an awareness of non-technical – ethical, societal, health and safety, environmental, economic and industrial – considerations;
  - choose suitable design methods and apply them;
  - design products, processes and unit operations of mass and energy transformation using some awareness of the forefront of their graduation field.
- **Investigations**

  The graduates have the ability to:
  - investigate a real chemical engineering problem by a scientific approach;
  - search, use and critically reflect on library and web resources for the acquisition of information regarding equipment characteristics and design methods, physical properties, kinetic and thermodynamic data or other technical information;

- formulate appropriate specifications, analysis and safety assessment before starting experimental work;
- plan and carry out experiments and to interpret the results and draw conclusions with guidance of a senior scientist (chemical engineer).

- **Engineering Practice**

  The graduates have the ability to:
  - combine theory and practice in order to analyse and solve problems of engineering science using methods based on fundamental principles;
  - evaluate the potential use and limitations of applicable techniques, methods, materials, equipment, tools, engineering technologies and processes;
  - organise and carry out projects;
  - work respectfully with specialists from other disciplines;
  - recognise and evaluate the importance of non-technical – ethical, societal, health and safety, environmental, economic and industrial – constraints and to behave accordingly
  - apply norms of engineering practice in their field of study.

- **Making Judgements**

  The graduates have the ability to:
  - gather and interpret relevant data and handle complexity, and to inform judgements that include reflection on relevant social and ethical issues;
  - organize complex technical or professional activities or projects, taking responsibility for decision making;
  - understand the impact of engineering solutions in an environmental and societal context.

- **Communication and Team-working**

  The graduates have the ability to:
  - present the results of their work in both written and oral form in an articulate way;
  - communicate effectively information, ideas, problems and solutions, with specialists and non-specialists (even with the society at large), using modern presentation tools as appropriate;
  - work individually and as team members in national and international and/or multidisciplinary teams, using more than one language, including English.

- **Lifelong Learning**

  The graduates have the ability to:
  - improve their knowledge and skills, learn on their own, and recognise the need for life-long learning;
  - follow developments in science and technology self dependently;
  - manage their work and time for lifelong learning.

Second Cycle ('Master')
Chemical Engineering programme outcomes

After graduation, a second cycle ("master's") degree chemical engineering graduate should fulfil the following qualifications in addition to the qualification acquired during the first cycle:

- **Knowledge and Understanding**

  The graduates have the ability to:

  - carry out scientific work and to act responsibly in their professions and in society based on the extensive and profound knowledge of mathematics, physics, chemical engineering and other sciences acquired at a level necessary to achieve the other programme outcomes;
  - recognize and evaluate new developments in their field;
  - recognize the wider multidisciplinary context of chemical engineering and of knowledge issues at the interface between different fields and interact across interdisciplinary boundaries.

- **Engineering Analysis**

  The graduates have the ability to :

  - identify, analyse and solve complex problems scientifically, even if the definitions are incomplete or are formulated in an unusual way and show competing specifications, and that may involve considerations from outside their field of study and non-technical – societal, health and safety, environmental, economic, ethics and industrial – constraints;
  - abstract, formulate and solve complex problems from a new or a developing field;
  - apply innovative methods in solving problems based on fundamental principles;
  - conceptualise chemical engineering products, processes and systems;
  - analyse new and complex products, processes and systems within broader or multidisciplinary contexts; to select and apply the most appropriate and relevant methods from established analytical, computational and experimental methods or new and innovative methods; to critically interpret the outcomes of such analyses.

- **Engineering Design**

  The graduates have the ability to:

  - develop concepts and solutions to problems based on fundamental principles but also to problems which are posed in an unusual way – if necessary involving other fields and non-technical – societal, health and safety, environmental, economic and industrial/commercial – constraints;

- develop and design new and complex products, equipment, processes or methods;
- use their powers of judgment as engineers in order to work with complex and possibly incomplete information, to recognise discrepancies and to deal with them;
- select and apply the most appropriate and relevant design methodologies and to use creativity to develop new and original design methodologies.
- design using knowledge and understanding at the forefront of their specialization.

- **Investigations**

  The graduates have the ability to:

  - tackle a real chemical engineering problem by a scientific approach, using their skills and knowledge to identify, critically evaluate, derive (if necessary) and quantify the required information or data;
  - recognise the need for information, the means of finding and providing reliable and relevant information;
  - plan and carry out theoretical and experimental work independently;
  - evaluate information and data critically and draw conclusions from it;
  - examine and critically evaluate the application of new and emerging technologies;
  - develop and apply codes of practice and safety regulations.

- **Engineering Practice**

  The graduates have the ability to:

  - classify knowledge from various fields methodically and draw systematic conclusions from it and also to deal with complexity;
  - familiarise themselves with new tasks systematically within an appropriate timeframe;
  - think systematically about the non-technical impacts of an engineer's job and to include these aspects responsibly in what they do;
  - find solutions which require very considerable competence as far as techniques and methods of analysis, design and investigation and of their limitations are concerned;
  - show practical skills, including the use of computer tools, for solving complex problems, realising complex engineering design, designing

and conducting complex investigations;
- critically use applicable materials, equipment and tools, engineering technologies, software and processes, and be aware of their limitations;
- work in a complex environment, being aware of ethical, societal, health and safety, environmental, economic and industrial implications of engineering practice;
- perform critical analysis of economic, organisational and managerial issues (such as project management, risk and change management).

- **Making Judgements**

  The graduates have the ability to:

  - integrate knowledge and handle complexity, to formulate judgements with incomplete or limited information that include reflecting on social and ethical responsibilities linked to the application of their knowledge and judgement;
  - manage complex technical or professional activities or projects that can require new strategic approaches, taking responsibility for decision making.

- **Communication and Team-working**

  The graduates have the ability to:

  - function effectively in national and international contexts, as a member or leader of a team, that may be composed of different disciplines and levels, and that may use virtual communication tools;
  - use diverse methods to communicate clearly and unambiguously their conclusions, and the knowledge and rationale underpinning these, to specialist and non-specialist audiences in national and international contexts in their mother tongue as well as in English.

- **Lifelong Learning**

  The graduates have the ability to:

  - follow developments in science and technology self dependently;
  - improve their knowledge and skills, learn on their own using appropriate media, and recognise the need for life-long learning;
  - manage their work and time for lifelong learning;
  - engage in independent life-long learning.

The EFCE expects that the final outcomes of second cycle (“master’s”) degree programme to be (at least) equivalent to those of traditional long-cycle (4½ – 5 years) programmes.

Third Cycle (‘Doctorate’)
Chemical Engineering programme outcomes

In addition to the qualification acquired during the first and second cycle, a graduate of the third cycle will:

- have demonstrated a systematic understanding of a field of study and mastery of the skills and methods of research associated with that field;
- have demonstrated the ability to conceive, design, implement and adapt a substantial programme of research with engineering integrity;
- have made a contribution through original research which extends the frontier of technology and knowledge by developing a substantial body of work, some of which merits national or international peer-reviewed publication and/or could result in patents;
- be able to compose a critical analysis, evaluation and synthesis of new and complex ideas and be able to justify choices taking into consideration technological, societal, temporal and economic constraints;
- be able to develop project plans and to specify required resources in international context.
- be able to communicate with their peers, the larger international scholarly community and with society in general about their ideas or expertise in the mother tongue as well as in English;
- be able to promote, within academic and professional contexts, technological, social or cultural advancement in a knowledge-based society.

Achieving the learning outcomes of the first cycle and second cycle

To ensure the appropriate common content and levels of the different first and second cycle degrees, EFCE recommends minimum requirements for certain subjects and topics (e.g. mathematics and reaction engineering) that form the core curriculum for each cycle.

Although the first cycle ('Bachelor') core curriculum is more detailed than the second cycle ('Master') programme, there is still much of the total study left to give the institutions the opportunity to implement their own specialism and/or new development in the field of chemical engineering.

For the second cycle the recommendations are very general, making it easy to give a broad range of different orientations within and between institutions while meeting the general learning outcomes.

Note that the curriculum recommendation lists topics. EFCE makes no recommendation on the number of courses that should be studied, or on how topics should be grouped in courses. Furthermore, in practice many of the listed topics may be part of larger courses.

A typical chemical engineering bachelor curriculum is 180-210 ECTS in Europe, but 240 ECTS are required in some countries. Chemical engineering master curricula are typically 60 to 120 ECTS. The tables below give suggested credit ranges of the required disciplines in a chemical engineering first cycle and a second cycle curricula. The credit ranges are applicable in the first cycle for 180-210 ECTS curricula and in the second cycle for 90-120 ECTS curricula. For other schemes the figures have to be adapted accordingly.

First Cycle ('Bachelor') Chemical Engineering programme

It is expected that the chemical engineering fundamentals are delivered through examples of their applicability in a wide range of chemical and process industries and hence the boundary between these outcomes and those in the chemical engineering sciences or field specific chemical engineering applications may be closely linked. Typically, a first cycle ("bachelor's") degree course will contain 20-30 % science courses, 40-50 % engineering courses, and up to 10 % complementary topics.

Core curriculum Chemical Engineering (First cycle)	Minimum ECTS Credits	Range in %
Fundamentals of science and natural sciences Mathematics, informatics (including data management and digitalization toolbox), physics, chemistry, biology.	35	20% to 30%
Chemical Engineering fundamentals Material and energy balances, thermodynamics, fluid dynamics, heat and mass transfer, separations processes, chemical reaction engineering, unit operations, bioprocess engineering, process control	50	30% to 40%
Core Chemical Engineering applications e.g. basic product engineering, chemical and process safety, health and environment, design and process software and analytical techniques	10	5% to 12%
Chemical Engineering sciences or field specific chemical engineering applications according to the main emphasis of the degree course of the university; it might include a longer industrial internship as well. Classical or modern areas of the field, e.g. bioprocess engineering, biomaterials, food engineering, pharmaceutical engineering	30	15% to 25%
Complementary fields e.g. economics, management, entrepreneurship, regulatory frameworks, teamwork professional English	10	5% to 12%
First Cycle ('Bachelor's') thesis project or design project Final thesis or design project is not required at the bachelor level, but if it is not included, minimum 10 engineering design credits (cumulative) are required in the curriculum	10	5% to 10%

Second Cycle ('Master') Chemical Engineering programme

Although no topics are specified here, other than illustrative examples, it is clear from the recommended learning outcomes that central chemical engineering topics such as transport phenomena, chemical reaction engineering, dynamic modelling as well as general topics such as statistics/optimization/parameter estimation must be included to the extent they have not already been covered in the bachelor study. It is recommended that the curriculum should include elective courses or applications to a high extent (up to 25%) to ensure that the chemical engineering master graduates are well prepared to meet their individual career goals.

Core curriculum Chemical Engineering (Second cycle)	**Minimum ECTS Credits**	**Range in %**
Mathematics and science Extension of mathematical and scientific subjects with special focus given to the requirement fundamentals of the digitalization, environment, energy or biotechnology, among others	9	10% to 20%
Advanced chemical engineering fundamentals and applications e.g. advanced courses in multiphase reactor engineering, catalysis, transport phenomena, modelling and simulation	25	25% to 50%
Advanced chemical engineering sciences, natural sciences or field specific chemical engineering applications according to the main emphasis of the degree course of the university; it might include a longer industrial or research internship/project as well. Classical or modern areas of the field, e.g. bioprocess engineering, biomaterials, food engineering, pharmaceutical engineering. Intersectoral influence	18	20% to 40%
Complementary fields e.g. advanced economics, project management, leadership, entrepreneurship, communication and other professional competencies	5	5% to 10%
Second Cycle ("Master's") thesis project	20	15% to 25%

Programme Management

The programme must be organized to enable students and teachers to achieve the outcomes. Some recommendations dealing with admission requirements, teaching and learning, international and industrial experiences, assessments, re-sources, ethics and quality assurance are proposed by the EFCE. The guidelines are taken from different references, as broadly as possible, are not prescriptive, but are intended to help Higher Education Institutions to meet the standards and maintain quality in teaching chemical engineering. Management concepts such as:

- Learning management system (course registration, teachers, training (online, offline, ...), portal for remote delivery)
- Project management system (resource and cost planning, control)
- Content management system (content, host IP for customization)
- Document management system (collaboration workspace, document repository, ...)

will serve as a training "back office".

Admission requirements

Admission to the Bachelor's degree requires an appropriate and satisfactory standard of knowledge of underpinning mathematics and sciences, certified by a qualification granting access to general higher education (International Baccalau-reate, Abitur, Senior Secondary Certificate of Education, A-levels, etc.).

Admission to the Master's level requires a Bachelor's degree in a relevant subject. Candidates with a bachelor's degree in a different (related) discipline should demonstrate a special aptitude for the subject and core knowledge enabling the candidate to successfully engage in the second cycle chemical engineering programme. The institutions offering these courses to candidates should provide the necessary mechanisms to these candidates to be able to demonstrate the achievement of the programme outcomes at the required (master's) level. This may be, for example, through complementary remedial courses.

Teaching and Learning

The teaching and learning process should enable the graduates to demonstrate their acquisition of the skills and knowledge specified in the programme outcomes. These should promote independent and team working, responsibility, multidisciplinary, systemic thinking, conceptualization, intrinsic safer and sustainable thinking, connections between different subjects, communication, interculturalism, innovation, management, and initiation to lifelong learning and time management.

The teaching and learning methods should be appropriate to the nature of content, the number of students taught, their various entry qualification levels and learning styles, and should be chosen so that the programme and learning outcomes can be achieved. The choice of the delivery method is at the discretion of the responsible teaching unit, consistency with the university requirements, but the use of various methods in teaching is encouraged. These should include lectures, problem and project based learning, tutorials, laboratory and workshop sessions, and could be completed by distance learning, blended, flipped, computer aided based, peer-assisted learning, etc. The use of innovative teaching methodologies and innovation in teaching is encouraged.

The use of instruments, such as student's feedback questionnaires and period institutional quality reviews, to increase the teaching effectiveness and learning quality should be also promoted.

International Experience

Chemical engineering graduates can frequently be employed in companies and organisations that are operating globally. Therefore, periods of learning in anoth-er country, either in industry or at university, are recommended.

The international experience should last at least 3 to 6 months, should be as-sessed and should contribute to the degree award. It should thus include clearly defined learning outcomes, assessed by relevant ECTS.

Mastery of at least one foreign language, including English, in the context of Chemical Engineering professional communication (lab or project reports for example) is strongly recommended. The level of acquisition can also be certified by international standard tests.

Industrial Experience

Industrial internships aim to familiarize prospective engineers with the industrial workplace. They are intended to contribute to the engineering practice, and to become familiar with a safe working environment, to illustrate the applications and limitations of theory, to set the courses in a wider context, to understand the nature and approach of applied industrial projects and to provide social and management skills. From the industrialist point of view, such internships allow to engage in the formation of the future engineers by providing them with the opportunity to participate in real industrial projects, to establish and maintain cooperation with universities, to meet potential future employees, and to contribute to the practical training of engineers. Internships may help students acquire job relevant skills such as communication skills (writing and oral), and help students put abstract concepts into context. By immersing students into real-world settings, we could observe that problem solving, critical thinking, and rhetorical skills are improved in non-academic settings. Internships reduce reality shock for students and prepare them for the first job employment. The benefits of industrial placement are underlined by students, academics providing academic support during such placements, and employers providing opportunities.

Industrial experiences are recommended for both Bachelor's and Master's degree.

For the Bachelor's degree, the internship objectives are to develop communication skills, to consolidate technical knowledge of processes and materials, to have a knowledge of an industrial environment, to discover the responsibilities of a manager and to become familiar with the culture of the engineer. The recommended duration is ca. 2 months.

For the Master's degree, the internships objectives are to reinforce the scientific, technical and managerial skills of future engineers in professional situations, to apply the technical and methodological skills learned at university on industrial situations, to present and defend his conclusions. The recommended duration is between 2 and 5 months.

Universities may use a dedicated department, who can advertise the placement opportunities, but students are also encouraged to apply for such internships, to enhance their professional communication skills. The internships should contribute to the achievement of the programme, and thus be supervised by an academic tutor, who may visit the student during the placement. A contract, which specifies the objectives and conditions of employment, can be signed by the university, the industrialist and students (as well as a potential non-disclosure agreement) and the placement should be assessed.

The company should issue an employer's referee to supervise the internship, and the Working Party Education does not recommend any unpaid placements.

Assessment

The assessment should be aligned with the programme outcomes and confirm that students are able to apply (transfer, see Figure 2) the learning outcomes of the teaching units. Compensation strategy (possibility for students to compensate a poor performance in a teaching unit by achieving better marks in another one) is not recommended. Assessments should be rigorous and fair and include safeguards against academic dishonesty (e.g. plagiarism and other forms of academic misconduct).

Diverse forms of assessments should be proposed, and may include classical examinations, continuous monitoring, labs and project reports, oral presentation and other innovative forms of assessment. EFCE emphasises the need for appropriate feedback to maximise the learning effect of the assessments.

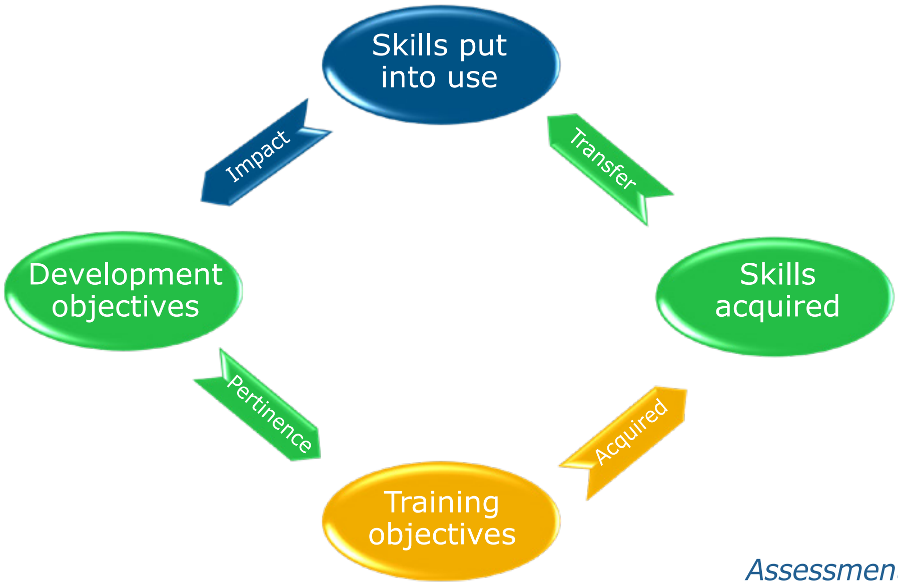


Figure 2: Assessment objectives

Resources

The human and physical resources must be sufficient to deliver the programme. The number of teaching staff should be adequate to enable the students to demonstrate their acquisition of the programme outcomes. The academic staff should be qualified in chemical engineering and cognate disciplines and should receive regular training and/or support in teaching methodologies.

The laboratory, teaching and working rooms, computing and software should support the programme and ensure active involvement of the students. Arrangements must be made for students to have safe access to these facilities, including practical work.

Ethics

It is recommended to include ethics as an integral part of the curriculum. In the field of (chemical) engineering, ethics learning outcomes should be related to:

- **Society:** The engineer is a responsible citizen ensuring the link between science, technology and the human community. He/she is aware of the issues that engineering raises for society and promotes the public awareness of engineering benefits and impacts.
- **Knowledge and skills:** The engineer acts with accuracy and rigour, he/she explains the basis of his/her decisions, regularly updates his/her knowledge and skills according to the evolution of science and technology. He/she is aware of other disciplines. The engineer is rigorous in the analysis, the treatment, the decision and the choice of the solution.
- **Profession:** The engineer acts honestly and with integrity, he/she fully utilizes his/her skills, while being aware of their limitations. He/she is loyal to the culture and values of his/her partners and customers. He/she cannot act contrary to his/her professional conscience and respects the opinions of profes-sional partners. The engineer behaves towards his/her em-ployees with loyalty and fairness without any discrimination.
- **Environment:** The engineer respects life, law and public good. He/she takes account of limited availability of human and natural resources, he/she holds paramount the health and safety of others and is aware of the impact of technical achievements on the society and on the environment. He/she seeks to achieve the best result by making the best use of the means at his/her disposal and integrating the human, economic, financial, social and environmental dimensions.

Introduction to the ethics of engineering helps students to prepare for professional life and to identify problems that may arise during their career. Ethics also helps students to develop broader skills, including implications of their work in society.

Quality Assurance

Each educational institution should have an ongoing review procedure of the educational process to ensure the programme outcomes are consistent with the needs of employers and other stakeholders, to ensure the teaching units learning outcomes aggregate to the programme outcomes and that the teaching methodologies are adapted to the students learning styles. In this context, EFCE recommends to regularly evaluate the effectiveness of each teaching unit (and the teaching staff involved), using for example student feedback surveys. They could be extended with external assessment of the outcomes by professional bodies and/or a panel composed of industrials, former graduates and academics involved in Chemical Engineering Education.

Annex –
Bloom's taxonomy and sample methods

Bloom's taxonomy (named after Benjamin Bloom, 1913–1999) is a system of terms that facilitate the qualitative evaluation of learning outcomes[4]. It distinguishes between six levels of competence (C1–C6). Each level includes all subordinate levels of competence (cf. Figure A.1) and some verbs are associated with the corresponding competencies (cf. Table A1)[5].

The taxonomy is used to specify the level of competence of proficiency. It is used for module descriptions and competence-based examination models.

For the completion of modules on a bachelor's degree course, the competence levels C1–C4 are normally used.

They are described as follows:

» C1: Knowledge

The recognition and recall of information, facts, definitions, structures, patterns, methods, etc. Learned knowledge can be reproduced.

» C2: Comprehension

The understanding of information, its significance and scope. Recognition of interrelationships in new contexts.

» C3: Application

The ability to convert information into action in familiar and new contexts. Application is a different process from learning. It may require the student to modify parts of the learned material to reach a solution.

» C4: Analysis

The ability to break down complex information into its component parts. This allows the student to recognise the structures, hierarchies and interrelationships between these parts. Intentions and possible contradictions are recognised. Analysis is a process with creative tendencies.

» C5: Synthesis

The component parts of information (cf. Analysis) are reassembled into new structures. Synthesis is a creative process.

» C6: Evaluation

The ability to evaluate the usefulness and quality of complex models and information. It allows the student to identify errors and their causes and make informed decisions. Evaluation is a critical process.

---

[4] Bloom, B. S., Engelhart, M. D., Furst, E. J., Hill, W. H., Krathwohl, D. R. (1956), Taxonomy of educational objectives: The classification of educational goals. Handbook I: Cognitive domain. New York: McKay

[5] Kennedy, Hyland, Ryan (2007) Writing and Using Learning Outcomes: a Practical Guide, Implementing Bologna in your institution, C 3.4-1

Figure A1: Different levels of competencies

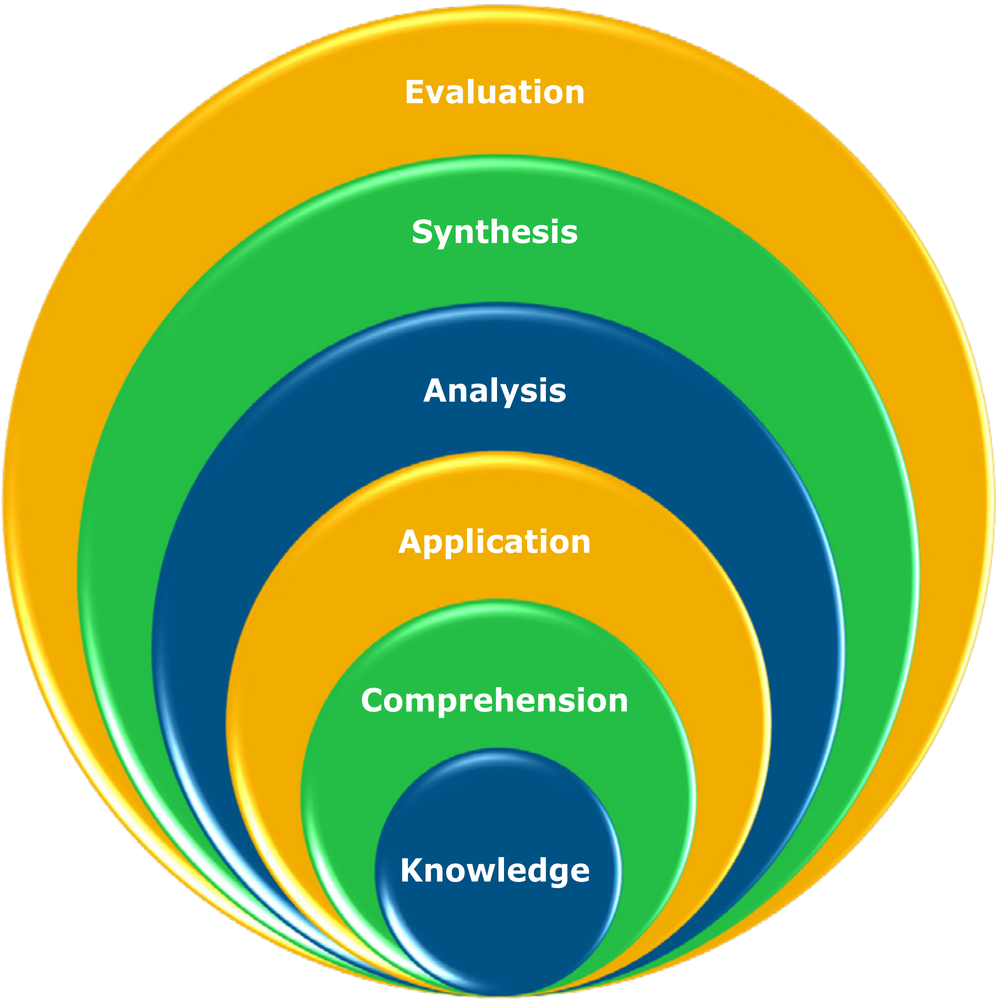


Table A1: List of verbs and their association with the corresponding competencies

Knowledge	Comprehension	Application	Analysis	Synthesis	Evaluation
Cite	Approximate	Adapt	Analyze	Appraise	Abstract
Define	Articulate	Allocate	Characterize	Assess	Arrange
Describe	Associate	Apply	Compare	Compare	Assemble
Draw	Characterize	Assign	Confirm	Conclude	Budget
Enumerate	Clarify	Calculate	Contrast	Contrast	Categorize
Identify	Classify	Capture	Correlate	Counsel	Code
Indicate	Compare	Classify	Detect	Criticize	Combine
List	Compute	Complete	Diagnose	Defend	Compile
Match	Contrast	Compute	Differentiate	Determine	Compose
Name	Convert	Construct	Discriminate	Discriminate	Construct
Outline	Describe	Customize	Dissect	Estimate	Create
Point	Detail	Demonstrate	Distinguish	Evaluate	Debug
Quote	Differentiate	Derive	Document	Explain	Depict
Read	Discuss	Determine	Ensure	Grade	Design
Recall	Distinguish	Draw	Examine	Hire	Develop
Recite	Estimate	Employ	Explain	Interpret	Devise
Recognize	Explain	Examine	Explore	Judge	Dictate
Record	Express	Exercise	Figure out	Justify	Enhance
Repeat	Extend	Explore	Identify	Measure	Explain
Reproduce	Give	Expose	Infer	Predict	Facilitate
Review	Interact	Express	Interrupt	Prescribe	Formulate
Select	Interpolate	Factor	Inventory	Rank	Generalize
State	Interpret	Figure	Investigate	Rate	Generate
Study	Observe	Graph	Layout	Recommend	Handle
Tabulate	Paraphrase	Handle	Manage	Release	Import
Trace	Review	Illustrate	Maximize	Select	Improve
Write	Rewrite	Manipulate	Minimize	Summarize	Incorporate
	Subtract	Operate	Optimize	Support	Integrate
	Summarize	Personalize	Outline	Test	Model
	Translate	Plot	Point out	Validate	Modify
	Visualize	Practice	Prioritize	Verify	Organize
		Prepare	Proofread		Outline
		Produce	Query		Plan
		Provide	Relate		Prepare
		Relate	Select		Prescribe
		Show	Separate		Produce
		Simulate	Subdivide		Program
		Sketch	Transform		Rearrange
		Solve			Reconstruct
		Subscribe			Reorganize
		Tabulate			Revise
		Transcribe			Rewrite
		Translate			Specify
		Use			Summarize