Discussion paper EFCE-WPE

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Recommendations for Chemical Engineering Education in a Bologna Three Cycle Degree System
(2nd, revised edition, 2010)

Foreword (to become part of the foreword by the Scientific VP)
The Bologna declaration in 1999 was the start of the introduction of a three cycle degree system in Higher Education in Europe. Nowadays many European universities have adopted this degree structure. In 2005 the European Federation of Chemical Engineering (EFCE) formulated recommendations for first and second cycle in chemical engineering education in Europe, and published a statement supporting the goals of the Bologna process. EFCE is convinced that there is no need for recommendations for the third cycle of chemical engineering study programmes.

On this occasion a few words of comment seem necessary.

The Federation has no intention to enforce any ready made teaching programmes on the institutions of higher learning, or to hinder the development of new concepts of study. However, it feels necessary to point out, that degree programmes comprising hardly any mention of such fundamental for the profession subjects as, for example, thermodynamics, fluid mechanics, transport phenomena, separation techniques or reaction engineering, cannot be called chemical engineering programmes (unfortunately, such programmes still do exist at some schools).

In past years many professional bodies in different countries used the EFCE recommendations as a basis for their “new” chemical engineering curricula. On national and international level many accreditation bodies also defined quality frameworks and learning outcomes for programmes in the field of engineering, including chemical engineering. For this reason the recommendations of the EFCE are updated to these recent developments

Introduction

According to the 2001 and 2003 communiqués of the Bologna Follow-up Conferences of the Ministers responsible for Higher Education, “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”. Therefore in a number of countries in Europe we can distinguish two types of higher education in chemical engineering: “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 credits (total 180-240 credits). The length of the programmes may depend on the length of pre-university education (age of students 17 or 18 years old). After completion of the undergraduate, first cycle (“bachelor”) curriculum, students can continue their study with a second cycle (“master”) programme in chemical engineering of 90-120 credits (1 ½ - 2 academic years).

Footnote:
1 Chemical Engineering Research and Design (Trans. IChemE) 81/A10, 1406, November 2003; www.efce.info/EFCE_Statements.html
The recommendations in this document are following the EUR-ACE® framework - standards for accreditation of engineering programmes\textsuperscript{2}. The recommendations cover the outcomes of “more research-oriented” chemical engineering programmes; the outcomes of “more application-oriented” programmes may be show less scientific depth but more practicable competences:

- Knowledge and Understanding;
- Engineering Analysis;
- Engineering Design;
- Investigations;
- Engineering Practice;
- Transferable Skills.

The document further covers some recommendations for achieving these programme outcomes containing:

- Core curriculum
- Teaching and learning
- Industrial experience
- Review of the educational process
- Student assessment

The programme outcomes are formulated in a general way, to emphasize 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 give a variety of concrete contents to the general outcomes. 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 level 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 much of the traditional chemical engineering skills, the EFCE feels there is now a need to include some knowledge of “product engineering” in the common core in order to reflect the increasing importance of modern materials science.

Further, these recommendations give the higher education institutions the opportunity to introduce their own “flavour” and/or innovative concepts in 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 right after graduation.

**Part 1: First Cycle (“bachelor”) Chemical Engineering programme outcomes**

After graduation, a first cycle degree chemical engineer should fulfil the following

\textsuperscript{2} European Accreditation of Engineering Programmes; [www.feani.org/webfeani/EUR_ACE/reports_accrstand.htm](http://www.feani.org/webfeani/EUR_ACE/reports_accrstand.htm)
qualifications:

• Knowledge and Understanding
  o The graduates have acquired basic knowledge of mathematics, physics, chemistry and biology which enables them to understand the phenomena which occur in the field of chemical engineering.
  o They have acquired the fundamental principles of chemical engineering for the modelling and simulation of chemical reactions and biomolecular processes, of energy, mass and momentum transport processes, and of separation processes on the micro, meso and macro scale.
  o They are familiar with the basic principles of measurement techniques and control.

• Engineering Analysis
  The graduates have the abilities:
  o to identify problems in their subject and to abstract, formulate and solve them holistically using fundamental principles;
  o to consider, analyse and evaluate products, processes and methods of their subject on a systems engineering base;
  o to select and apply suitable methods of analysis, modelling, simulation and optimisation.

• Engineering Design
  The graduates have
  o the ability to develop a basic design for products and processes according to specified requirements;
  o a basic understanding of design methods and the ability to apply them

• Investigations
  The graduates are able
  o to tackle a real chemical engineering problem by a scientific approach.
  o to use resources at library and on the web for the acquisition of information regarding equipment recipes, physical properties, kinetic and thermodynamic data.
  o to enhance the communication skills, both in writing and presentation, and their ability to work effectively in team efforts.
  o to make a safety assessment sheet before starting the experimental work.
  o to plan and carry out experiment and interpret the results with guidance of a senior scientist (chemical engineer).

• Engineering Practice
  The graduates have
  o the ability to combine theory and practice in order to analyse and solve problems of engineering science using methods based on fundamental principles;
  o understanding for applicable techniques and methods and their limits;
  o the ability to apply their knowledge of different areas taking safety measures and ecological and economic demands into account responsibly, and also to extend their knowledge on their own responsibility;
  o the ability to organise and carry out projects;
  o the ability to work with specialists from other disciplines;
  o the ability to present the results of their work in both written and oral form in an articulate way;
  o an awareness of the non-technical implications of engineering practices.
• Transferable Skills
  The graduates are able to
  o communicate effectively with specialists and non-specialists, including in English, using modern presentation tools as appropriate
  o work individually and as a team member in international and/or multidisciplinary teams
  o understand of the impact of engineering solutions in an environmental and societal context
  o have an understanding of professional and ethical responsibility
  o learn on his/her own, and have a recognition of the need for life-long learning

Part 2: Second Cycle (‘master’) Chemical Engineering programme outcomes

After graduation, a second cycle (‘master’s’) degree chemical engineer should fulfil the following qualifications:

• Knowledge and Understanding
  o The graduates have acquired extensive and profound knowledge of mathematics, chemical engineering and other sciences which enable them to carry out scientific work and to act responsibly in their professions and in society. They are aware of new developments in their field.

• Engineering Analysis
  The graduates have the following abilities:
  o to analyse and solve problems scientifically, even if the definitions are incomplete or are formulated in an unusual way and show competing specifications;
  o to abstract and formulate complex problems from a new or a developing field;
  o to apply innovative methods in solving problems based on fundamental principles and to develop new scientific methods.

• Engineering Design
  The graduates are able to:
  o 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;
  o develop new products, processes and methods;
  o 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.

• Investigations
  The graduates are able to
  o tackle a real chemical engineering problem by a scientific approach.
  o recognise the need for information, to find and provide information
  o plan and carry out theoretical and experimental research independently
  o evaluate data critically and to draw conclusions from it
  o examine and evaluate the application of new and emerging technologies

• Engineering Practice
  In addition to the qualification acquired during their first cycle degree course the graduates are able to:
  o classify knowledge from various fields methodically and draw systematic conclusions from it and also to deal with complexity;
- familiarise themselves with new tasks systematically and without taking too long;
- be able to think systematically about the non-technical effects 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 methods are concerned.

- Transferable Skills

  In addition to the qualification acquired during their first cycle degree course the graduates are able to:
  - function effectively as leader of a team that may be composed of different disciplines and levels;
  - work and communicate effectively in national and international contexts.

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 (4.5 – 5 years) programmes.

**Achieving the learning outcomes**

To ensure the proper common content and proper levels of the different first and second cycle degrees, EFCE recommends minimum amounts of subjects (e.g. mathematics) for both degrees and in addition topics (e.g. reaction engineering) for the first cycle. These minimum amounts are called the core curriculum.

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 (one academic year) 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 outcomes.

Note that the curriculum recommendation lists topics. EFCE makes no recommendation on the number of courses that should be given, or on how topics should be grouped in courses. Furthermore, in practice many of the listed topics will be part of larger courses containing more than just the core.

As the common European credit unit is the ECTU (European Credit Transfer Unit) of which there are 60 per year, all recommendations here are given using ECTU. The EFCE has chosen a 3 + 2 years two cycle scheme as an example. For other schemes the figures have to be adapted accordingly.

**Part 1: First Cycle (“bachelor”) Chemical Engineering programme**

<table>
<thead>
<tr>
<th>Core curriculum Chemical Engineering (first cycle)</th>
<th>Credits (minimum requirements)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fundamentals of science and natural sciences</td>
<td>45</td>
</tr>
<tr>
<td>mathematics, computer science, physics, chemistry, biology</td>
<td></td>
</tr>
<tr>
<td>Chemical Engineering fundamentals</td>
<td>35</td>
</tr>
<tr>
<td>material and energy balances, thermodynamics, fluid dynamics, heat and mass transfer, separations, chemical reaction engineering, bio molecular and biological engineering</td>
<td></td>
</tr>
<tr>
<td>Chemical Engineering applications</td>
<td>15</td>
</tr>
<tr>
<td>e.g. basic product engineering, safety, health and environment, design and process analytical techniques</td>
<td></td>
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</tbody>
</table>
Typically, a first cycle (“bachelor’s”) degree course will contain 20-30 % science courses, 40-50 % engineering courses, and up to 10 % non-technical topics. The core recommended here gives a science content of 25 %, an engineering content of 36 %, and a non-technical content of 6 % of the total study (180 credits), leaving one third to deeper coverage of some of these topics and to other topics.

**Part 2: Second Cycle (“master”) Chemical Engineering programme**

Although no topics are specified here, 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.

The core curriculum makes up 63 % of the total study (of 120 credits), leaving 37% of the second cycle (“master”) study for additional specialization and broadening.

**Teaching and learning**

Irrespective of the degree structure, the teaching and learning methods must be appropriate for the topic in question, and be chosen so that the learning outcomes can be achieved. The teaching and learning methods should also help develop students’ skill to work both independently and in teams. Thus, to learn to function in teams, group work is necessary. To be able to communicate, communication tasks must be given and solved. To learn to learn and to take responsibility for their own learning, students must be given appropriate self-study and problem solving tasks.
during their study. To understand ethical, societal, environmental and professional issues, suitable examples for illustration or discussion must be included. The study should be organized to ensure that students work during all of the semester, and are able to make the relevant connections between the different subjects.

All courses should as far as possible give examples from several areas, to show the broad applicability of chemical engineering methods.

**Industrial experience**

Industry has an important role to play in the education of chemical engineers. Industrial experience serves to illustrate the applications and limitations of theory, helps to set the courses in a wider context and motivates for the remaining study. In addition, it provides social skills for later leadership roles. Industrial experience for all can only be obtained if industry accepts the responsibility of providing sufficient placements.

**Review of the educational process**

Each educational institution should have an ongoing review of the educational process, to ensure that the parts are up to date and properly coordinated, and that each and every part contributes towards the aims of the course, and in general to improve the educational outcomes.

**Student assessment**

EFCE would like to emphasize the need for appropriate feedback to maximise the learning effect of the assessments.