SUBJECT BENCHMARK STATEMENT

IN

CHEMICAL AND PROCESS ENGINEERING

Quality Assurance and Accreditation Council
University Grants Commission
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CONTENT

FOREWORD

The work in connection with the development of Subject Benchmark Statements was begun in August 2003 as a part of the overall quality assurance framework that supports academic standards and the furtherance and dissemination of good practice in Universities in Sri Lanka.

Subject Benchmark Statements will support and promote quality and standards by:

- Providing universities with a common and explicit reference point for internal and external programme approval and review;

- Guiding and promoting curriculum development, especially in new departments and new universities, and in other institutions of higher education;

- Evolving over time to take account of changes and innovations that reflect subject development and new expectations;

- Providing an authoritative and widely recognized statement of expectations of what is expected of a graduate in a specific (or designated) subject area in a form readily accessible to students, employers and others with a stake in higher education;

- Providing a clear and transparent reference point for External Examiners;

- Assisting international comparison and competitiveness of higher education awards and student achievement.

SUBJECT BENCHMARK STATEMENT

CHEMICAL AND PROCESS ENGINEERING

1. Introduction

1.1 Scope and Purpose

Benchmark statements in chemical engineering basically outline the expected standards of a degree programme leading to the award of degree in B.Sc. Engineering or its equivalent with chemical engineering or chemical and process engineering specialization. The benchmark statements are drawn with an understanding that the graduates of such programmes are expected to possess not only a sound understanding of the underlying principles of chemical engineering, but also be able to adopt themselves to work in a fast changing professional practice environment of chemical engineering.

The primary purposes of the benchmark statements in chemical engineering are the following:

- To assure and maintain the basic quality required of a chemical engineering degree programme
- To guide in designing a degree programme in chemical engineering or allied field
- To provide guidelines for academic reviewers and external examiners of the degree programme
- To set the minimum standard to be expected during accreditation and review processes
- To provide information of the programme concerned to potential students and employers

1.2 What is Chemical Engineering?

Chemical engineering is concerned with the design and development of industrial processes, using scientific and mathematical principles, by which either raw or processed materials can be converted into products useful to the society. These end products are wide ranging, such as refined fules, chemicals, processed food, composite materials, electronics and pharmaceuticals.

The one who practices chemical engineering is called a chemical engineer. Those chemical engineers involved in the design and maintenance of large-scale manufacturing processes are known as process engineers.

1.3 Degree Levels

The benchmark statements in chemical engineering are designed to apply to the following degree levels:

- Bachelor of the Science of Engineering (BScEng) with specialization in chemical or chemical and process engineering

- Bachelor of the Science of Engineering with class honours (BScEng Hons) with specialization in chemical or chemical and process engineering
- Any other first degree in Engineering (eg. BEng, MEng) with chemical or chemical and process engineering specialization at general, honours or higher levels

1.4 Nature and Extent of the Subject

Chemical engineering has traditionally been the in-depth study of mass, momentum and energy transfers occurring during the formation of products used by the society. Primary concerns of the chemical engineering discipline have been the design, operation and control of large-scale physical, chemical and bio processing plants. Safe, sustainable and economical operations of these plants are the prime responsibility of chemical engineers. The products from these processing plants are wide ranging, such as refined fuels, pulp and paper, polymers, processed food, paints, solvents, drugs and pharmaceuticals.

Since processing involves extensive use of energy and since securing reliable, affordable and non-polluting supplies of energy is the prime concern of the world today, chemical engineering is also concerned with efficient use of energy at the design and operation stages of processing plants, carbon management at the processing plants, sustainable energy technologies, and power storage systems.

Chemical engineering has adopted sustainable process technologies as alternatives to conventional process technologies to ensure ecological sustainability, a pressing issue today. Chemical engineering practice and education have, over the decades, evolved into establishing Industrial Ecological projects, which integrate several different processes into synergistic complexes and thereby radically increase the resource productivity, maximize the productive use of viable waste streams and reduce the ecological and societal impacts of chemical engineering processes.

Modern chemical engineering deals with the development and production of high performance materials such as ultra-strong fibres, membranes, composites for vehicles, bio-compatible materials for implants, and films for opto-electronic devices. Chemical engineering has also made strong links with biomedical engineering, with practical applications including the design and optimization of short-term organ replacement devices, such as artificial kidney and the heart-lung machine, the development of artificial bloods, and controlled delivery devices for release of drugs or of specific molecules missing in the body because of disease or genetic alteration.

Chemical engineering also addresses the issues arising from health, safety, environment and public perception of risk seriously by creating cultures to deliver risk reduction, and improvement in health, safety and environmental performance.

1.5 Scope of Employment of Graduates

Chemical engineers are primarily employed by the processing industries to operate, modify, control and manage processing plants. They also design processing equipment and plants, evaluate the feasibility of process engineering project proposals and provide consultancy. Some chemical engineers work in the Research & Development field inventing new processes.

Petroleum refineries, chemical manufacturing facilities, pharmaceutical industry, food processing industry, biotechnology industry, process-software development businesses, quality control and management authorities, industrial pollution control and environmental pollution abatement organizations, sustainable development initiatives and strategies development cells, and composite material using industries such as aerospace, automotive, biomedical, electronic, environmental and space industry are some of the employment providers of chemical engineers.

Since chemical engineering education embraces understanding of other scientific and engineering fields such as chemistry, physics, mathematics, biology, mechanical engineering and electrical engineering, a chemical engineer can find a niche in any scientific or engineering field.

2. INTENDED LEARNING OUTCOMES

The following intended learning outcomes are based on the necessity to produce chemical engineering graduates who could successfully deal with the evolving academic and professional character of the discipline as well as the diverse nature of chemical engineering practice in the field:

- Good grasp of the mathematical methods and scientific principles needed to understand the underlying principles of chemical engineering science, and of the mathematical tools and scientific knowledge needed to analyze the chemical engineering systems
- Effective use of computer techniques for the quantitative analysis, simulation and solution of chemical engineering and related problems
- Conversant with static and dynamic modelling, simulation, analysis and control of chemical engineering and allied process equipment and plant
- Acquainted with the operation of small and pilot-scale equipment and acquisition of essential data using them
- In-depth knowledge in process design, equipment selection and the use of integrated approaches to solve complex process design problems
- Adequate exposure to complementary fields of chemical engineering, such as mechanical engineering and control and instrumentation engineering
- Awareness of the practical dimension to chemical engineering discipline, and the ability to formulate and solve technical, economic and managerial problems applicable to processing industries
- Working experience in open-ended project/projects, preferably in a multi-disciplinary framework
- Ability to embed sustainability aspects, loss prevention, hazard minimization, health and safety concerns, risk issues, ecological responsibility, quality issues, professional ethics and code of practice, political concerns, regulatory framework

and financial viability into the design and operation of chemical engineering and related plants and processes

- Skilled in communication, effective working with others, effective use of information technology, manipulation and presentation of engineering information, persuasive report writing, information retrieval, presentational skills, project planning, self learning, performance improvement.

3. THE SKILLS, QUALITIES AND ATTRIBUTES

Owing to the nature and scope of the traditional and modern chemical engineering fields, outlined in Section 1.4, it is essential that a graduating chemical engineer possess the following skills, qualities and attributes:

3.1 Knowledge and Understanding

Graduating chemical engineers should demonstrate a sound knowledge and understanding of the following:

- Underpinning mathematics and basic sciences, and relevant information technology and communication principles
- Essential facts, concepts, principles and theories relevant to chemical engineering discipline
- General principles underlying the design, analysis, control and operation of chemical engineering and allied processes
- Industrial safety, health, loss prevention, and sustainability
- Management, engineering economics, finance, law, marketing, and related study areas
- Codes of engineering practice and the regulatory framework requirements
- Professional and ethical responsibilities of a chemical engineer

3.2 Intellectual Skills

Graduating chemical engineers should be provided with adequate opportunity to cultivate the following intellectual skills during their degree program:

- Solve chemical engineering problems, which may be underspecified or involve limited and/or contradictory information
- Analyze and interpret data and, when necessary, design experiments to gain new data
- Evaluate designs, processes and products, and make improvements
- Maintain a sound theoretical approach in enabling the introduction of new and advancing processing technology to enhance current practice
- Take a holistic approach to chemical engineering problems, taking into account professional judgement, cost, benefit, safety, quality, reliability, environmental impact, and sustainability

- Assess and manage risks

3.3 Professional Practical skills

Graduating chemical engineers should be able to do the following:

- Use appropriate mathematical and other tools and techniques, equipment, and pertinent software and appropriate programming language
- Use laboratory and workshop equipment to generate valuable data, to perform tests, and to test a design idea
- Design a system, process or plant item
- Work within the real-world constraints in applying chemical engineering solutions to real-world problems
- Manage projects
- Embed industrial safety, health, loss prevention, and sustainability in chemical engineering solutions
- Work within the framework of codes of engineering practice, the regulatory requirements and professional and ethical responsibilities of a chemical engineer

3.4 Transferable/Key Skills

Graduating chemical engineers should have the following abilities:

- Apply mathematical skills to practical problems
- Communicate effectively, both orally and in writing
- Effectively use Information Technology and Communication
- Effective management of time and efficient use of resources
- Work in multi-disciplinary teams
- Be creative, particularly in design
- Be analytical in the formulation and solution of problems
- Extract information from published sources
- Undertake lifelong learning, particularly for continuing professional development
- Be innovative in the solution of engineering problems and the transfer of technology
- Self-disciplined and self-motivated, in the pursuit of their studies and professional practice
- Have an enquiring mind, eager for new knowledge and understanding
- Possess the independence of mind, with intellectual integrity, particularly in respect of ethical issues
- Be enthusiastic in the application of their knowledge and understanding and skills in the pursuit of the practice of engineering and the promotion of the engineering disciplines

4. STRUCTURE AND CONTENT OF THE PROGRAM

In order for the graduating chemical engineers to attain the knowledge, understanding and the skills outlined in Section 3, the structure of the chemical engineering or chemical and process engineering degree programme must have the following contents:

- Mathematical methods needed to analyse chemical engineering and allied systems
- Basic sciences, such as chemistry and biology, needed to strengthen the chemical engineering education
- Information technology and communication principles required to support the chemical engineering analysis
- Essential facts, concepts, principles and theories of chemical engineering
- General principles underlying the design, analysis, control and operation of chemical engineering and allied processes
- Chemical engineering design of industrial plants and design and selection of individual processing equipment
- Industrial safety, loss prevention and occupational health

As ecological sustainability is the prime concern of the technological society today, the content of a chemical engineering programme must be extended to include the following:

- Sustainable chemical and process technologies
- Sustainable resource usage
- Radical resource productivity and Whole system design

Because of the professional context of chemical engineering, a chemical engineering programme must also include the following:

- Management, engineering economics, finance, law, marketing, and related study areas
- Constraints within which chemical engineering judgment must be exercised
- Codes of engineering practice and the regulatory framework requirements
- Professional and ethical responsibilities of a chemical engineer
- Impact of chemical engineering activities in a global and societal context
- Relevant contemporary issues

Contents of the programme may be structured as shown in Table 1 to assure the effective delivery of the intended learning outcomes outlined in Section 2.

Table 1. Recommended minimum percentage shares of the total credits of the degree programme for different contents

Content	Minimum percentage share
Mathematics, Basic Sciences and Computing	20%
Core chemical engineering courses	35 – 45%
Safety, Health, Environment and Ecology, and Sustainability	5 – 10%
Chemical engineering design practice	2.5 – 5%
Open-ended (research) projects	2.5 – 5%
In-plant training at the chemical engineering or allied industry	2.5 – 5%
Complementary studies in Management, Engineering Economics, Finance, Law, Communication and related study areas	15%
Complementary studies in Humanities, Social Sciences, Arts and Professional Ethics	7.5%

In addition to courses explicitly dealing with the aspects of Sustainability, Safety, Health, Environment and Ecology, and other professional skills such as Ethics, it is essential that the courses throughout a programme include, illustrate and reinforce the above aspects.

A wide variety of delivery and assessment strategies must be used throughout the degree programme so that students acquire the range of transferable/key skills such as development of abilities within problem solving, communication, effective team work, effective use of Information Technology, persuasive report writing, information retrieval, presentational skills, project planning, self learning, performance improvement, and awareness of the benefits of continuing professional development

5. DELIVERY - TEACHING AND LEARNING STRATEGIES

The success of the teaching and learning strategies in achieving the intended learning outcome depends totally on the active participation of the students in the programme. Firstly, they should be made aware of the aims and objectives of the degree programme, the assessment regulations and strategy, and the learning outcomes of the modules or subjects studied. Secondly, the teaching strategies must be flexible, designed to encourage student-participation, and learning-outcome oriented as opposed to the traditional covering-the-syllabus-orientation.

A mixture of the following and other suitable delivery methods are suggested:

- Lectures in which the students and the lectures share with each other information about underlying principles and concepts central to chemical engineering discipline
- Tutorials which offer students the opportunity to practise the analytical and theoretical skills which have been introduced in lectures, and to deal with a wide range of applications
- Assignments which offer the opportunity to retrieve and self-learn materials available in sources outside the lecture classes
- Open-ended assignments/projects without known or not so well-defined solutions which offer students the opportunity to cultivate the confidence needed to work with

real-life engineering and related problems, and also the awareness of the creative process

- Laboratory-based sessions which allow students to carry out experimental work to gain an understanding of the limitations and assumptions used in theoretical and modelling tools
- Laboratory experiments designed and carried out by students to arrive at required information or testing of ideas
- Practical sessions on computing classes where students use software and numerical tools to analyse engineering problems, or as design tools
- Design projects which provide an opportunity to undertake design case studies
- Literature surveys to gather information from previously published sources
- Project work involving planning and managing project work, meeting deadlines, individual effort, teamwork, working within other externally defined constraints, and presentation and interpretation of technical information in various ways.
- Open-ended research project work carried out over an extended period of time at the final year of study is essential in a chemical engineering programme since it calls for synthesising the knowledge and understanding acquired in different subject areas of the degree programme to apply to unfamiliar problems
- Well-planed, objective-oriented industrial visits
- In-plant training at chemical and allied industry
- Seminars and Workshops

6. ASSESSMENT STRATEGIES

A combination of assessment strategies from the list below may be used with the objective of assessing the success of the delivery methods practised and the degree of achievement of the intended learning outcomes:

- Closed, Open-book and/or Take-home examinations
- Oral examinations, Interviews and/or Viva-Voce
- Laboratory practical sessions and examinations
- Synoptic examination
- Assignments
- Case studies
- Laboratory, design and research reports
- Oral presentations
- Student-led seminars/discussions
- Design tasks
- Computer-based / simulation exercises
- In-plant training reports

- Learning logs/diaries or portfolios
- Group projects
- Independent studies/projects
- Informal workshops to assess the intended learning outcomes of deliveries such as in-plant training, and also the degree of attainment in transferable/key skills

Assessment strategies mentioned above and others must be based on testing of how much a student has learned in a particular course than on the traditional testing of how much a student could put out on paper from his/her memory within a given period of time. To this effect, assessment strategies involving oral presentations, student-led seminars and discussions, assignments, case studies, interviews, Viva-Voce, projects and workshops must be encouraged over written examinations, wherever possible.

7. QUALITY MANAGEMENT

The quality of the degree programme may be maintained by accommodating and constructively responding to the information gathered on the course content and the delivery methods used by the following and other means:

- Student feedback through teacher and end-of-course questionnaires
- Student feedback by representatives on the Staff-Student Consultative Committee
- Student feedback describing their learning experiences to teaching staff of the department other than those involved in delivering the course concerned
- Peer reviews
- Comments and suggestions made by the external examiners on the quality and relevance of the assessment strategies used
- Dynamic process of curriculum revision
- Feedback from the industry personals such as the members of the industry-department interaction cell, supervisors of the in-plant trainees and employers of fresh graduates
- Periodic reviews on the quality and relevance of the course content, delivery strategies and assessment strategies of the degree programme concerned

8. BENCHMARK STATEMENTS - STUDENT ATTAINMENT

Student performance in either a general or an honours chemical engineering degree programme could be at a threshold level or at an excellent level as described in Table 2. It must be noted that while a student performs at a threshold level in one aspect of the student attainment, he/she may attains excellent level performance in another aspect.

Table 2. Description of student attainment at threshold and excellent levels

Threshold Level	Excellent Level
Has the understanding and ability to perform the basic tasks in chemical engineering and allied fields	Has a comprehensives understanding, takes an enquiring and innovative approach, and aware of limitations of theories and applications in chemical engineering and allied fields
Apply mathematical methods and scientific principles, as taught, to model and analyze simple and/or familiar chemical engineering processes and systems	Research, learn and apply appropriate mathematical/ analytical/ numerical methods and new theories and concepts of scientific principles to model and analyze complex and/or unfamiliar chemical engineering processes and systems
Use computer techniques, as taught, to analyze, simulate and solve simple and/or familiar chemical engineering problems	Select and use appropriate computer techniques to analyze, simulate and solve complex and/or unfamiliar chemical engineering problems
Has the basic knowledge and understanding of the various techniques available for static and dynamic modelling, simulation, analysis and control of chemical engineering equipment and plant.	Has a comprehensive knowledge and understanding of the various techniques available for static and dynamic modelling, simulation, analysis and control of chemical engineering equipment and plant, and the limitations of the techniques
Acquire essential data conducting laboratory and pilot-scale experiments, and use it to verify familiar theories and principles in chemical engineering and allied fields	Design novel experimental procedure, fabricate experimental setups, where necessary, acquire essential data, and analyze the data in detail to verify theories and principles in chemical engineering and other fields
Has a basic knowledge and understanding of essential process design methodologies and equipment selection, and the ability to carry out routine design of familiar processes and equipment and selection of equipment	Has comprehensive knowledge and understanding of process design methodologies and equipment selection, and the ability to initiate an innovative integrated approach to solve a wide range of process design problems
Has a basic understanding of the practical dimension to chemical engineering discipline, and the ability to formulate and solve familiar technical, economic and managerial problems applicable to processing industries	Has a comprehensive understanding of the practical dimension to chemical engineering discipline, and the ability to initiate an innovative integrated approach to solve a wide range of technical, economic and managerial problems applicable to processing industries

Threshold Level	Excellent Level
Adopt appropriate tools, as taught, to improve the safety, health, environmental and sustainability dimension of the chemical engineering and related plant and/or system	Research and adopt innovative tools required to improve the safety, health, environmental and sustainability dimension of the chemical engineering and related plant and/or system
Aware of the professional and ethical responsibilities of a chemical engineer.	Ability to embed professional and ethical responsibilities of a chemical engineer into the technical, economic and managerial practices
Possess the basic key skills, and improves under guidance	Remarkable demonstration of key skills, and self-motivated continual improvement of key skills
Indifferent to new developments in chemical engineering and allied fields	Enthusiastic about learning and adopting, wherever possible, new developments in chemical engineering and allied fields
Good team player	Excellent team player; Ability to provide leadership with high level of integrity

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9. ANNEX1. MEMBERS OF THE BENCHMARK GROUP

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Prof. B. A. J. K. Premachandra	University of Moratuwa
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