Quality Assurance Council

2022

Subject Benchmark Statement

Chemistry

University Grants Commission – Sri Lanka

SUBJECT BENCHMARK STATEMENT

IN

CHEMISTRY

2020

Contents

FOREWORD

The Subject Benchmark Statement that was developed in the year 2003 has been improved in the year 2020, to provide guidelines for BSc Degree with Chemistry as a Major Subject under SLQF Level 5 and BSc Honours in Chemistry, BSc Double Major Degree with Chemistry as a Major Subject and other Chemistry-related Honours Degrees under SLQF Level 6. As such, the present form of the Subject Benchmark Statement in Chemistry covers all Degree Programmes that involve chemistry as a major subject and supports and promotes quality and standards of these degree programmes by,

- providing Sri Lankan Universities with a common and explicit reference point for all the BSc degree programmes that involve chemistry as a major subject under both SLQF Levels 5 and 6,
- guiding and promoting curriculum development in chemistry, especially in new departments and newly-established 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 in chemistry and chemistry-related subjects,
- providing an authoritative and widely recognized statement of expectations of a graduate in chemistry in a form readily accessible to students, employers and others with a stake in higher education,
- assisting international comparison and competitiveness of higher education awards and student achievement,
- recognizing the need to improve soft skills and other requirements in addition to subject-specific knowledge for improving the employability of chemistry graduates and incorporating them in the respective chemistry curricula.

SUBJECT BENCHMARK STATEMENT

CHEMISTRY

1 INTRODUCTION

1.1 Subject Benchmark Statement – Scope and purpose

The Subject Benchmark Statement (SBS) of Chemistry describes the nature of study in chemistry and academic standards that should be achieved at the completion of a BSc degree. It is a combination of subject material, essential skills and attitudes that are necessary for acquiring the level descriptors stated in the SLQF Levels 5 and 6. It also provides the boundaries and the specific threshold for awarding a Bachelor's Degree with the required knowledge, competencies, abilities and skills that have to be developed to create innovative ideas in learning and teaching chemistry. The SBS is also used as a reference material when new Bachelor's Degree programmes with chemistry as a subject are designed and developed, in compliance with the SLQF Levels 5 and 6, in higher education institutes of Sri Lanka.

1.2 Defining principles

The Subject Benchmark Statement of Chemistry provides threshold descriptors of the standards expected for graduates in SLQF Levels 5 and 6. Accordingly, the Bachelor's Degree programmes in chemistry are designed to produce graduates who are competent in understanding theory and applying it in problem solving. Further, the graduates of these programmes are also capable of professionalism, independent thinking, taking personal responsibility, creativity, and decision-making in complex and unpredictable circumstances.

The main areas covered by the SLQF Level 5 or 6 degree programme in chemistry are Analytical Chemistry, Biochemistry, Inorganic Chemistry, Organic Chemistry and Physical Chemistry. The details of the key topics to be covered in each area are given in Annexe 1. These degree programmes with chemistry as a major subject are underpinned by a number of related scientific disciplines including biology, mathematics, information technology and physics.

2 DEGREE PROGRAMMES

The BSc degree programmes with chemistry as a subject fall into two categories, namely, SLQF Level 5 and Level 6. A graduate at SLQF Level 5 should follow a minimum of 24 credits of chemistry which includes a minimum of 6 credits of laboratory work during the three-year academic program. The BSc Honours degree programmes in chemistry and chemistry related disciplines are of four-year duration (SLQF Level 6) and include the learning of both basic and advanced topics in the subject covering a minimum of 72 credits of chemistry or chemistry related discipline with a minimum of 12 credits of laboratory work. A key component of the latter program would be the research project worth of a minimum of 6 credits that is carried out under the supervision of academic(s) of chemistry or a related discipline, or a comparable research work carried out in an industrial setting. The BSc Honours degree in double major with chemistry as one subject is also of four-year duration (SLQF Level 6) which includes the learning of both basic and advanced topics covering a minimum of 48 credits of chemistry with a minimum of 8 credits of laboratory work.

3 NATURE AND EXTENT OF THE SUBJECT

Chemistry is the subject that engages in an in-depth study of the structure, properties and changes in matter at both microscopic (atomic and molecular) and macroscopic levels. The undergraduate programmes in chemistry should develop the necessary skills for transforming the molecular view of understanding to solve real world problems.

4 AIMS AND OBJECTIVES OF THE SUBJECT

Acceptable undergraduate programmes must provide their students with a broad based and rigorous chemistry education that provides them with the intellectual, experimental and transferable skills, and attitudinal traits (as opposed to rote learning of facts) needed to become successful scientific professionals.

Systems Thinking is the process of understanding how parts of a system influence one another within a whole. Such understanding is essential in solving problems in day-to-day life as well as future problems faced by the humanity. As such, learning approaches which incorporate Systems Thinking, and Green and Sustainable Chemistry show promise in helping chemistry students zoom out from detailed and fragmented disciplinary content to obtain a more holistic view of chemistry and its integral connection to earth and societal systems.

The curricula of an individual institution may depend on several factors. Availability of the academic staff and their subject specializations, the laboratories and other facilities, library and information sources, number of students following the course and also the needs of the people in the society specially under the concept of "university village" as applicable to some universities of the country. However, in order to recognize chemistry as a subject in a BSc degree program, it is necessary to ensure that the programmes cover the following broad objectives of learning at the end of the appropriate level.

SLQF Level 5

- Develop the ability in using chemical terminology.
- Develop an understanding of fundamental physicochemical principles with the ability to apply knowledge to solve theoretical and practical problems.
- Develop an understanding of the qualitative and quantitative aspects of chemical analysis and the concepts of metrology with special reference to chemical metrology.
- Develop understanding of purification and characterization techniques of chemicals.
- Develop skills and knowledge in operating instruments related to characterization of materials.
- Develop an awareness of issues within chemistry that overlap with other related science subjects, in particular, physics and biology, and the traditional knowledge.
- Develop knowledge and understanding of ethics, societal responsibilities, environmental impact and sustainability in the context of chemistry.

- Develop an understanding of safe working practice in terms of managing chemical toxicity, chemical stability and chemical reactivity through knowledge-based risk assessments.
- Develop the ability to read and engage with scientific literature using traditional and modern information sources.
- Develop the ability to effectively communicate scientific ideas.

SLQF Level 6

In addition to the objectives specified for the SLQF Level 5 the following are also applicable to the SLQF Level 6.

- Develop an in-depth understanding of synthesis, including related isolation, purification and characterization techniques.
- Develop a thorough understanding of physicochemical principles and techniques in solving chemical problems and societal issues related to chemistry.
- Develop in-depth understanding of quantitative chemical analysis, chemical metrology, measurement traceability, experimental error and statistics, method validation, and proficiency testing.
- Develop the ability to engage in research in chemistry creating new knowledge, including identification and prioritization of research projects of relevance.
- Develop the ability to engage in further learning and innovations.
- Develop the ability to clearly communicate scientific ideas to subject experts and general audiences.

5 SUBJECT-SPECIFIC LEARNING OUTCOMES IN CORE AREAS

5.1 Knowledge

The following learning outcomes indicate the level of knowledge in chemistry and the skills required in its practical application that should be developed by a graduate at the respective SLQF level.

5.1.1 Subject / Theoretical Knowledge

After a successful study of an undergraduate programme, with chemistry as a subject, a student should be able to demonstrate the following.

SLQF Level 5

- Knowledge and understanding of essential facts, concepts, principles and theories at microscopic and macroscopic levels.
- Skills in the generation, evaluation and interpretation of chemical information and data.

SLQF Level 6

- In-depth knowledge and understanding of essential facts, concepts, principles and theories relating to chemistry covered in the program at microscopic and macroscopic levels.
- Skills in the generation, evaluation, interpretation and synthesis of chemical information and data.

5.1.2 Practical Knowledge and Application

After a successful study of an undergraduate program, with chemistry as a subject, a student should be able to demonstrate the following. See Annexe 2 for details.

SLQF Level 5

- Develop arguments and make sound judgments, from the results obtained in basic chemistry experiments, in accordance with basic theories and concepts of chemistry.
- Apply practical knowledge and understanding of concepts and principles of chemistry in solving real world problems.

SLQF Level 6

- Develop arguments and make sound judgments, from the results obtained in advanced chemistry experiments, in accordance with theories and concepts of chemistry.
- Apply practical knowledge and understanding of concepts and principles of chemistry in solving real world problems and in scientific research for generating new knowledge.

5.2 Skills

Students obtaining a degree in chemistry should be well versed in chemical concepts and trained in laboratory practices. However, to be effective and productive scientists and professionals in the 21st century, graduates need to master a variety of transferrable skills. An important aim of degree programmes, stated in the section 4, is to develop certain transferrable skills which are required in the field of chemistry or outside chemistry. The way to achieve this is to integrate and assess transferrable skills within the chemistry curriculum.

After successful completion of SLQF Level 5 degree programme with chemistry as a subject or SLQF Level 6 degree in chemistry or chemistry related discipline, the graduates should demonstrate the following skills given in Table 1. See Annexe 2 for details.

Table 1 Transferable skills expected from graduates in SLQF Levels 5 & 6.

Skills	SLQF Level 5	SLQF Level 6
Communication skills	Present information, ideas, and concepts efficiently and effectively	Clearly communicate information, ideas, issues, problems and solutions to specialist as well as non-specialist audiences. Demonstrate awareness of the current developments in the areas related to chemistry.
Teamwork and leadership	Exercise personal/team responsibility, and leadership in the professional environment/workplace	Work in teams, exercise initiative, identify situations where you need support from others
Creativity and problem solving	Develop arguments and make appropriate judgments in accordance with theories and concepts in chemistry and related	Construct and sustain arguments and make appropriate judgments in accordance with theories and concepts in chemistry and related

	areas	areas and use these arguments, ideas and techniques in problem solving
Management and Entrepreneurship	Take initiative, assume personal responsibility and demonstrate accountability	Take initiative, assume personal responsibility and demonstrate accountability and ability for entrepreneurship
Information usage and management	Demonstrate specialized transferable skills related to ICT	Thorough in transferable skills related to ICT and information literacy
Networking and social skills	Develop good communication habits	Practice good communication habits and promote social engagements
Adaptability and flexibility	Appropriate strategies for adapting to changing environments	Analyse and devise appropriate strategies for adapting to changing environment

5.3 Attitudes

Graduates of a degree programme are expected to be productive professionals and law-abiding citizens. Attitudinal traits have shown to be excellent predictors of the future behaviour of human beings. Hence, the development of favourable attitudinal traits in graduates should be an integral part of a curriculum of a degree programme. In order to be successful in learning a subject, the student should have a positive attitude towards that subject. As such the attitudinal dimension in a curriculum plays an important role in enhancing and enriching the learning experience of a student.

The chemistry curriculum in a degree programme is partly responsible in developing well rounded graduates. Hence, it should provide opportunities to a student to develop favourable attitudinal traits as outlined in Table 3 (See Annexe 3 for more details).

Table 2 Attitudinal traits expected from graduates in SLQF Levels 5 & 6.

Attitudinal traits	SLQF Level 5	SLQF Level 6
Attitudes, Values and Professionalism	Exercise initiation, creativity, personal responsibility and accountability in tasks performed. Demonstrate positive attitudes and social responsibility.	Exercise initiation, creativity, personal responsibility and accountability in tasks performed. Demonstrate positive attitudes and social responsibility.
Vision for Life	Identify career path related to available job market and develop long term goals. Acquire new competencies that will enable them to assume major responsibilities.	Exercise and further develop the new competencies and assume major responsibilities with confidence as a professional chemist.
Updating Self / Lifelong Learning	Undertake further training and develop additional skills that will	Engage in independent learning using scholarly reviews and

	enable to make sound decisions in chemistry related activities. Identify ways of independent learning and lifelong learning with respect to chemistry.	secondary sources of information with respect to chemistry.

6 TEACHING, LEARNING AND ASSESSMENT PROCESS

6.1 Teaching and learning

Theoretical understanding of the basic principles of chemistry and practical skills, including an appreciation of the link between theory and application are important and essential requirements.

Higher education providers use appropriate teaching methods to ensure that students are engaged, motivated and challenged to learn. The chemical science profession requires graduates who are safe and competent practical workers and as such a substantial laboratory-based practical component is crucial. The teaching-learning methods may include:

- Lectures and tutorial discussions
- Peer Learning
- Laboratory work
- Assignments
- Writing reports
- Seminars and presentations
- Study visits and industrial trainings
- Blended learning
- Online student presentations and group discussions
- Case studies (for attitudinal developments)
- Perspective sharing via reflection (for attitudinal developments)

Additionally, in SLQF Level 6

- Research project or industrial training including literature survey

6.2 Assessment methods

The assessment of students' achievement in chemistry aligns with learning outcomes and is appropriate to the knowledge, abilities, academic and professional skills and attitudes that the programme aims to develop. There should be an explicit and demonstrable assessment strategy which makes the appropriateness of the assessment methods used in relation to the learning and teaching strategy adopted and the anticipated learning outcomes and skills developed.

Overall, the assessment methods should aim to assess achievement, both formative and summative, over the entire degree programme. It is recognized that achievement in certain (skills) components (skills and attitudes) may be difficult to assess. Nevertheless, graduates will be expected to attain appropriate achievement in knowledge, understanding and skills and attitudes taken as a whole. Also, they are expected to have IT skills in chemistry through animation and simulation.

The appropriate assessment methods are given below.

- Theory examinations
- Oral examinations/presentations
- Laboratory reports and practical examinations
- Problem-solving exercises
- Literature surveys and evaluations
- Online student presentations
- Essay assignments
- Portfolios (can be used to measure attitudes)
- Poster presentations
- Reports on external placements
- Production of online and other media outputs such as video, audio, animation and simulation.
- Questionnaires (can be used to measure attitudes)
- Internship supervisor surveys (can be used to measure attitudes)

In addition to those stipulated for SLQF level 5 the following assessment methods are applicable to SLQF Level 6.

- Planning, conducting and reporting research project/industrial training (including the dissertation)
- Outputs from collaborative work.

7 PERFORMANCE STANDARDS

Performance standards are defined based on the GPA obtained by the student for the chemistry component of the degree as shown in Table 3.

Table 3: Grade Point and Performance Standard

Grade	Grade Point (GP)	Performance Standard
A+	4.00	Excellent
A	4.00	
A-	3.70	
B+	3.30	Good
B	3.00	
B-	2.70	
C+	2.30	Threshold
C	2.00	
C-	1.70	Poor
D+	1.30	
D	1.00	
E	0.00	

<u>SLQF Level 5</u>

BSc degree programme with Chemistry as a subject, offering qualifications equivalent to SLQF level 5 should cover the Chemistry component in 24-30 credits. Subject must include both, theory and practical components. Practical component should not be less than total of six credits, comprising compulsory units and student should obtain an overall minimum performance standard of Grade Point (GP) 2.00.

It is recommended that the workload is distributed as evenly as possible throughout the programme.

<u>SLQF Level 6</u>

BSc Degree programmes offering qualifications equivalent to SLQF level 6 are expected to impart knowledge, skills and attitudes at a higher level. These programmes typically offer the chemistry and chemistry related components including practical components within 72-80 credits. Practical component should not be less than total of 12 credits, comprising compulsory units and student should obtain an overall minimum performance standard of GP 2.00.

In addition, an academic staff (permanent) member(s) guided research project, not less than compulsory six credits or an industrial training worth of 8 credits with a GP of 2.00 should be obtained by the student as the minimum standard. It is recommended that the workload is distributed as evenly as possible throughout the programme.

Students obtaining a Degree with chemistry as a subject should demonstrate that they have reached to an acceptable level of achievement in (i) subject specific core knowledge and understanding, (ii) subject specific intellectual and practical skills, (iii) transferable skills, and (iv) attributes specified under the Section 5 in this Benchmark statement.

The standards required of students are different for the levels of attainment in BSc and BSc Honours degree programmes in Chemistry. In each case the standards are divided into four levels namely; Poor, Threshold, Good, and Excellent. The final Chemistry Grade Point Average (GPA) is calculated from the corresponding Grade Point (GP) values based on all course units he/she faced and should be used to indicate one's performance standard (see Table 4).

Table 4 Overall Chemistry GPA and Performance Standard

Overall Chemistry GPA	**Performance Standard**
≥3.70	Excellent
3.69-2.70	Good
2.69-2.00	Threshold
≤1.99	Poor

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ANNEXE 1

The coverage of basic chemistry subtopics in the BSc Degree programmes is given in Annexe 1. The curricula of BSc Degree programmes (SLQF levels 5 and 6) are expected to cover the subtopics listed in this Annexe, using at least the specified minimum credit limits which are given in Table 5 below. The minimum credit limit for each subtopic is shown next to the heading in the Sections 1 and 2 of this Annexe.

Table 5 Minimum credit requirement for BSc Degree Programmes in Chemistry in SLQF levels 5 and 6 for each activity

Activity	Minimum credits for the degree programmes			
	BSc Degree with Chemistry as a subject* (SLQF level 5)	BSc Honours Degree Double Major with Chemistry as a subject** (SLQF level 6)	BSc Honours Degree in Chemistry*** (SLQF level 6)	BSc Honours Degrees in Applied Chemistry**** (SLQF level 6)
Theory courses of section 1	18	18	18	18
Theory courses of section 2	-	14	33	11
Practical courses	6•	8	12	9
Research project	—	6	6	8#
Essays and seminars (or activities designed to develop the skills)	0	2	3	2
Total	24	48	72	48

* All the topics in Section 1 are expected to be covered.

** All the topics in Section 1 and selected topics from Section 2 are expected to be covered. In the event the research project is outside the discipline of chemistry, the 6 credits allocated for the research project can be covered from subtopics listed in Section 2.

*** All the topics in both Sections 1 and 2 are expected to be covered.

**** All the topics in Section 1 and selected topics in Section 2 are expected to be covered.

• Practical courses should include laboratory experiments, mini-projects and seminars.

\# Industrial training

Annexe 1 is divided into two sections. The coverage of conceptual and practical chemistry topics in the BSc Degree programme (SLQF Level 5) is given in Section 1. The BSc Honours Degree programmes (SLQF Level 6) are expected to cover those given in Sections 1 and 2.

The laboratory courses in the BSc Degree programmes in Chemistry (SLQF Levels 5 and 6) should be designed in accordance with the following guidelines.

Students must be guided to plan and carry out laboratory work in a correct, safe and efficient manner, conduct simple risk and security assessments, document laboratory work in a lab log and account for the results of the laboratory session orally and in writing. Students must be aware of disposal methods of toxic and non-toxic chemicals, various methods of gathering experimental data using basic physico-chemical and analytical instruments, their operating principles, calibration, validity and accuracy of data, error and statistical analysis of experimental data, plagiarism and laboratory report writing. Experiments should be designed in a manner to cover the whole spectrum of basic chemical techniques. Conducting laboratory classes are solely on student-centred and outcome-based manner. Students are expected to plan the laboratory experiments after referencing and assemble relevant set-ups to carry out experiments and perform laboratory work on individual basis and as group work. The laboratory course should include pre-laboratory learning and exercise classes, laboratory manuals with necessary protocols and guidance and lab-based in-class exercises for monitoring of acquiring knowledge, skills and techniques.

Section 1

The expected minimum academic weight (credits) of the total set of courses offered under each subtopic of chemistry (including the practical work relevant to the subtopic) is indicated within brackets next to its designation.

Analytical Chemistry (5 credits)

Classroom and laboratory experiences in analytical chemistry at the undergraduate level should present an integrated view of methods and instrumental techniques, including their theoretical basis, for solving a variety of real chemical problems. Students should receive a coherent treatment of the various steps of the analytical process, including: problem definition, selection of analytical method, sampling and sample preparation, validation of analytical method, data collection and interpretation, and reporting. The problem-oriented role of chemical analysis should be emphasized throughout the student's experience. Such experiences provide an excellent introduction to the analytical process while engaging students in relevant societal problems requiring modern chemical analysis. Lectures should be supplemented by lecture demonstrations, wherever applicable. Exercises and Problems at the end of each session is a must for the student to master the subject.

The student should emerge from an undergraduate programme of study having been exposed to a systematic treatment of the entire sequence of steps of the analytical process, including:

<u>Conceptual Topics</u>

Definition of Analytical Requirements

Sampling of solid, liquid and gas phases for quantitative analysis, sampling errors, storage and stability Calibration plots, pre-concentration methods, standard addition, detection limits, error propagation, error bars, standard deviation, precision, accuracy and outliers.

Quantitative Chemical Analysis

Theory behind quantitative chemical analysis methods, wet and instrumental techniques; solubility, activity and equilibrium of the analyte, conventional analytical techniques (titrimetric, gravimetric, potentiometric, coulometric); instrumental techniques, spectroscopic methods of analysis (UV-Vis, IR, AAS), chromatographic methods of analysis (TLC, GC, LC, Ion exchange, IC), interference in chemical analysis and dynamic range

Sampling and Sample Preparation

Sampling approaches (homogenous, heterogeneous, segregated, random, stratified, composite, power analysis) sampling error, sample stability and storage; analyte separation from complex matrices, elimination or reduction of interferences, derivatization/solubilization

Selection of Analytical Methods

Criteria**:** Information content, specificity, limit of detection, interferences, dynamic range, sampling methods (gas, liquid, solid), sample preparation (solid phase extraction, digestion), accuracy, speed, ease of use, cost, temporal and spatial resolution, regulatory requirements (FDA, EPA, NMRA, Food Authority, CEA).

Capabilities and Limitations of Analytical Methods

Troubleshooting: Identification and correction of problems when executing a method

Quality Infrastructure

Relationship between International, Regional and National Bodies responsible for the Quality Infrastructure: Metrology, Standards, Accreditation, Scientific Metrology and Legal Metrology, Concepts of Conformity Assessment. Quality management in the analytical laboratory, quality management systems ((ISO 17025) and related Standards (ISO 9000, ISO 14000, ISO 13485, ISO 15189)

<u>Practical Topics</u>

The laboratory experience needs to reflect the entire "analytical process" and not focus only on the measurement step. Problems to which students are exposed should reflect the diversity of analytical problem-solving scenarios: Various physical states of matter, chemical speciation, comparison and selection of analytical methods for qualitative and quantitative analyses reflecting a range of accuracy, precision, dynamic range, limit of detection, and limit of quantitation. It also should include diverse approaches that reflect the wide range of analytical tools available (equilibrium-based methods, kinetic-based methods, physical properties) using various families of instrumentation including spectroscopy (atomic and molecular), separations, mass spectrometry and electrochemistry. Calibration of volumetric glassware, gravimetric analysis, preparation of standard acid, base and pH Buffer solutions, titrimetric analysis – monoprotic, diprotic acids, analysis of N, P, K using standard methods (Kjeldhal, FP, Spectrophotometry), complexometric titration, redox titration (COD), potentiometric titration (e.g. halide), spectrometric determination.

Biochemistry (1 credit)

Biochemistry explores the chemical processes to understand the molecular aspects of biological structures, equilibria, energetics, and reactions within and related to the living organism. Undergraduates must be presented with sufficient flavor of modern biochemistry with chemical properties of molecules, components of the cell, and biomolecular processes explaining living processes and their uses in biotechnology.

Biochemistry comprises of three general subject areas with specific topics in each appropriate for meeting the biochemistry requirement. In most approved curricula the three general subject areas are covered and not necessarily all the specific areas are covered under each section.

Conceptual Topics

Biological structures and interactions

Fundamental building blocks (amino acids, carbohydrates, lipids, nucleotides, and prosthetic groups). Biopolymers (nucleic acids, peptides/proteins, glycoproteins, and polysaccharides)

Biological Reactions

Vitamins and organic and inorganic cofactors

Practical Topics

Biochemistry laboratory courses can explain some topics practically and the importance can be emphasized through the techniques described in the general guidelines outlined above.

Hands-on experience on preparation of buffers, chemical identification of macromolecules and metabolites

Inorganic Chemistry (6 credits)

Inorganic Chemistry is the study of the structures, physical and chemical properties of elements and chemical compounds other than organic compounds. The distinction between inorganic and organic chemistry is far from absolute, as there is much overlap in the sub-discipline of organometallic chemistry. Many chemical industries add value to inorganic raw materials by transforming them into the chemicals required for the manufacture of consumer products. Inorganic chemistry plays a key role in the science of materials, catalysis, biological processes, environmental chemistry and green chemistry.

Curriculum should emphasize descriptive and theoretical aspects of modern inorganic chemistry. Teaching goal of the curriculum is to guarantee the students with the ability to analyze and solve the practical problems related to inorganic chemistry. Therefore, course contents should be delivered in a manner to cultivate the students' scientific thinking ability and innovation ability. Topics for the inorganic curriculum are listed below.

Conceptual Topics

Fundamental particles and fundamental forces, nuclear stability, atomic structure, atomic spectra, quantum numbers and atomic orbitals, atomic properties, chemical bonding, molecular shapes, molecular structure (VSEPR and molecular orbital theory) and molecular symmetry; acid base concepts.

Chemistry of the Main Group Elements

Group relationships and trends of properties of main group elements and their compounds in the modern Periodic Table

Chemistry of d- and f-block Elements and Organometallic Chemistry

Trends in properties of d- and f- block elements and their compounds, nuclear reactions, ligands, hapticity, 18-electron rule to predict stability of organometallic compounds, metal-carbon bonding in metal carbonyls and metal alkenes and application of IR spectroscopy

Coordination Chemistry

Coordination number, stereochemistry, nomenclature; valance bond theory, crystal field theory for octahedral, tetrahedral and square planer crystal fields; introduction to electronic spectra and reaction mechanisms of coordination complexes

Introduction to Spectroscopic Methods in Inorganic Chemistry

Applications of UV, IR, NMR, XRD and ESR

Special Topics

Environmental and Green Chemistry, Industrial Inorganic Chemistry

Practical Topics

The goal of the inorganic chemistry laboratory is to give students an experience in a range of techniques used in qualitative and quantitative analysis of inorganic materials and synthesis, purification and characterization of various classes of inorganic compounds. Suitable methods should be developed to give awareness on toxicity of specific chemicals and disposal methods for such chemicals, safe handling and good laboratory practices. Techniques recommended for inclusion in the inorganic laboratory are the following:

Qualitative and quantitative analysis of inorganic materials by classical methods,

Synthesis of selected inorganic complexes covering basic synthetic methods, purification methods such as recrystallization, characterization methods: UV-Vis, AAS, IR.

Experiments to demonstrate applications of paper/ion exchange chromatography.

Organic Chemistry (6 credits)

Organic chemistry is a branch of chemistry that studies the structure, properties and reactions of organic compounds, which contain carbon in covalent bonding with itself and other elements. Since carbon forms unlimited number of compounds, a separate branch of chemistry called organic chemistry is justified. Carbon-based molecules are central to a host of chemical and biological processes because of their broad range of structure and reactivity. The uses of organic compounds impact our lives daily in medicine, agriculture, and general life. Organic chemistry is a highly integrated discipline that impacts and is impacted by the other branches of chemistry and other sciences.

An introductory sequence should drive the student to appreciate the breadth of organic chemistry by facilitating an understanding of basic concepts in organic chemistry, organic reactions, synthesis, analysis and the practice of applying them, to gain a working knowledge and appreciation of organic structure and reactivity. Teaching is mainly done through students-centred learning and outcome-based education modes where students are provided with theoretical facts, supplementary reading material, assignment on group learning and group presentation, role play on understanding concepts of chemistry and monitoring of students' learning through frequent assessments (in-class).

Conceptual Topics

Fundamentals in Organic Chemistry

Basic concepts in organic chemistry, IUPAC nomenclature, stereo and conformational isomerism, steric and electronic effects on physical properties and reactivity

Structure and Reactivity of Organic Compounds

Structure and reactivity of organic compounds, basic organic reactions such as proton transfer, addition, substitution, elimination, oxidation, reduction and free radical reactions in organic chemistry; aromaticity, mono- and poly-substituted aromatic compounds and reactivity

Organic Synthesis and Physical Methods in Structure Elucidation

Reactive intermediates in organic reactions, principles in organic synthesis, retrosynthetic analysis, functional group inter-conversion and synthesis of simple organic molecules; applications of spectroscopic methods in structure elucidation

Chemistry of Natural Products

Classes of natural products, structure and abundance, extraction, analysis and purification methods, structure elucidation; primary and secondary metabolites, biosynthetic pathways and synthesis

Connectivity of Chemical Concepts in the Industry, Society and Environment

Organic Chemistry in pharmaceuticals and food industries, organic compounds in indigenous processes (traditional medicine) and quality evaluation, industrial polymers, waste management at laboratory and industrial scales, organic chemistry related to environmental issues

Practical Topics

The laboratory of organic chemistry should demonstrate how organic chemical knowledge is acquired through experimentation and how chemical safety is important in an organic chemistry laboratory. Students are required to develop skills, techniques and gain experiences in organic chemistry laboratory in order to apply them in related testing processes, industrial processes and in research.

Students must be trained on basic laboratory techniques such as filtration, extraction, purification, drying, melting point determination. They must be exposed to separation techniques based on solubility, functional group identification, organic synthesis, monitoring of organic reactions using TLC, distillation, recrystallization and sublimation.

Use of spectroscopic data (^{1}H NMR, ^{13}C NMR, MS, FTIR and UV-visible spectra) of simple organic compounds for structure elucidation must be incorporated in the laboratory course.

Physical Chemistry (6 credits)

Physical chemistry is the branch of chemistry that consists of concepts and principles. It provides the theoretical basis and mathematical models that enable quantitative predictions. It enables detailed explanation of chemical phenomena underlying the other branches of chemistry and related areas.

Physical chemistry should provide the knowledge to understand the connection between microscopic models and macroscopic phenomena both from theoretical and experimental perspective. Physical chemistry courses should aim at developing qualitative and quantitative models, starting from assumptions that relate physical properties, chemical change and interplay of energy. Students should be able to critically apply the concepts and models in solving problems related to the course and in the real world. It is advised that the required working knowledge in mathematics should be developed through a suitable course.

Conceptual Topics

Energetics

Thermodynamics and its applications: Thermodynamic functions (internal energy, enthalpy, entropy, Gibbs energy, Helmholtz energy), First and Second laws of thermodynamics and applications. Chemical and Phase equilibria: Reaction Gibbs energy and thermodynamic equilibrium constant, standard state and activity, thermodynamic aspects of phase transitions, Gibbs phase rule, single and multi-component phase diagrams and their applications. Surface equilibria: adsorption and desorption, Chemisorption and physisorption, adsorption isotherms and experimental techniques and applications

Chemical Kinetics

Elementary and non-elementary chemical reactions, definition of rate, rate law, order, molecularity and rate constant, rate law in differential and integral forms as applied to elementary and multistep reactions, derivation of rate law, predicting mechanisms of chemical reactions, factors affecting the rate of a chemical reaction and optimizing the rate, temperature dependence of reaction rates, catalysis (homogeneous, heterogeneous and enzyme catalysis).

Quantum Mechanics

Experiments that led to the development of quantum mechanics, wave-particle duality, energy quantization, operators, Schrodinger equation and solutions (1D-3D), probability, eigenvalues, eigenfunctions and expectation values, overview of H-atom solutions.

Spectroscopy

Interaction of radiation and matter, atomic absorption and emission spectroscopy, rotational, vibrational, electronic and Raman spectroscopy of molecules, nuclear magnetic resonance spectroscopy

Electrochemistry

Electrolyte solutions, conductance, conductivity and molar conductivity and their determination; strong and weak electrolyte solutions, ionic mobility, transport number, relationships between ionic mobility, conductivity and transport number, conductometric titrations; electrodes and electrode potential, electrochemical cells (Galvanic and electrolytic), Nernst equation and thermodynamic aspects in equilibrium electrochemistry, Potentiometric sensors and titrations.

Interdisciplinary Applications

Atmospheric, biophysical, advanced materials, polymer chemistry.

<u>Practical Topics</u>

Physical chemistry laboratory provides an opportunity for the students to experience the connectivity between conceptual quantitative models with chemical phenomena. The goal of the laboratory course is to provide an understanding of the limitations, assumptions and accuracy of the models in explaining chemical phenomena. Students must be aware of significant figures, accuracy and precision of data, types of errors and propagation of errors, graphing with suitable software, data processing, analysis and report writing. The practical course should cover experiments chosen from all the theory courses outlined above.

Section 2

The expected minimum academic weight (credits) of the total set of courses offered under each subtopic of chemistry (including the practical work relevant to the subtopic) is indicated within brackets next to its designation.

Analytical Chemistry (7 Credits)

__Conceptual Topics__

Advanced Instrumental Techniques for Chemical Analysis

Thermal methods (TGA, DSC, DTA): Spectroscopic methods, inductively coupled plasma spectroscopy and direct current plasma spectroscopy in chemical analysis, mass spectrometry, ionization methods and mass analyzers, hyphenated techniques (GC-MS, LC-MS, ICP-MS, ICP-AES, TGA-GCMS), X-ray fluorescence. Sample preparation techniques specific to instrumental methods: Separation methods, theory and applications of chromatography (plate theory, rate theory, size exclusion, affinity), gas chromatography, high performance liquid chromatography, size exclusion chromatography, supercritical fluid chromatography, affinity chromatography, capillary electrophoresis and electro chromatography. Filtration techniques: Air filtration, micropore filtration and ultra filtration. Electrochemical methods: Characterization of samples using electrochemical methods (Voltammetry, Impedance spectroscopy, ChronoAmperometry, ChronoCoulometry), investigation of corrosion and inhibition of corrosion.

Signal Measurement and Processing Concepts

Basic electronics, signal/noise ratio, signal transducers, signal processing (filtering, Fourier transform).

Quality Infrastructure

The Meter Convention overview with special reference to Chemical Metrology (BIPM, CIPM, CIPM-MRA, CMC, KCDB, Certified Reference Materials and Reference Measurement Methods)

Quality and International Trade (WTO, TBT, SPS-Codex Alimentarius, OIE, IPPC, ISO/IEC)

In depth understanding of Quality Assurance and Quality Control; traceability, measurement of uncertainty, reference standards, test methods, method validation, repeatability and reproducibility, proficiency testing.

Practical Topics

Environmental analysis, heavy metal analysis and analysis of food additives; Hands on experience on analytical instrumentation such as AAS, FT-IR, HPLC, GC, mass spectrometry are recommended.

Biochemistry (2 Credits)

Conceptual Topics

Biological Structures and Interactions

Protein folding, protein structure and function, supramolecular architecture of membranes

Biological Reactions

Metabolic cycles, their regulation (enzymes and hormones) and metabolomics, kinetics and mechanisms of biological catalysis

Biological Equilibria and Thermodynamics

Thermodynamics of binding and recognition, oxidation and reduction processes, electron transport and bioenergetics, protein conformation/allostery, folding, oligomerization, and intrinsically disordered proteins (IDPs),flow of genetic information and mutations, biochemical and biophysical methods (purification identification & sequencing)

Practical Topics

Spectroscopic methods for identification and quantification of protein and DNAs, chromatographic separations of macromolecules, protein purification, molecular biology techniques (including PCR), electrophoretic techniques, kinetics, bioinformatics and omics, molecular modelling, protein engineering.

Inorganic Chemistry (12 Credits)

Conceptual Topics

Molecular Structure and Molecular symmetry

Molecular orbital theory for triatomic and polyatomic molecules; symmetry and point groups of molecules and application of group theory.

Advanced Topics in Chemistry of Elements

Condensed materials having chain, ring, sheet, cage, and network structures, supramolecular structures, smart materials

Advanced Organometallic Chemistry and Advanced Coordination Chemistry

Advanced organometallic chemistry: Synthesis and properties of metal carbonyls and complexes of hydrocarbons: Types of organometallic reactions and organometallic compounds in catalysis: Crystal field theory, molecular orbital theory, electronic spectra of octahedral and tetrahedral transition metal complexes, reaction mechanisms of coordination complexes

Advanced Spectroscopic Methods in Inorganic Chemistry

Applications of UV, IR, NMR, ESR, NQR, MOSSBAUER, Diffraction methods

Solid State Materials

Crystalline solids, unit cell, classification based on unit cell, miller indices, metallic, semiconducting and insulating solids, band theory, electronic, magnetic and optical properties of solids.

Special Topics

Environmental chemistry, Green chemistry, Bioinorganic chemistry, Radiochemistry, Industrial Inorganic chemistry

<u>Practical Topics</u>

Attention should be given on providing competence in calibration of basic analytical equipment, advanced laboratory experimental techniques in classical and instrumental analytical methods and advanced synthetic and purification methods for inorganic materials. Experience in handling modern analytical instruments should be provided. Experiments should be more than a list of instructions to be followed. Instead, they should illustrate how characterization methods provide insight into fundamental electronic structure and structure-property relationships. Students should be provided opportunities to design certain experiments.

Following components should be included.

Advanced classical analytical methods for inorganic materials (suitable titrimetric and gravimetric experiments), analysis of natural inorganic materials,

Inorganic synthesis: Synthetic methods for various inorganic compounds which require special conditions.Characterization methods that involve IR, UV-Vis, AAS, conductivity, oxidation-reduction potentials

Purification methods such as paper, column and ion exchange chromatography; solvent extraction, and resolution of optically active compounds; electronic properties (band gaps, conductivity, etc.).

Organic Chemistry (12 Credits)

<u>Conceptual Topics</u>

Advanced Organic Reactions Mechanisms, Stereochemistry and Synthesis

Organic reaction mechanisms, retrosynthetic analysis, synthesis and stereochemistry of complex biologically important molecules, application of protecting groups in organic synthesis, green organic synthesis

Advanced Spectroscopic Methods in Structure Determination of Organic Molecules

Application of advanced spectroscopic techniques in structure elucidation of organic molecules (NMR spectroscopy; Pulsed FT NMR and high-resolution NMR- spectroscopy, ^{13}C NMR spectroscopy, Nuclear Over Hauser effect (NOE), The DEPT experiment and the APT experiment. 2D NMR, COSY, HETCOR, HMQC, HQBC, FT IR Mass spectrometry).

Advanced Natural Product Chemistry

Biosynthesis pathways, isolation of pharmaceutically important natural products, transformation of natural products into compounds with enhanced biological activity, value addition to natural products and reuse of waste from processing industries. Analysis of natural product extracts, bioassay guided fractionation and identification of active compounds.

Physical Organic Chemistry

Models for characterizing reaction progress (Transition state theory and Hammond postulate), rates of reactions, effects of substituents on the reaction rate, reaction mechanisms, Hammett relationship, linear free energy relationship, Curtin-Hammett principle, effective molarity, primary and secondary kinetic isotope effects, solvent isotope effects, neighbouring group participation

Chemistry of Heterocyclics

Nomenclature of heterocyclics, aromaticity, reactivity and synthesis of five-membered and six-membered heteroaromatics: Structure, reactivity and synthesis of pyridine –N-oxide, quinolines, isoquinolinesand indoles: Chemistry of biologically and pharmacologically important aromatic heterocycles

Pericyclic Reactions

Classification of Pericyclic reactions: Cycloadditions, electrocyclic reactions, sigmatropic rearrangements, cheletropic reactions and aromatic transition structures. Molecular orbitals, correlation diagrams of [4+2], [2+2] additions, Woodward-Hoffman rules, frontier orbital method, group transfer reactions. Diels-Alder reaction, Cope rearrangement, Oxy-Cope rearrangement, Claisen rearrangement, determination of stereochemical outcome of above reactions

<u>Practical Topics</u>

Organic syntheses that illustrate both theory and different methodologies and different laboratory techniques with respect to synthesis of pharmaceutically important organic compounds

Use of different monitoring procedure for execution of the synthesis, develop workup procedure to get desired products from reaction mixture, use of chromatographic techniques to purity the compounds, characterization of compounds using different chemical and spectroscopic measurements and data.

Use of advanced extraction methods to extract natural products from its sources, screening of them for phytochemical classes, purification of crude extracts to get biologically interesting compounds, instrumental analyses of synthesized compounds and natural extracts from plants for authentication, identification/ characterization

Apply of spectroscopic and computational data to answer the formulated hypothesis; analysis of various materials including natural, industrial, environmental and biological samples.

Physical Chemistry (12 Credits)

<u>Conceptual Topics</u>

Advanced Thermodynamics

Third law of thermodynamics and applications, thermodynamics of mixing, activity and chemical potential, partial molar quantities

Advanced Chemical Kinetics

Collision theory, transition state theory, unimolecular reactions, isotope effect, molecular reaction dynamics, photochemistry

Advanced Quantum Mechanics

Spin, Pauli principle, rotational motion, vibrational motion, H-atom, approximation methods, multielectron atoms and molecules

Advanced Spectroscopy

NMR spectroscopy, NOE effect, second order spectra, shift reagents and chiral resolving agents, 13C NMR spectroscopy, 2D NMR, COSY, HETCOR and HMBC spectra, mass spectrometry, rotation and vibration spectroscopy, UV- Visible spectra of diatomic and polyatomic molecules, Raman spectroscopy, atomic absorption spectroscopy

Statistical Thermodynamics

Ensembles, Maxwell-Boltzmann distribution, standard thermodynamic functions expressed in partition functions, Partition function expressions for translational, rotational and vibrational motion of molecules

Advanced Electrochemistry

Electrolyte solutions: Solvents, effects of ions on solvent, metal/solution interface, ideally polarized electrodes, electrical double layer, thermodynamics of the double layer, theories and models for double layer structure, dynamic electrochemistry, electrode kinetics, Butler-Volmer equation /exchange current density, overpotential, Tafel plots, corrosion, electroanalytical chemistry (amperometry, voltammetry, coulometry).

Computational Chemistry

Introduction to computational chemistry software based on quantum mechanics and classical mechanics

Practical Topics

Use of instruments in making measurements relevant to the advanced topics of thermodynamics, kinetics, photochemistry and electrochemistry

Exposure to chemistry related software to perform quantum mechanical calculations and molecular modelling, interpretation of results and using them for prediction.

ANNEXE 2

This Annexe stipulates the details of practical knowledge and applications in chemistry and the transferable skills that should be developed in a student through the chemistry curriculum of a BSc programme.

Practical knowledge and application
Practical knowledge and application involve skills that are largely cognitive in nature. The chemistry curriculum of a BSc programme is expected to develop the following skills in a graduate at the appropriate level.

SLQF Level 5

- The ability to develop arguments and make sound judgments in accordance with theories and concepts in chemistry.
- The ability to apply the knowledge and understanding of concepts and principles in chemistry.
- The ability to determine hazards associated with carrying out chemical experiments in terms of chemical toxicity, chemical stability and chemical reactivity.
- The ability to find information necessary to carryout effective risk assessments in conducting chemistry experiments and chemical reactions in a safe manner.
- Skills required for conducting documented laboratory procedures involved in synthesis and analysis, in chemical systems.
- Skills in monitoring of chemical properties, events or changes by observing and measuring appropriate parameters, and the systematic and reliable recording and documentation thereof.
- Skills in the operation of standard chemical instrumentation.
- Using the significance and the relevant theory, explain and interpret the limits of accuracy of experimental data.

SLQF Level 6

- The ability to construct and sustain arguments and use these arguments, ideas and techniques in problem solving.
- The ability to use practical skills and enquiry efficiently and effectively within chemistry.
- The skills in the practical application of theory using computational methodology and models.
- The ability to plan experimental procedures, given well-defined objectives.
- The ability to engage in research and the selection and prioritization of projects of relevance.

Skills
In order to prepare students to enter the workforce or postgraduate education, SLQF Level 5 with chemistry as a subject and SLQF Level 6 in chemistry degree programmes must provide experiences that go beyond the knowledge in chemistry to develop competence in other critical skills necessary for a professional chemist. It includes skills in Communication, Problem Solving, Chemical Literature and Information usage and Management skills, Teamwork and

Leadership, Entrepreneurship, Networking and Social skills and at the highest level, commitment to be a good citizen by practicing adaptability and ethics in day to day life.

Therefore, chemistry curricula for degree programmes should have established processes to develop and assess those skills in students. Integration of learning opportunities throughout the curriculum or dedicated courses can be used for this purpose.

The chemistry curriculum of a degree programme should provide opportunities for the students to develop the following transferrable skills at the SLQF Level indicated.

SLQF Level 5

5.2.1 Communication skills

- Present information, ideas, and concepts efficiently and effectively using modern and conventional media.
- Scientific writing, data presentation and referencing literature.
- Writing reports and essays in media targeting the public.
- Systematic and reliable record keeping and documentation
- Effective use of communication technology, e.g. presentations using ICT, software for word processing, chemical-structure drawing, and poster preparation etc.
- Synthesize information from a variety of sources using a scientifically appropriate style.
- Communicate scientific material and arguments in a professional environment and workplace.

5.2.2 Teamwork and leadership

- Exercise personal/team responsibility, and leadership in the professional environment/workplace.
- Interpersonal skills
- Ensure equal opportunities to all irrespective of gender, ethnicity, age and personal relationships.

5.2.3 Creativity and problem solving

- Analytical critical, innovative and logical thinking for problem solvingusing qualitative and quantitative information.
- Recognise and analyse problems and plan strategies for their solutions.
- Understand the fundamental uncertainties in experimental measurements, and make conclusions.
- Monitoring by observations and measurements.
- Numeracy and mathematical skills
- Evaluations and estimations.
- Decision making.

5.2.4 Management and Entrepreneurship

- Calculated risk taking and creative thinking.
- Transform innovations into the marketplace.

- Time management
- Business awareness
- Budgeting and managing funds.

5.2.5 Information usage and management

- Skills which support the location, management, processing, analysis and presentation of scientific information
- Ability to assess the quality of information.
- Risk assessment of chemicals used in a laboratory using Material Safety Data Sheet(MSDS)
- Independent learning

5.2. 6 Networking and social skills

- Listening skills
- Asking focused questions
- Build trust and respect others
- Build relationships with colleagues and superiors in a professional manner.
- Ability to use social media
- Appreciation of ethical behaviour
- Ability to use social media professionally.
- Ability to put forward constructive criticism in a respectful manner.
- Ability to receive constructive criticism without malice.
- Discipline

5.2.7 Adaptability and flexibility

- Positive attitude towards culture of change and continuous improvement
- Respond positively to changes and challenges
- Adapt to changing circumstances and environments
- Adopt new ideas and concepts
- Flexible in the way you work and think within the scope.

In addition to the above skills graduates of SLQF Level 6 should possess the following specific skills.

<u>SLQF Level 6</u>

5.2.1 Communication skills

- Clearly communicate information, ideas, issues, problems and solutions to specialist as well as non-specialist audiences

- Write critical reviews in media targeting the public.
- Write scientific communications.

5.2.2 Team work and leadership

- Work in teams, give leadership and promote social engagement.

5.2.3 Creativity and problem solving

- Planning and designing of experiments
- Evaluation of technical/research articles critically
- Able to construct and sustain arguments and solve problems using appropriate ideas and techniques in a professional context.

5.2.4 Management and Entrepreneurship

- Take initiative, assume personal responsibility and demonstrate accountability and ability to instill entrepreneurship

5.2.5 Information usage and management

- Information sourcing and retrieval skills in relation to primary and secondary information sources.
- Thorough in transferable skills related to ICT and information literacy

Suggested teaching learning techniques

Communication	Student presentations, role play, debates, dramas games, peer learning

Teamwork and Leadership	Group projects, industrial training, small group learning; e.g. problem-based learning, peer learning, games

Creativity and Problem Solving	Assignments, projects, small group learning activities; e.g. problem-based learning, research project, etc.
Managerial and Entrepreneurship	Group projects, industrial training, small group learning; e.g. problem-based learning, games, simulated training, industrial (workplace-based) training etc.

Information Usage and Management	Assignments, presentations, projects, case studies

Networking and Social Skills	Student presentations, role-play, debates, dramas, peer learning

Adaptability and Flexibility	Group projects, industrial training, small group learning; e.g. problem-based learning, role play, portfolios, peer learning etc.

ANNEXE 3

The attitudinal (affective) domain of learning is about values, attitudes and behaviours. According to Bloom's taxonomy, it includes, in a hierarchy, an ability to listen, to respond in interactions with others, to develop attitudes or values appropriate to particular situations, to prioritise such attitudes and values, and at the highest level, to display a commitment to principled practice on a day-to-day basis, alongside a willingness to revise judgement and change behaviour in the light of new evidence.

Developing a positive attitude towards chemistry is important in motivating a student to learn chemistry. In addition, attitudinal traits are good predictors of the future behaviour of students as law abiding citizens and effective professionals.

Compared to knowledge traits, assessing and evaluating attitudinal traits is challenging. However, it is necessary to evaluate such traits in students and give credit to those who develop them to acceptable levels.

The chemistry curriculum of a degree programme should provide as many opportunities as possible in developing the following attitudinal traits in SLQF Levels 5 and 6.

- Positive academic self-concept in chemistry and related subjects.
- Intrinsic motivation in learning chemistry.
- Rigour, honesty and integrity in practicing chemistry by strict adherence to scientific method, by understanding how your results have been informed by the work of other chemists, and by acknowledging those factors which have influenced you.
- Respect for life, gender, ethnicity, age, the law and the public good.
- Responsibility by seeking to discuss the issues that science raises for society, by listening to the aspirations and concerns of others, by not knowingly mislead, or allow others to be misled, about scientific matters and by presenting and reviewing scientific evidence, theory or interpretation honestly and accurately.

Suggested teaching learning techniques

- Teacher lead discussions
- Open debate among students
- Peer learning
- Role playing
- Problem-based learning
- Engaging with role models
- Analysis of simulated events
- Games
- Group analysis of case studies
- Expert engagement
- Perspective sharing via reflection
- Appropriate use of multimedia to trigger responses
- Development of portfolios

Assessment and evaluation

Bloom's taxonomy in the affective domain may be used as a basis in designing assessment methods which include the following.

- Questionnaires
- Internship supervisor surveys
- Portfolios