Subject Benchmark Statement

Materials

October 2019

Contents

How can I use this document?

This is the Subject Benchmark Statement for materials. It defines the academic standards that can be expected of a graduate, in terms of what they might know, do and understand at the end of their studies, and describes the nature of the subject.

The UK Quality Code for Higher Education (Quality Code) sets out the Expectations and Core practices that all providers of UK higher education are required to meet. Providers in Scotland, Wales and Northern Ireland must also meet the Common practices in the Quality Code.

The Quality Assurance Agency for Higher Education (QAA) has also published a set of Advice and Guidance, divided into 12 themes, and a number of other resources that support the mandatory part of the Quality Code. Subject Benchmark Statements sit alongside these resources to help providers develop courses and refine curricula but are not part of the regulated requirements for higher education providers in the UK.

This Statement is intended to support you if you are:

- involved in the design, delivery and review of courses of study in materials or related subjects
- a prospective student thinking about studying this subject, or a current student of the subject, to find out what may be involved
- an employer, to find out about the knowledge and skills generally expected of a graduate in this subject.

Subject Benchmark Statements provide general guidance for articulating the learning outcomes associated with the course but are not intended to represent a national curriculum in a subject or to prescribe set approaches to teaching, learning or assessment. Instead, they allow for flexibility and innovation in course design within a framework agreed by the subject community.

It may be helpful to refer to relevant Advice and Guidance when using this statement.

Explanations of unfamiliar terms used in this Subject Benchmark Statement can be found in QAA's Glossary.

Please note that the amendments made to this subject benchmark statement are not as in depth as those of other statements due to this benchmark being of much poorer quality/much more dated than other statements and the reviewers not having deep enough knowledge of material to compensate for this alone.

About the Statement

This Subject Benchmark Statement refers to the bachelor's degrees with honours (for example, BSc, BEng) and integrated master's degrees (for example, MEng, MSci) in materials[1].

It has been produced by a group of subject specialists drawn from, and acting on behalf of, the subject community. The process is facilitated by QAA, as is the full consultation with the wider academic community and stakeholder groups each Statement goes through

In order to ensure the continuing currency of Subject Benchmark Statements, QAA initiates regular reviews of their content, five years after first publication, and every seven years subsequently, or in response to significant changes in the discipline.

Relationship to legislation

Higher education providers are responsible for meeting the requirements of legislation and any other regulatory requirements placed upon them, for example, by funding bodies. This Statement does not interpret legislation, nor does it incorporate statutory or regulatory requirements. The responsibility for academic standards remains with the higher education provider who awards the degree.

Higher education providers may need to consider other reference points in addition to this Statement in designing, delivering and reviewing courses. These may include requirements set out by professional, statutory and regulatory bodies (PSRBs), and industry or employer expectations.

Sources of information about other requirements and examples of guidance and good practice are signposted within the Subject Benchmark Statement where appropriate. Individual higher education providers will decide how they use this information.

[1] Bachelor's degrees are at level 6 (integrated master's at level 7) in *The Framework for Higher Education Qualifications in England, Wales and Northern Ireland* and level 10 (integrated master's at level 11) in *The Framework for Qualifications of Higher Education Institutions in Scotland*, as published in The Frameworks for Higher Education Qualifications of UK Degree-Awarding Bodies

Summary of changes from the previous Subject Benchmark Statement (2017)

This version of the Statement forms its fourth edition, following initial publication of the Subject Benchmark Statement in 2002 and review and revision in 2008 and 2017.

This latest version of the Statement is the consequence of the revision to the UK Quality Code for Higher Education which was published in 2018. It has been revised to update references to the Quality Code and other minor changes within the sector. Changes have been made by QAA and confirmed by the Chair of the most recent review group.

There have been no revisions to the subject-specific content of the statement.

1 Introduction

1.1 Materials science and engineering is an interdisciplinary subject combining chemistry, physics, mathematics, biology, environmental sciences and more, with engineering so as to understand what makes any specific material, from graphene to wood, behave in a particular way and the environmental and social impact of extracting, growing or manufacturing the material. Traditionally, a wide range of material classes are studied, including metals and alloys, ceramics and glasses, polymers and composites, and biologically derived materials alongside, more recently, new materials such as engineered living materials (ELMs), semiconductors and superconductors, liquid crystals, nanomaterials and superfluids, all with particular focus on how the properties of these different material classes make them suited to applications that improve society and the environment.

1.2 This understanding, or materials know-how, is generally achieved through the study of how a material's chemical, physical and biological characteristics, from the atomic level to the macro-structural (engineering) level, combine to control all aspects of a material's properties, from its uses in application (for example to harvest the energy in sunlight in PV solar cells, or direct bone regeneration in a hip replacement), to the environmental longevity of the material, and the associated risks of producing/extracting the material and recycling it at the end of a product lifetime (with particular emphasis on how material properties can be manipulated to create materials suitable for closed-loop recycling).

1.3 Key to this field is the knowledge that the route used to synthesise or fabricate a material (that is, processing) significantly impacts its chemical and physical structure, and thus the characteristics, performance and environmental sustainability, including degradability, of the material as well as how it can be handled safely. Knowledge of this processing-structure-property relationship is exploited to fine tune a material's behaviour, to model its performance under specific environmental conditions, for example finding the conditions under which a material will degrade in ways suitable for closed-loop recycling, and in the discovery and design of new materials. It is also used to inform modification of materials most used in society (such as concrete and polyethylene) to render them fit for application in a circular economy and to ensure their production and use has minimal impact on the environment, society and nature.

1.4 This Statement is primarily concerned with honours degree courses with a major materials science or materials engineering component. However, parts are applicable to interdisciplinary courses with a minor materials component and to taught master's courses with significant materials science or engineering content.

1.5 Accreditation of a particular course by the professional engineering institutions, for their own membership requirements, is an entirely separate exercise, but this Statement is intended to assist professional institutes during the accreditation and course review process. This Statement is primarily concerned with the bachelor's degree with honours and with integrated master's degrees (for example, MEng and MSci) which are required to complete the academic requirements for the achievement of Incorporated Engineer (IEng) and Chartered Engineer (CEng) status - in accordance with the United Kingdom Standards for Professional Engineering Competence (UK-SPEC), published by the Engineering Council UK; and Chartered Scientist (CSci) status - in accordance with the United Kingdom Standards for Chartered Scientist Status, as published by the Science Council UK.

2 Nature and extent of materials

2.1 The academic study of materials links the natural sciences[2] (at length scales from nm to mm) with engineering applications (at length scales from cm to km). At the core of the subject is how the (bio)chemical composition and physical microstructure of a material can be understood and, hence, designed or controlled by processing in order to optimally fulfil an engineering application.

2.2 The range of courses to which this Statement applies, is diverse and extends from science-based to engineering-based courses.

2.3 Materials science is predominantly concerned with understanding the relationships between the microstructure and composition of a material and its physical, chemical and mechanical properties and how these properties shape the impact of the material on humans, nature and the environment; by using tools such as imaging, characterisation and simulation. Whereas materials engineering seeks to design or optimise a particular microstructure or composition, through synthesis, processing, manufacture or modelling in order to meet an engineering or product need. Materials engineering and materials science are strongly interlinked and cannot be delivered in isolation, although a particular degree course may choose to emphasise these two aspects differently.

2.4 Materials are central to the socio-economic wellbeing of a country. However, the socio-economic benefits have historically been very unequally distributed between demographic groups and remain similarly unequally distributed, typically with working class communities, communities of colour, disabled people, women, and immigrant communities receiving the least, while contributing the most physical labour and experiencing the most danger while working on and living near material extraction and processing sites. Additionally, material processing and trading industries are often based far from where the materials are extracted, remaining unaware of or unaffected by the negative impacts extraction has on individuals, homes, communities, and the natural environment. This pattern is also present in the disposal and attempted recycling of materials. Students should be made aware of the inequalities and societal and environmental impacts of the production and disposal of materials and taught about contemporary case studies which have reduced such impacts.

[2] Physics, Chemistry, Biology, Environmental and Planetary Science, and Ecology.

2.5 Materials scientists and engineers help to develop the materials required for new products, improve and lower the environmental, societal and economic cost of manufacturing and closed-loop recycling routes, and enhance the performance of existing materials. They consider the environmental impact and sustainability of their products, for example, by replacing materials that rely on scarce elements or are hazardous to health in their manufacture or use. They discover how to optimise the selection of materials and create sophisticated models and databases from which properties and service behaviour can be predicted

2.6 Materials scientists and engineers may be employed in a wide range of industrial and commercial sectors, with careers in manufacturing, research, product or process development, production management, consultancy, advocacy for materials processors, regulating extraction and processing, waste management and technical sales, as well as education, all of which can contribute to sustainable development on multiple levels. As materials science and engineering is a broad underpinning subject, materials graduates may be involved with advanced transport systems (aircraft, automotive and high-speed rail), healthcare (implant materials, diagnostic methods and medical devices), energy generation (efficient thermal, photovoltaic, nuclear, wind), forensics, high-performance sports equipment, environmental protection (ecosystem protection, recycling and pollution control), electronics (from consumer products to novel smart devices), as well as many more traditional sectors (materials production and disposal, construction, packaging and domestic goods).

3 Knowledge, understanding and skills

Introduction

3.1 This Section describes the knowledge, skills and attributes that materials graduates are expected to possess, including reference to materials-specific aspects, background science and generic skills.

In this section, knowledge and skills are grouped into three distinct areas:

i materials related
ii science and engineering
iii generic.

Materials-related knowledge and skills

3.2 Materials courses may be general or specialist, theoretical or applied. Degree courses offered by individual providers may vary considerably. However, it is expected that materials graduates will have an awareness of the full range of materials including metals, alloys, composites, ceramics, glasses, polymers and biomaterials and their applications in the sustainable economy (for example in renewable energy generation or ecosystem management).

3.3 A key to the application of materials is to understand the links between structure and properties, and between processing and structure with particular emphasis on how these links are being utilised to create the materials needed for a sustainable economy. Hence, materials graduates have the ability to choose materials, and their synthesis/fabrication routes, in order to provide desired properties.

3.4 Students should also appreciate the inequities created, facilitated and perpetuated by the material science and material engineering industry (see 2.4-2.6 for more detail) both on local and global scales in order to reduce the inequities still present today and assist the industry in contributing to an environmentally sustainable, global society.

3.5 An understanding of pre-industrial, traditional cultural, artisanal and alternative production methods among students is also important to ensure culturally significant, independent arts are not forgotten. Many of these methods provide structural benefits, levels of customisation, cultural and historical significance that post-industrial mass- and machine-production cannot. They also function as personal hobbies with mental and physical health benefits to many individuals and are often less damaging to the environment across the product's lifecycle. This understanding could be achieved by undertaking both laboratory work focusing on understanding the materials themselves, and creative workshops teaching students historical and artisanal processing techniques through hands-on experience.

3.6 All materials graduates will have an understanding of how materials science can contribute to maintaining a sustainable and equitable economy.

3.7 Materials graduates are also familiar with at least a majority of the concepts under each of the following headings:

Structure

i atomic bonding, crystalline lattices, defects and disorder, amorphous materials

ii phase equilibria and phase transformations, multiphase materials, thermodynamic and kinetic aspects

iii structure on the nano, micro, meso and macro scales

Properties

iv mechanical behaviour - elastic and plastic deformation, creep and fatigue, fracture, strengthening, toughening and stiffening mechanisms

v functional behaviour - the control through composition and structure of electrical, optical and magnetic properties as well as biocompatibility and the nature, speed, and conditions required for the material to degrade into something that can be used in a raw material in another process (so the material can be used in the circular economy)

Characterisation

vi structural characterisation - optical and electron microscopy techniques, electron and X-ray diffraction, scanning probe techniques, thermal analysis

vii compositional analysis - spectroscopic methods (electron/X-ray probe/infra-red/ultra-violet techniques), chemical analysis

viii mechanical test methods

ix techniques for determining electrical, optical, magnetic and biodegradation properties x functional analysis - biocompatibility testing (acellular, cellular and in vivo), accelerated ageing, environmental wear testing

Modelling and simulations

xi computational simulation of materials across the length-scales and corresponding timescales, from atomistic (classical and quantum) to finite elements including modelling the lifespan of materials in the natural environment, and human and other animal bodies

Processing

xii materials synthesis - vapour, liquid, colloidal, powder, solid-state deposition and biological techniques

xiii bulk processing, heat and mass transfer, and fluid mechanics

xiv joining methods, surface treatment and the application of coating

xv layered and additive manufacturing techniques, for example, 3D printing, including the creation of 'intelligent' products and living tissues

xvi impacts of the processing and extraction methods, the resources and energy required, by-products and the lifespan of the product on the natural environment, its method of disposal and the health and safety of individuals working in processing, extraction and disposal settings.

Application

xvii materials design - compositional variation and processing to achieve required microstructures and, hence, properties

xviii materials selection - consideration of all material types and their associated longevity in the environment after use, materials processing methods and product vs labour costs in safe working conditions where living wage or higher is paid

xix degradation/durability of materials - effect of environment upon performance, corrosion, wear and biodegradation

xx lifecycle analysis, sustainability and environmental impact

xxi understanding a material's position in a circular economy

xxii contribution of materials towards a more sustainable, ethical society or whether it should be phased out of use

xxiii impact on the health, safety and mental wellbeing of individuals using or around the material once in use.

3.8 Materials graduates will have had opportunities, through practical work, for first-hand experience of a range of techniques and materials (artefact analysis, characterisation, processing, computational simulation, testing and so on) designed to develop the ability to plan, implement and interpret experimental investigations. In addition, graduates will have had hands-on experience of historical materials processing techniques such as glassblowing or ironwork, which develops their understanding of materials processing as a wider field, and facilitates graduates to bridge the scientific and artistic fields of materials use.

Scientific and engineering-related knowledge and skills

3.9 In order to understand the materials topics discussed above, materials graduates need to acquire an adequate knowledge of mathematics and science to prepare a foundation for learning within the subject. Examples of these requirements are given below. It is not expected that materials graduates have studied all of these (for example, biology). Materials graduates also need to acquire adequate engineering knowledge and skills in order to understand aspects of materials production and behaviour in service and to be able to communicate effectively within the engineering profession at large. In addition to being able to communicate with the scientific and engineering communities, graduates should also be able to effectively communicate key information about materials science and its impacts on society/other sectors to a wide range of audiences with differing levels of scientific knowledge.

3.10 Such requirements include the following knowledge and skills:

i **Mathematics**: fluency in mathematics, and familiarity with a range of mathematical and computational methods, for expressing the laws of science, for formulating and solving problems, for experimental design and for assessing and presenting experimental data including competency in probability and statistics.

ii **Chemistry**: an adequate understanding of organic, inorganic and physical chemistry to support a range of materials subjects. Knowledge on or ability to infer the by-products of processes on certain materials based on their constituent components, structure and properties and the environmental and physical health impacts of these by-products. Thermodynamics and kinetics are essential components, alongside chemical characterisation techniques, and chemical aspects of materials production such as catalysis, processing, stability and degradation so students understand the causes of the varying levels of toxicity different materials have for the Earth, humans, other animals, plants and ecosystems as a whole.

iii **Physics**: a broad foundation in physics for understanding and characterising materials' structures and properties, including solid-state physics, waves and optics, electronics, mechanics, efficiency and energy storage and transformation including introductory knowledge of aerodynamics (for wind turbines and hydro power) and transistors and semiconductors (for solar cells).

iv **Engineering principles**: including design, manufacturing and processing. There should be a strong focus on encouraging students, especially those in the latter years of their course, to consider how work in university labs vary from industrial manufacturing and recycling processes. This could include how the processes they carry out during practical or dissertation sessions could be scaled up for industrial use which is especially important when considering recycling processes or the manufacturing of renewable energy devices. Industrial scales often present unique challenges, from the mechanisation of the production process to a magnification of associated risk from a material if it is hazardous in a certain phase or its extraction causes environmental, humanitarian, or societal harm. Students should be taught how to minimise these risks by selecting and improving their materials or processing choices based on the current data of associated risk.

v **Biology**: appropriate understanding of biology where it is required to support course which include aspects of biomaterials such as bioplastics (including an understanding of why bio-engineered materials are not-necessarily biodegradable, and how they can be used in greenwashing rather than for true environmental gain) or tissue engineering (for example, basic cellular structure and function, protein structure, human, animal and plant physiology, pathology, regenerative medicine and so on), or interactions with the natural environment (such as degradation, impact of toxins and pollution, food hygiene, structural integrity against nature, and materials to mimic the natural environment). The biochemistry of how materials (as they degrade over the course of their lifecycle of use) interact with plant and animal cells, what possible toxins may be released by/present in a material, and how such toxins may flow through natural systems is a key area for students to grasp. A good understanding of the variety of ways biological organisms can be useful for releasing the stored energy in waste materials, as well as new techniques using enzymes and other biological tools for the circular recycling of plastics through depolymerisation is also essential. Students should be familiar with the differences between recycling techniques that allow a material to be recycled infinitely compared with the which degrade the material and allow only a finite amount of recycling. Students should understand how the most suitable choice of recycling method is affected by a material's properties and how it has been incorporated into a product or device.

vi **Environmental science**: including a basic understanding of climatology, evidence and causes for global warming as well as an understanding of what the various IPCC predicted scenarios would mean for humanity and the planet. Students should understand the various ways in which production will have to adapt to climate change and assist in its mitigation via the materials they use as described in 3.10 iii and 3.10 v.

Generic skills

3.11 Those graduating with a degree in materials will have good professional judgement, are able to exercise critical and interdisciplinary thought, logic and empathy and, having gained experience, take responsibility for the direction of important tasks and being part of shaping the direction of their workplace or research institution to be more sustainable, ethical, and equitable. In order to demonstrate these skills, they need to possess:

i the ability to communicate with audiences with a wide range of technical and scientific knowledge, including the general public and those in political spheres in writing, orally and using graphical representations

ii the ability to demonstrate critical and interdisciplinary "big picture" thinking in reviewing the state of the art and in the analysis of experimental data both in isolation and in the context of the wider literature

iii the relevant mathematical and computational skills

iv problem-solving skills

v an understanding of how to approach "wicked problems" such as the climate crisis, biodiversity loss and global inequality

vi competence in using information technology effectively, for example, to support oral presentation, literature searches and report writing vii the ability to work in teams of diverse individuals, acknowledging and supporting each other’s strengths and needs, and with an awareness of functions required for organisational success

viii the ability to manage time, resources (including the Earth's finite resources), projects and finances

ix study skills needed for planning, monitoring and recording continuing professional development

x an awareness of and commitment to incorporate health and safety, sustainability and environmental issues, and ethical considerations into all aspects of work

xi ethical entrepreneurship and an awareness of issues related to intellectual property and its protection

xii In addition to the above, graduates would generally have had opportunities to tackle open-ended problems, which provide opportunities to demonstrate problem-solving skills, creativity, innovation, leadership and team working. These activities would also embed aspects of ethics, health, safety and social and environmental sustainability considerations on both local and global scales.

4 Teaching learning and assessment

4.1 Existing materials courses have been developed over many years and deploy a diverse range of teaching, learning and assessment methods to enhance and reinforce the student learning experience. The courses covered by this Statement encompass a wide range of types of material and are offered through many modes and patterns of study. Teaching, learning and assessment methodologies are justified in terms of the learning outcomes of the course and the background of the students. The methods used are made explicit to the students taking each course, and evaluated regularly (and modified where appropriate) in response to generic and subject-specific developments as well as student and staff feedback.

4.2 Course design is informed by research, scholarship and an understanding of the potential destinations of graduates. It is not possible for students to achieve an understanding of materials science and engineering which is conducive to a sustainable, equitable global society without significant exposure to laboratory work and undertaking a substantial project. The course develops in graduates, both independence of thought and the ability to work effectively in a diverse team, either comprised of materials experts or interdisciplinary in nature. Where appropriate, all teaching is placed within the context of social, legal, sustainability, environmental and economic factors relevant to the production and use of materials during their lifecycle.

4.3 All course modules should include teaching on topics, ideas, and pioneering individuals in the materials field from marginalised backgrounds as well as the white, Western males and their ideas who dominate the field and have historically taken or been given credit for the work of women, people of colour, disabled people, and other marginalised people. Course designers should also make their best efforts where possible to include the interactions between colonialism and material science and engineering, including its impacts on traditional, cultural material uses and processing practises. As well as a materials science course showing the production methods in use since the industrial revolution, it is important for courses to showcase the materials techniques that have been used around the world for millennia. Many of these techniques are considered artisanal but offer valuable insight for students into the day-to-day uses of materials, and how the material properties interact with design elements.

4.4 Methods of assessment reflect the specified learning outcomes. There is a balance between the need to assess a student's understanding, knowledge and ability for the award of a qualification, and providing appropriate, actionable feedback that fosters a student's development. Where possible, assessment methods reflect the demands that graduates are likely to face in their future careers, including problem solving and the need to express technical material clearly and accurately in writing. Assessments should measure a student's ability to meet these outcomes and their potential to thrive in a modern materials industry, which increasingly values sustainability and utilises green skills, rather than their ability to take assessments. Additionally, to reflect work scenarios, time should not be a major limiting factor in assessments. An important element of assessment is that students are given feedback to allow continuing personal development.

4.5 Examples of teaching and assessment methods which might be appropriate for use within materials courses are given in Appendix 1. However, these lists are not intended to be either prescriptive or comprehensive, since imaginative innovation in teaching often plays a large role in motivating students and expanding their interest in the subject.

Project work

4.6 Materials graduates are expected to have carried out a group (minimum requirement for bachelor's level) or individual project (minimum requirement for master's level). These projects develop competence in investigating, managing and applying knowledge, usually in the solution of a complex materials problem. Such a project is described in a report, which demonstrates the abilities to:

- i understand the published literature on the topic of the investigation encompassing both what is known and the limits of current, formally recorded knowledge
- ii use critical analysis in the evaluation of the current literature and its exclusion or inclusion of traditional, cultural knowledge
- iii understand and work to meet the needs of diverse users
- iv create and work to a brief that ensures the material produced meets diverse users' needs and is both environmentally, economically and socially sustainable
- v formulate the problem in appropriate terms and select appropriate, sustainable methodologies to undertake investigations
- vi present findings in a clear and concise manner to a range of audiences

vii analyse findings qualitatively and quantitatively as appropriate, and use appropriate statistical methods to assess the uncertainty of any quantitative results

viii critically interpret and discuss findings in the light of current knowledge accounting for the needs of future users' and wider society

ix summarise the main conclusions and provide an accurate synopsis of the work undertaken.

4.7 Team working and experience of leadership on a project is a necessary requirement for MEng course and CEng registration according to the UK-SPEC.

Professional experience

4.8 The opportunity for students to gain experience in or about the professional environment during the degree is highly recommended. There should be a variety of ways that students learn about professional applications of materials science which may include speakers from industry and commerce, materials-related work placements, site visits, or participation in external projects including local community and stakeholder engagement. Materials graduates are also familiar with the organisation and structure of business, the relevant legislative requirements and ethical and professional behaviour which will lead to a sustainable society.

5 Benchmark statements

5.1 The standards of student achievement for a bachelor's degree with honours in materials are divided into three attainment levels: excellent; typical; and threshold.

Benchmark standards for honours degrees

Attainment level: threshold

i Understanding of the subject and techniques is basic and selective. There is a recognition of what generic knowledge should apply to a new situation, but there may be a lack of confidence in how to use it. The methodology for solving problems and meeting the sustainability and inclusivity requirements can be explained even if it cannot be applied. New knowledge is acquired with perseverance.

ii Routine calculations, explanations, interpretations and analysis can be identified but may require checking and assistance to complete the task. There is general competence in answering questions concerning routine aspects. There is selective knowledge of terms and their application. Some assistance may be required in explaining fundamental concepts. Mistakes can be identified, but not necessarily rectified.

iii Project or practical work is planned and executed with reasonable success but writing up may require help to identify the full significance of the results and some assistance may be required in their interpretation and discussion. A list of essential literature may be quoted without critical analysis. There is an indication of future work.

iv Practical or relevant competence is selective but may be good in specific areas. Sustainable practices utilised in the materials industry from resource extraction to product disposal are known and understood but prompting may be required to fully implement them during practical work where possible.

v Generic skills may be good in certain aspects.

5.2 A graduate at this level would be a good potential trainee for either a technical or general management position. After an appropriate period of professional experience, the graduate is likely to develop into a good practitioner in a specific field, where an awareness of materials and their sustainable use is essential but without the need to apply fundamental knowledge on a regular basis, for example, production control.

Attainment level: typical

i Understanding of the subject and techniques is good, but generally confined to the information provided in the course. There is an understanding of what knowledge and techniques can be applied to new situations. The methodology for solving problems and meeting or surpassing sustainability and inclusivity requirements can be clearly demonstrated. New knowledge is readily acquired.

ii Routine calculations, explanations, interpretations and analysis are executed accurately and demonstrate interdisciplinary "big picture" thinking. Understanding of relevant facts and techniques is good. There is a fluency and confidence in the method of approach over most of the subject.

iii Project or practical work is planned, executed and written up with guidance. All stages or project or practical work show a good understanding of how to carry out work sustainably and ethically. Results are analysed and discussed in a competent manner. There is good understanding of literature and relevant practice with suggestions for future work. There is an understanding of how the current and future work can contribute towards the development of a more sustainable, ethical global society and where caution must be taken to ensure this is not inhibited.

iv Practical or relevant competence is demonstrated over most of the range expected. The ability to innovate sustainably and ethically is demonstrated. Sustainable practices utilised in the materials industry from resource extraction to product disposal are well known, understood implemented during practical work, where possible.

v Students have good generic skills, including collaboration within teams diverse in background and sustainability in practice, and time-management ability.

5.3 After an appropriate period of professional experience, the graduate is likely to become a good practitioner capable of exercising sound judgement. Career prospects could include research, innovation or technical management, with the expectation of significant managerial responsibility and the possibility of achieving a skilled technical or specialised position, or positions in research and teaching.

Attainment level: excellent

i Understanding of the subject and techniques is extensive, extending beyond the information provided in the course. Knowledge and techniques are applied quickly and readily to new situations, including unseen or open-ended problems. Sustainability and inclusivity demands can be identified and integrated into solutions seamlessly, innovative, and independently. Both the problem and the solution can be critically appraised. New knowledge is acquired quickly and accurately.

ii Routine calculations, explanations, interpretations and analysis are executed swiftly and accurately and demonstrate interdisciplinary "big picture" thinking. Non-routine calculations, explanations, interpretations and analysis are executed with assistance and readily picked up. Understanding of relevant facts and techniques is excellent. There is a fluency and confidence in the method of approach.

iii Project or practical work is planned, executed and written up with little assistance. There is clear evidence of critical and interlinked thinking in the analysis and discussion of results, with excellent understanding of literature and of relevant practice. There is a clear plan of future work. There is a detailed understanding of how both the current and future work can contribute towards the development of a more sustainable, ethical global society and where caution must be taken to ensure this is not inhibited.

iv Practical (or relevant) competence is clearly demonstrated. The ability to innovate is also clearly demonstrated. Sustainable practices utilised in the materials industry from resource extraction to product disposal are well known, understood, fully implemented (within the Higher Education provider's limitations) during practical work and graduates are able to contribute to and further sustainability practises within the workplace and industry.

v Students have excellent generic skills, including collaboration within teams diverse in background and sustainability in practice, and time-management ability.

5.4 A graduate at this level would be a highly sought-after honours graduate. After an appropriate period of professional experience, the graduate is likely to become an excellent practitioner capable of exercising sound judgement. Career prospects could include research, innovation or technical management with the expectation of significant managerial responsibility. There is likely to be rapid progress to a highly skilled technical or specialised position, or positions in research, consulting or teaching.

Integrated master's (MEng, MSci)

5.5 An MEng or MSci is an integrated master's course, which provides an extended and enhanced course of study. It is usually designed with reference to UK-SPEC or the Science Council CSci standards as a preparation for professional practice and attracts the more able student. The period of study is usually equivalent to at least four years of academic learning (five years in Scotland) and the course of study is both broader and deeper than a corresponding bachelor's degree with honours and has an increased emphasis on industrial relevance.

5.6 MEng or MSci students undertake both an individual research/design project and a more wide-ranging group project with strong industrial involvement, with master's level work in the later stages of the course is more industrially-focused or advanced specialist interest modules in the final year. These courses maintain the deep integration of sustainable practices and concerns, care for the environment and commitment to global equity in the curriculum, as well as sustainability and accessibility practises for all students in course design, as in Bachelor's degrees. MEng and MSci students also have good generic skills, with particular emphasis on critical and interlinked "big picture" thinking, sustainability in practice and ethical leadership for global benefit. Further guidance can be found in the Subject Benchmark Statement for Engineering.

Threshold performance for integrates master's (MEng, MSci)

5.7 MEng or MSci graduates demonstrate greater attainment in the areas of fundamental knowledge and generic skills described above. Students are unlikely to be able to progress within/onto the master's course if they do not reach at least the typical attainment level for a bachelor's degree with honours.

Appendix 1: Examples of teaching, learning and assessment

This appendix contains examples of teaching, learning and assessment methods which may be appropriate for specific elements of materials courses. The lists are intended to be illustrative and not exhaustive.

Teaching/study methods

Formal lectures – synchronous, asynchronous, in-person, or online
Interactive lectures – synchronous, asynchronous, in-person, or online
One-to-one tutorials
Small group tutorials
Laboratory classes - structured or open-ended
Examples classes
E-learning tools
Guided reading
Student study groups
Peer mentoring – as mentor or mentee
Library/information retrieval tasks
Field trips/works visits
Training during work placements
Case studies
Problem-based learning
Individual projects – to address real life issues or developed for the course
Team projects – to address real life issues or developed for the course
Project consulting - including for community projects
Reflective journals
Concept mapping

Assessment methods

Timed examinations
Open-book or untimed examinations
Laboratory examinations
Computer-aided assessment - including using visualisation software
Problem-solving tasks
Essays
Oral presentations

Poster presentations
Laboratory reports
Work-placement reports
Learning logs/portfolios
Project reports
Self-assessment
Peer assessments
Critical review of literature

Appendix 2: Membership of the benchmarking and review groups for the Subject Benchmark Statement for Materials

Membership of the review group for the Subject Benchmark Statement for Materials (2019)

The fourth edition, published in 2019, was revised by QAA to align the content with the revised UK Quality Code for Higher Education, published in 2018. Proposed revisions were checked and verified by the Chair of the Subject Benchmark Statement for Materials review group from 2017.

Professor Peter Haynes (Chair)	Imperial College London
Dr Alison Felce	QAA

Membership of the review group for the Subject Benchmark Statement for Materials (2017)

Details provided below are as published in the third edition of the Subject Benchmark Statement.

Professor Cris Arnold	Swansea University
Professor Zoe Barber	University of Cambridge
Professor Peter Haynes (Chair)	Imperial College London
Dr Karin Hing	Queen Mary University of London
Professor Stuart Lyon	University of Manchester
Professor Rachel Thomson	Loughborough University

Student reader

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Membership of the review group for the Subject Benchmark Statement for Materials (2008)

Details provided below are as published in the second edition of the Subject Benchmark Statement.

The revision to this Subject Benchmark Statement was coordinated by:

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The review involved extensive consultation across the sector.

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Details below are as published in the original Subject Benchmark Statement for Materials (2002).

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