Geology Subject Area Group: *General Characteristics of a «European Core Curriculum» in Earth Sciences*

1. **Introduction**

1.1. *General*

This document, which has been compiled by the Geology Subject Area Group of the «Tuning Higher Educational Structures in Europe», describes the general characteristics of a «European core curriculum» in Earth Sciences or Geology (in future referred to as Earth Sciences for simplicity)[1]. Within Europe different types of higher education institutions offer programmes of studies that mutually differ in their general approach to teaching and learning and in the level they demand from students. It should be noted that the present document refers only to universities and that the considerations and recommendations presented below do not apply to other type of institutions. Our principal concern at this stage is with single first cycle (bachelor) programmes over three to four years, leading to an award in Earth Sciences, Geology or related subject, but our recommendations often relate more broadly. The present statement should be seen as a starting point: departments and subject groups within the European higher education space will have the chance to demonstrate how benchmarking standards can be built on by the provision of additional or perhaps alternative opportunities.

[1] This paper is based amongst others on the UK QAA benchmark documents for History and for Earth and Environmental Sciences.

The only possible aim to agree on a «European core curriculum» in Earth Sciences should be to facilitate an automatic recognition of degrees in Earth Sciences in Europe in order to help mobility. Earth Science education is characterized much more by its approach, which concentrates on using selected knowledge in order to develop certain skills and qualities of mind, than by specific content. Indeed, degree programmes in Earth Sciences apart from serving the purpose of educating future earth scientists, also provide valuable general education, providing young people with a variety of transferable theoretical and practical skills: from problem solving and decision making in the light of uncertainty to operating in a variety of cultural environments and to the application of modern technology *etc. etc*. Therefore, although the importance of solid geoscientific knowledge is self-evident, a core curriculum in Earth Sciences cannot and should not be described in terms of a narrowly defined specific body of required knowledge, even if it is possible to indicate some subject matter that will, to some extent, form part of most programmes of study.

By its nature the present paper does not provide a basis for judgements to be made about a particular student's learning achievement, or about academic standards and performance of individual departments or subject groups in individual countries. The latter cannot be but the responsibility of academic reviewers appointed by the Universities or other national bodies. Finally, the «core curriculum» outlined below cannot be used as a tool for automatic transfer between universities. Such transfer will always require consideration by case, since different programmes can get students to adequate levels in different but coherent ways, but an inappropriate mixing of programmes may not.

1.2. *Guiding assumptions*

1.2.1. Earth Science differs from many subjects in that we are not bound by a specific body of required knowledge or a core with surrounding options. We take it as self-evident that knowledge and understanding of the earth and its systems are of incalculable value both to the individual and to society at large, and that the first object of education in Earth Science is to enable this to be acquired. We accept variation in how the vast body of knowledge which constitutes the subject is tackled at undergraduate degree level. This is related to an approach which concentrates on using selected knowledge in order to develop certain skills and qualities of mind and which also seeks to respond to students' interests.

1.2.2. Earth Sciences as a discipline, distinguishing it from other sciences, focuses on the understanding of Earth systems in order to learn from the past, understand the present and predict and influence the future. Earth Sciences provide a distinctive education by providing a multi-disciplinary and inter-disciplinary and, although reductionist methodology is involved, mostly holistic approach, comprehensive field training, and a range of spatial and temporal values and by encouraging graduates to use their powers of observation, analysis and imagination to make decisions in the light of uncertainty.

1.2.3. We recognise that the concepts, theories and methodologies of other sciences are themselves used by many earth scientists and applied to the Earth system. We, therefore, accept that training in relevant aspects of such basis disciplines will normally constitute a part of an Earth Sciences degree. We also recognise that especially with a view to application it might be appropriate to include relevant elements of humanities, economics and social sciences in degree programmes in Earth Sciences.

1.2.4. Important abilities and qualities of mind are acquired through the study of Earth Sciences. They are particularly valuable for the graduate as citizen and are readily transferable to many occupations and careers. Some of these qualities and abilities such as the ability to communicate ideas and information and to provide solutions to problems are generic, in that most degree programmes, notably in the other Sciences, impart them. But degree-level study in Earth Sciences also develops ways of thinking which are intrinsic to the discipline while being no less transferable. These include 1) a four-dimensional view —the awareness and understanding of the temporal and spatial dimensions in earth process—; 2) the ability to integrate field and laboratory evidence with theory following the sequence from observation to recognition, synthesis and modelling; 3) a greater awareness of the environmental processes unfolding in our own time, and 4) a deeper understanding of the need to both exploit and conserve earth resources. These qualities of mind and abilities are most effectively and economically developed by deep and prolonged immersion in, and engagement with, the practice, methods and material of the subject itself. The cumulative acquisition of, and ability to apply transferable skills, and the development of students as competent earth scientists thus necessarily proceed hand-in-hand. The link between the two lies ultimately in the habits of mind or intellectual approach developed by students who have been trained as capable earth scientists. These will continue to inspire the application of their minds to other matters later in life.

2. **Programmes, knowledge and skills**

2.1. *Introduction*

2.1.1. The core curriculum of an Earth Sciences degree programme should be directed towards the development of an understanding of the key concepts, a sound background in the subject specific knowledge, and the development of transferable skills. In practice programmes will take the form of different thrusts, in relation to specific fields of application.

2.1.2. Earth Science is an essentially empirical science, in which the ability for prediction is based on the explanation that follows recognition. It covers a broad field, ranging from the scientific study of the physical characteristics of the Earth to that of the human influence on its environmental systems. Nevertheless an Earth Sciences degree programme should share the following important features:

- most tuition has an **holistic, multi-disciplinary and inter-disciplinary** approach;
- the **integration** of **field studies, experimental** and **theoretical** investigations is the basis for much of the learning experience in Earth Sciences, but may be less significant in, but not absent from, courses in geophysics and geochemistry;
- **quantitative** and **qualitative** approaches to acquiring and interpreting data, with strong dominance of the quantitative approach in geophysics and geochemistry;
- examination of the exploration for, and exploitation of resources in the context of **sustainabilit**y.

2.1.3. Earth Sciences is so broad that as far as subject matter is concerned a large variation in degree programmes exists in European practice: some programmes encompass Earth Sciences in the broadest sense, while others are concerned with geology in a strict sense or with more specialist subjects.

2.2. *Degree programmes broadly concerned with Earth Sciences*

2.2.1. Degree programmes in Earth sciences typically involve:

- a systems approach to understanding the present and past interactions between the processes operating in the Earth's core, mantle, crust, cryosphere, hydrosphere, atmosphere, pedosphere

and biosphere, and the perturbations of these systems by extra-terrestrial influences and by man,
— the scientific study of

- the physical, chemical and biological processes operating on and within the Earth,
- the structure and composition of the Earth and other planets,
- the history of the Earth and its spheres over geological time scales,
- the use of the present to understand the past and the past to understand the present.

2.2.2. Typical programme elements might include:

— geophysics, geochemistry, geomathemathics, geoinformatics and geostatistics,
— mineralogy, petrology, palaeontology, sedimentology, stratigraphy, structural geology and tectonics, general geology'
— geomorphology, Quaternary studies, soil science, palynology and archaeological science'
— palaeobiology, palaeoclimatology, palaeoecology and palaeo-oceanography'
— hydrology and hydrogeology, environmental geoscience, meteorology, climatology, glaciology and oceanography
— geological, geomorphological and soil mapping, remote sensing applications'
— volcanology, ore geology, petroleum geology, geomaterials, geotechnics, and economic geology.

Depending on the positioning of institutions within the broad field of Earth Sciences degree programmes will normally include some, but not all, of these elements.

2.2.2a. An Earth Sciences degree programme requires underpinning knowledge especially in the fields of Chemistry, Physics, Biology, Mathematics and Information Technology, some of which may properly constitute part of the Earth Sciences curriculum.

2.2.2b. Material relevant to the applications of Earth Sciences are elements of Law and Economics, Town and Country Planning, Human Geography, Politics and Sociology, and Management, Business and Safety studies.

2.2.3. Applications of the subject areas might include developing exploration and exploitation strategies for resource industries (e.g. hydrocarbons, minerals, water, bulk materials, industrial minerals), site investigations for civil engineering projects including waste disposal and land restoration, and understanding and developing mitigation measures for geohazards such as floods, earthquakes, volcanic eruptions and landslides, environmental assessment, impact monitoring, modelling and prediction which provide a framework for decisions concerning environmental management (e.g. the management of surface and ground water, human, agricultural and industrial waste, natural and semi-natural habitats).

2.2.4. The subject area overlaps with others such as environmental sciences, social science-based environmental studies, biology, chemistry, physics, mathematics, civil engineering, geography and archaeology. Earth Science is defined by many to include engineering geology, mining engineering, petroleum engineering and physical geography, while some would also include oceanography and meteorology.

2.2.5. The subject area promotes an awareness of the dual context of the subject in society, namely that of providing knowledge and understanding for both the exploitation and the conservation of the Earth's resources.

2.3. *Subject knowledge*

Each undergraduate Cycle 1 degree will have its own characteristics with a detailed rationale for the content, nature and organisation as outlined in the relevant programme specification. While it is recognised that degree courses will vary considerably in the depth and specificity to which they treat subjects, it is expected that all graduates should be acquainted to some degree and depending on subject matter choice with:

- modern earth processes, including the understanding of the cycling of matter and the flows of energy into, between and within the solid Earth, hydrosphere, atmosphere, pedosphere and biosphere;
- the principles of stratigraphy and the concept of Uniformitarianism;
- plate tectonics as a unifying concept;
- some palaeontology;
- some mineralogy, petrology and geochemistry;
- some tectonics and geophysics;
- relevant terminology, nomenclature, classification and practical knowledge;
- relevant chemistry, physics, biology and mathematics.

2.4. *Graduate key skills*

2.4.1. The term «Graduate» Key Skills is employed here to imply that the skills work is being undertaken and eventually passed in an higher education context and the student is following a coherent, structured progression of learning. It is noted that «skills» is defined in a broad sense and that the skills listed below often have a high cognitive content consistent with the expectations of undergraduate programmes.

2.4.2. The Graduate Key Skills that should be developed in an Earth Sciences degree programme is subdivided into the following headings:

- Intellectual Skills.
- Practical Skills.
- Communication Skills.
- Numeracy and Information and Communications Technology (ICT) Skills.
- Interpersonal/Teamwork Skills.
- Self-Management and Professional Development Skills.

2.4.3. Whereas these skills will normally be developed in a subject-specific context, they have wider applications for continuing personal development of students and in the world of work.

Intellectual skills

- recognising and using subject-specific theories, paradigms, concepts and principles;
- understanding the quality of discipline related research;
- analysing, synthesising and summarising information critically, including prior research;
- collecting and integrating several lines of evidence to formulate and test hypotheses;
- applying knowledge and understanding to address familiar and unfamiliar problems;
- recognising the moral and ethical issues of investigations and appreciating the need for intellectual integrity and for professional codes of conduct.

Practical skills

- planning, organising and conducting, and reporting on investigations, including the use of secondary data;

- collecting, recording and analysing data using appropriate techniques in the field and laboratory;
- undertaking field and laboratory investigations in a responsible and safe manner, paying due attention to risk assessment, rights of access, relevant health and safety regulations, and sensitivity to the impact of investigations on the environment and stakeholders;
- referencing work in an appropriate manner.

COMMUNICATION SKILLS

- receiving and responding to a variety of information sources (e.g. textual, numerical, verbal, graphical);
- communicating appropriately to a variety of audiences in written, verbal and graphical forms.

NUMERACY AND ICT SKILLS

- appreciating issues of sample selection, accuracy, precision and uncertainty during collection, recording and analysis of data in the field and laboratory;
- preparing, processing, interpreting and presenting data, using appropriate qualitative and quantitative techniques and packages;
- solving numerical problems using computer and non-computer based techniques;
- using the Internet critically as a means of communication and a source of information.

INTERPERSONAL/TEAMWORK SKILLS

- identifying individual and collective goals and responsibilities and performing in a manner appropriate to these roles;
- recognising and respecting the views and opinions of other team members;
- evaluating performance as an individual and a team member.

SELF MANAGEMENT AND PROFESSIONAL DEVELOPMENT SKILLS

- developing the skills necessary for self-managed and lifelong learning (e.g. self-discipline, self-direction, working independently, time management and organisation skills);
- identifying and working towards targets for personal, academic and career development;
- developing an adaptable and flexible approach to study and work.

3. **Learning, teaching and assessment**

3.1 The Group considers that it is inappropriate to be prescriptive about which learning, teaching or assessment methods should be used by a particular programme. This is because Earth Sciences programmes may (e.g. based on the requirements of different subdisciplines) be differently oriented within Europe and within individual European countries and are embedded in diverse educational cultures. Different institutions, moreover, have access to different combinations of teaching resources and the variable modes of study include a range of patterns of study in addition to the traditional full time degree course. However, staff involved in course delivery should be able to justify their choices of learning, teaching and assessment methods in terms of the learning outcomes of their courses. These methods should be made explicit to students taking the courses concerned.

3.2. Learning, teaching and assessment should be interlinked as part of the curriculum design process and should be appropriately chosen to develop the knowledge and skills identified in section 2 and in the programme specification for the student's degree programme. Research and scholarship inspire curriculum design of all Earth Science programmes. Research-led programmes may develop specific subject-based knowledge and skills.

3.3. The Group believes that it is impossible for students to develop a satisfactory understanding of Earth Sciences without a significant exposure to field based learning and teaching, and the related assessment. We consider this learning through experience as an especially valuable aspect of Earth Science education. We define «field work» as observation of the real world using all available methods. Much of the advancement in knowledge and understanding in our subject areas is founded on accurate observation and recording in the field. Developing field-related practical and research skills is, therefore, essential for students wishing to pursue careers in Earth Sciences. Additionally field-based studies allow students to develop and enhance many of the Graduate Key Skills (e.g. teamworking, problem-solving, self-management, interpersonal relationships) that are of value to all employers and to life-long learning.

3.4. Existing Earth Sciences programmes have developed and used a very diverse range of learning, teaching and assessment methods to enhance student learning opportunities. These methods should be regularly evaluated in response to generic and discipline-specific national and international developments and incorporated where appropriate by curriculum developers.

4. **Performance levels**

In this section levels of performance are expressed as statements of learning outcomes. It is recognised, however, that not all learning outcomes can be objectively assessed. Whilst it is relatively easy to examine knowledge of the curriculum, it is less easy to assess the ability to carry concepts across different strands of the discipline and extremely difficult to accurate measure the improvement in a student's cognitive skills. However, it is important to emphasise that levels of performance can only be established in terms of the shared values of the academic community as moderated internally and externally by academic quality procedures. In this respect and in order to facilitate mobility and the professional recognition of grades within Europe, the Group considers it necessary to develop a scheme that should enable comparison of the significance of grades (not the standardization) in individual European countries. It is felt that in general three levels of performance should be recognized:

- —*Threshold* is the minimum performance required to gain a Cycle 1 degree.
- —*Typical* is the performance expected of students.
- —*Excellent* is the performance expected of the top 10 % of students.

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