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The Need for an International Geoscience School Syllabus: Its Development and Publication

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ABSTRACT: International comparisons of school-level geoscience education across the world had shown great variability in the amount and content of the geoscience materials and in the ways in which it was taught. When this situation was discussed at meetings of organisations concerned with international school-level geoscience education in 2012, the decision was taken to develop an international geoscience syllabus that could be used in future discussions with curriculum developers, many of whom have little geoscience understanding.

The new syllabus that was developed was based on a holistic systems approach, as advocated in the literature, and is presented in ways most easily assimilated by non-geoscience expert curriculum developers. The more detailed content was determined through an analysis of the geoscience content of curricula of a range of countries, since it is easier to argue for material to be included if it is already being taught elsewhere across the world.

The syllabus was published on websites in January 2014. It has the potential to enhance Earth science education across the world, increasing the Earth science literacy of all pupils involved, whilst encouraging some to become the geoscientists of the future.

KEY WORDS: Geoscience education; Earth science education; syllabus; curriculum development

INTERNATIONAL SURVEYS OF GEOSCIENCE EDUCATION

An overview of geoscience education across the world conducted prior to 2008 concluded, ‘This review indicates that geoscience education will only progress through: • ensuring geoscience education becomes part of the curriculum of every child; • providing effective geoscience learning, through innovative, engaging and motivating curriculum developments; …’ (King, 2008: 214). Another survey concluded: ‘However, the ability of educators to establish earth science as a sustainable course of study in schools is highly dependent on the ability of science teachers to overcome many barriers, including their own lack of background and the persistently low stature of the field.’ (Orion & Ault, 2007: 679).

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These findings provoked the International Geoscience Education Organization (IGEO) and the International Union of Geological Sciences Commission on Geoscience Education (IUGS-COGE) to review and expand a review of international school-level geoscience education in order to provide a broader basis of data and wider international comparisons. The results, covering 32 countries, were published in 2013 (King, 2013a) and updated with some additional data in 2013 so that the full survey now covers 34 countries. The full data is available on the IGEO website (IGEO, 2014).

The survey showed that 27 of the 34 countries surveyed do have national standards in Earth science, and that these are compulsory for most children (around 80% of 7-16 year olds). Nevertheless, the subject was approached in very different ways in the countries surveyed, as shown in Table 1.

Table 1 The different approaches to teaching Earth science in the curriculum (from IGEO, 2014: 18)

Earth science teaching approach	Countries
Compulsory – part of Natural Sciences – taught mostly by biology teachers	Argentina, Brazil, Czech Republic, France, Italy, Portugal, Spain
Compulsory – part of chemistry and geography – taught mostly by these teachers	England, Sri Lanka
Compulsory – part of general science and geography – taught mostly by these teachers	Bangladesh, India, New Zealand, Norway, Russia
Compulsory – part of general science – taught mostly by these teachers	Canada, Israel, Philippines, South Africa
Compulsory – part of science – taught mostly by Earth science teachers	Japan, South Korea, Taiwan
Compulsory – part of geography – taught mostly by geography teachers	Belgium, Germany, Finland, Indonesia
Compulsory – part of primary science and geography – taught mostly by primary teachers	Scotland
Not compulsory	Malawi

The compulsory curricula of 27 countries were further analysed against a bank of 124 Earth science terms, finding great variation in the data (data analysed from IGEO, 2014, 28-9), as in Table 2. This shows that, whilst some countries have comprehensive Earth science coverage in their curriculum, others have a minimalist approach.

In the free response part of the survey, comments related particularly to the school-level Earth science curriculum included:

- Bangladesh – 'In the next three years, we expect that we will be able to convince our concerned Ministry to introduce geoscience curricula into the syllabuses of pre-college and college level of education.'
- Canada – 'Earth science is not a teachable subject in most provinces/territories'
- Finland – 'The number of students taking the geography courses in high school is declining. More active promotion of Geology and Geosciences is urgently needed.'
- Germany – 'The tradition of teaching geoscience topics in geography: very descriptive, quite idiographic, less process-oriented, less connected to biology/ chemistry/ physics.'
- India – 'In future, it is visualized that a standard curriculum integrating physics, chemistry, biology, and Earth science will be required and has to be done.'
- Indonesia – 'We found the following deficiencies especially in geography:

1. Topics are introduced too early and in too much detail in the elementary school (Year four elementary school). Too much detailed information (but without real examples) make it difficult for pupils to understand.
2. Some information concerning rock formation and rock classification are not correctly introduced to students. There are some mistakes in the knowledge provided'

- Israel – 'the implementation of Earth science education in Israel is still limited.'
- New Zealand – 'Earth science continues to be a major issue in curriculum design' (IGEO, 2014: 82-89).

When these issues were discussed at meetings of the International Geoscience Education Organisation (IGEO) and the International Union of Geological Science Commission on Geoscience Education (IUGS-COGE) held at the 34th International Geological Congress in Brisbane, Australia in 2012, the decision was made to prepare a recommended international school-level geoscience syllabus. Such a syllabus could be used to assemble a rational case for the inclusion of Earth science in the curriculum, and as the basis for further discussion during curriculum development, in all countries developing an Earth science component to their curriculum in science and or geography.

Table 2 The numbers of a bank of 124 Earth science-related terms included in compulsory Earth science curricula of 27 countries.

	Range		Mean
Age range	Minimum no. of terms, with example(s)	Maximum no. of terms, with example(s)	Mean no. of terms, with closest example(s)
5-7 year olds	0 (Scotland, Uruguay)	41 (Spain)	10 (Sri Lanka = 5; Taiwan = 15)
7-11 year olds	1 (Scotland)	85 (Spain)	31 (Russia = 34; Trinidad and Tobago = 25)
11-14 year olds	11 (Saudi Arabia)	103 (Spain)	56 (Russia = 60; South Africa = 49)
14-16 year olds	0 (Scotland)	116 (Spain)	61 (South Africa = 76; Portugal = 87)
16-18 year olds	0 (Scotland, Russia)	124 (Spain)	72 (Portugal = 85l Saudi Arabia = 86)
All ages			88 (= 71% of the 124 terms)

The syllabus was prepared, as described below, and published as an internal report on their websites by IGEO and IUGS-COGE (e.g. IGEO website).

ARGUING FOR A PLACE IN THE CURRICULUM

Many years of arguing that Earth science should be included in the curriculum, and of developing the Earth science content (for example: King, 1989; 1991; 193; Orion et al, 1999a; 1999b; King, 2001; 2005; 2010, King & Bilham, 2012; King, 2013b) has shown that, in order to convince curriculum developers to include key ideas and coherent content in Earth science, these ideas need to be set out simply and rationally. A good example comes from the most recent curriculum debate in England, where the curriculum was agreed between the organisations involved and set down on a single page, so that it could easily be understood and assimilated by the non-Earth scientists involved in the curriculum development, see Figure 1. This was partially successful in that it resulted in the reinstatement of the rock cycle into the science curriculum.

On the basis of this experience, the decision was made to present the international geoscience syllabus on a single page as well. However, since the brevity of this approach could be misunderstood by curriculum developers, exemplification would also be provided, to illustrate the scope of the individual components and also to provide flexibility for developing the syllabus in context of the different countries applying it during curriculum development.

The place of Earth science in the curriculum has long been argued for by science curriculum developers who have included one or more Earth science statements as 'big ideas' in science that all pupils should cover (e.g. Harlen, 2015, 2010, Quinn et al., 2012, Miller & Osborne, 1998). Harlen argues that by learning the big ideas listed, including Earth science, pupils will encounter principles that include:

- 'curiosity about the world, enjoyment of scientific activity and understanding of how natural phenomena can be explained.'
- 'take an informed part in decisions, and to take appropriate actions, that affect their own wellbeing and the wellbeing of society and the environment.'
- 'understanding ... ideas of science and ideas about science and its role in society; scientific capabilities concerned with gathering and using evidence; and scientific attitudes.'
- 'study of topics of interest to students and relevance in their lives.'
- 'understanding of scientific ideas as well as having other possible aims, such as fostering attitudes and capabilities.' (Harlen, 2010:7)

All these principles are well exemplified by the new international geoscience education syllabus, which develops the 'big ideas' related to Earth science listed in these curriculum documents, to show how they might be effectively addressed in a complete curriculum.

Rationale

A systems approach to the modern teaching of Earth science has long been advocated (e.g. Mayer & Armstrong, 1990, 1997; Mayer & Kumano, 1999; Mayer 2002, 2003; King, 2008; IESO website). This has been highlighted by Orion & Ault, 'Making sense of Earth's processes and patterns, structures and changes, and systems and cycles depends upon visualization and spatial reasoning … This chapter presents a holistic view of earth sciences education and a holistic perspective for achieving meaningful learning of the earth sciences.' (Orion and Ault, 2007: 680). For this reason, a holistic systems approach was taken to provide the framework for the development of the new syllabus, with the following sections.

- Earth as a changing system
- Earth is a system within the solar system, within the universe
- Earth is a system which has changed over time
- Earth's system comprises interacting spheres – geosphere, hydrosphere, atmosphere, biosphere
- Earth's system produces resources
- Human/Earth system interactions
- Earth's system is explored through fieldwork and practical work

It was not possible, using this structure, also to indicate progression. Therefore, those using the syllabus in future discussion with curriculum developers will have to keep this consideration in mind.

SELECTING MATERIAL TO INCLUDE

The meetings of the International Geoscience Education Organisation (IGEO) and the International Union of Geological Science Commission on Geoscience Education (IUGS-COGE) held in 2012 concluded that an international syllabus was most likely to be acceptable in countries undertaking curriculum development across the world if it were justified by the fact that the material proposed was also contained in the syllabuses of many other countries. Therefore, the first phase of the syllabus development should be to collect and analyse the Earth science content data of current syllabuses.

Members of the two organisations were invited to submit syllabuses, and nine countries did so - Australia, England, Japan, New Zealand, Norway, Portugal, Scotland, South Africa and the United States of America. The existing syllabus for the International Earth Science Olympiad (IESO) was added. Documents from the curriculum developments then taking place in England and the United States (although not implemented at that time) were also added. The sources of this information are shown in Appendix 1.

Data from all these syllabuses was collated and analysed, and the frequency of concepts covered across the syllabuses was determined. Those concepts occurring most frequently were incorporated in the new international syllabus. When the first draft of the international syllabus had been developed, this was cross-checked against the syllabus analysis, to ensure that all key concepts had been covered.

An early decision was made to base the new international geoscience syllabus on published international syllabuses and not on commonly used international assessments. Nevertheless, it is reassuring to note that the assessment syllabus provided by TIMSS (Trends in International Mathematics and Science Study) includes a major section on Earth science (Mullis & Martin, 2013), with similar coverage to the new international geoscience syllabus. Meanwhile the OECD PISA cognitive assessment items (OECD website), include sections on natural resources, the environment and hazards with exemplar questions on volcanic eruptions, groundwater and earthquakes, all items covered by the new international syllabus. Thus those students who had studied the content of the new international geoscience syllabus would be better prepared for TIMSS and PISA assessments than those who had not.

Review

The first draft version of the syllabus was circulated to all those who had provided syllabus material, for comment. The constructive criticism received was vital and resulted in a more rounded perspective to the whole syllabus, as well as a series of minor 'tweaks'. The second iteration was again circulated for comment, and met with general approval and the requirement for more minor 'tweaking'. Those included in the Acknowledgments section played a very important part in the development of the final syllabus – and their contribution is greatly appreciated.

Publication

The final draft of the syllabus was approved by the Senior Officers of IGEO and IUGS-COGE and published on their respective websites in January 2014 (e.g. IGEO website), and an article was written to publicise the syllabus to IUGS members (King, 2015). The content of the syllabus is provided in Tables 4 (International syllabus) and 5 (International syllabus, with exemplification).

CONCLUSION

The impact of the development and publication of the first '*International Geoscience Syllabus, to be encountered by all pupils by the age of 16'* (Appendix 2) will only become clear as the existence of the syllabus becomes internationally known and colleagues' feedback on the value of the syllabus in their own national discussions about the component of Earth science in their curricula, its principles, details and development processes.

One of the important contributions of the syllabus should be the fact that it presents a holistic view of Earth science that should be readily assimilated by curriculum developers unfamiliar with Earth science content. Meanwhile, Earth science educators will be able to use the structure and coherence of the holistic approach to strengthen their arguments in promoting this content. The fact that this approach has emerged from literature study, from discussion with those involved in the development of the syllabus and from the perspectives provided by the senior officers of the two international organisations involved, should give the holistic systems-based approach, together with the more detailed listing of content and exemplification added 'clout' in the discussions.

The international consensus necessary for the development of this syllabus should ensure that it is used effectively by curriculum developers, Earth science educators, geoscientists and science and geography educators across the world to develop a coherent, well-structured, Earth science component to the curriculum. The presentation of the syllabus should make it flexible enough to be developed in national contexts and therefore with clear relevance to those involved.

The syllabus should therefore have the potential to improve teaching and learning in Earth science internationally, developing understanding of the past, present and future of our globe whilst providing crucial background education to the decision-makers of the future. It may also enthuse some pupils to become the geoscientists too.

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APPENDICES

Appendix 1 Sources of information of coverage by current school-level Earth science syllabuses (adapted from King, 2015:73, originally taken from IGEO website).

Curriculum	Submission by:	Source details
International Earth Science Olympiad	Syllabus submitted by Nir Orion, Israel	International Earth Science Olympiad (IESO) syllabus, IESO website: http://ieso2012.gl.fcen.uba.ar/index.php/ieso-downloads/syllabus/
Australia	One document précised and submitted by Bronte Nichols, others submitted by Ian Clark and Greg McNamara	'Australian Curriculum Science: Summary of Earth and Space Science strand; prepared by Bronte Nicholls' Australian Curriculum, F – 10 Curriculum: Science. Found at: http://www.australiancurriculum.edu.au/Science/Curriculum/F-10
England	Chris King	Geography at KS2 (7-11 year olds): https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/239044/PRIMARY_national_curriculum_-_Geography.pdf Geography at KS3 (11-14 year olds): http://media.education.gov.uk/assets/files/pdf/g/geography%202007%20programme%20of%20study%20for%20key%20stage%203.pdf Science at KS1 (5-7 year olds): http://www.education.gov.uk/schools/teachingandlearning/curriculum/primary/b00199179/science/ks1/sc3 Science at KS2 (7-11 year olds): http://www.education.gov.uk/schools/teachingandlearning/curriculum/primary/b00199179/science/ks2/sc3

		Science at KS3 (11-14 year olds): https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/335174/SECONDARY_national_curriculum_-_Science_220714.pdf Science at KS4 (14-16 year olds): http://media.education.gov.uk/assets/files/pdf/q/science%202007%20programme%20of%20study%20for%20key%20stage%204.pdf King, C. & Bilham, N. (2012) Towards a balanced Earth science Curriculum for England – science and geography perspectives. *Teaching Earth Sciences* 37.1, 45-48.
Japan	List of national curriculum content submitted by Ken-ichiro Hisada, Japan	'Geoscience Basics' and 'Geoscience' syllabuses.
New Zealand	Specially prepared document submitted by Glenn Vallender, New Zealand	'Summary of the New Zealand curriculum in science' based on the National Curriculum documents available on the following internet pages: http://nzcurriculum.tki.org.nz/Curriculum-documents/The-New-Zealand-Curriculum http://nzcurriculum.tki.org.nz/The-New-Zealand-Curriculum/Learning-areas/Science
Norway	Documents submitted by Merethe Frøyland and Kari Remmen, Norway	Natural science subject curriculum. Found at: http://www.udir.no/kl06/NAT1-03/Hele/?lplang=eng Social studies subject curriculum [including geography]. Found at: http://www.udir.no/Stottemeny/English/Curriculum-in-English/Upper-secondary-education-/ Geosciences – programme subject in programmes for specialisation in general studies. From: http://horselshemmet.vilbli.no/?Lan=3&Program=V.ST&Side=1.2.1&Fag=V.GFG1-01

Scotland	Chris King	Curriculum for excellence; sciences – experiences and outcomes. From: http://www.educationscotland.gov.uk/learningteachingandassessment/curriculumareas/socialstudies/eandos/index.asp (indicated as 'S' above) Curriculum for excellence; social studies – experiences and outcomes. From: http://www.educationscotland.gov.uk/learningteachingandassessment/curriculumareas/sciences/eandos/index.asp
South Africa	Documents submitted by Ian McKay, South Africa	Department of Education (2002) *Revised national curriculum statement for grades R – 9 (schools): Natural sciences*. D of E, Pretoria. ISBN: 1-919917-48-9.) Department of Education (2002) *Revised national curriculum statement for grades R – 9 (schools): Social sciences*. D of E, Pretoria. ISBN: 1-919917-47-0.
United States of America	Documents précised and submitted by Mary Dowse, USA	National Science Education Standards (1996) National Academy Press: Washington DC ('S' above) A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas (2012), National Academies Press http://www.nap.edu/catalog.php?record_id=13165
Portugal	Information provided by Luis Marques and Clara Vasconcelos	Personal communication

Appendix 2a International Geoscience Syllabus, to be encountered by all pupils by the age of 16 – core syllabus

By the age of 16, pupils should develop an understanding of the following:

Earth as a changing system	
• Attributes	open to energy, almost closed to matter, changing over time, within the solar system, comprising geosphere, hydrosphere, atmosphere, biosphere
• Interactions	interaction of geosphere, hydrosphere, atmosphere, biosphere
• Feedback	positive and negative
• Processes and products	water cycle, rock cycle, carbon cycle
• Energy sources	solar, internal
Earth is a system within the solar system, within the universe	
• Origins	big bang; accretion from dust; stars; planets
• The Sun	only external energy source; fluctuations
• Rotational effects	day/night, seasons, moon phases, eclipses
Earth is a system which has changed over time	
• Geological time	span, major events, relative and absolute dating methods, rates of processes
Earth's system comprises interacting spheres -	
- geosphere	
• Earth materials and properties	minerals, fossils, sedimentary, igneous and metamorphic rocks, soil
• Earth processes and preserved characteristics	surface processes, sedimentary, igneous and metamorphic processes, deformation (AW)
• Structure of the Earth and evidence	crust, mantle, core, lithosphere

• Plate tectonics and evidence	unifying theory, plate construction and subduction, characteristics of plate margins, mechanism, rates of movement; evidence
- **hydrosphere**	
• Continental water	location, processes of movement, uses
• Oceanic water	composition, processes of movement
- **atmosphere**	
• Composition	evolution, current composition
• Flow	processes of movement
• Change	greenhouse effect, planetary influences, human influence, impact on sea level
- **biosphere**	
• Evolution	natural selection, fossil evidence, mass-extinction
• Impact on other systems	role of biosphere in Earth systems
Earth's system produces resources	
• Raw materials and fossil fuels	naturally concentrated, non-renewable, uses, need careful managing (sustainable development), potentially polluting
• Renewable energy	issues
Human/Earth system interactions	
• Natural hazards	human impact, forecasting, mitigation
• Environmental issues	local to global, mitigation
• Impact on human history	resource wars; migration due to climate change
Earth's system is explored through fieldwork and practical work	
• Observation	observation, measurement and recording
• Synthesis of observations	interpretation
• Investigation and hypothesis-testing	devising and implementing plans, processing data, drawing conclusions, evaluating results and communicating findings

Appendix 2b International Geoscience Syllabus, to be encountered by all pupils by the age of 16 – core syllabus with exemplification

By the age of 16, pupils should develop an understanding of the following:

		Exemplification of the core to indicate the extent of coverage (it is anticipated that this will vary from country to country)
Earth as a changing system		
• Attributes	open to energy, almost closed to matter, changing over time, within the solar system, comprising geosphere, hydrosphere, atmosphere, biosphere	
• Interactions	interaction of geosphere, hydrosphere, atmosphere, biosphere	*lithosphere/hydrosphere interaction causes coastal processes; hydrosphere/atmosphere interaction causes waves and atmospheric warming; atmosphere/biosphere interaction climatically controls vegetation; lithosphere/biosphere interaction affects soil quality; rates vary from fast to slow*
• Feedback	positive and negative	*positive – increasing area of polar ice sheets gives increased reflection of solar energy, gives increased cooling, gives increasing area of polar ice sheets; negative – the more carbon dioxide is released into the atmosphere, the more that is absorbed in the oceans*
• Processes and products	water cycle, rock cycle, carbon cycle	*unique properties of water, evaporation, transpiration, condensation, precipitation; weathering/erosion, sedimentation, metamorphism, melting, igneous activity; photosynthesis, respiration, burial as limestone/fossil fuel, release by burning/weathering*
• Energy sources	solar, internal	*internal energy from radioactivity and energy from Earth's formation*

Earth is a system within the solar system, within the universe		
• Origins	big bang; accretion from dust; stars; planets	
• The Sun	only external energy source; fluctuations	*solar energy driving the water cycle and weather; long term fluctuations of energy from the Sun related to climate change*
• Rotational effects	day/night, seasons, moon phases, eclipses	
Earth is a system which has changed over time		
• Geological time	span, major events, relative and absolute dating methods, rates of processes	*major events: 4600 million years (Ma) – formation of Earth; 3600Ma – early life; 550Ma – animals with hard parts; 250Ma – major extinction, including trilobites; 65Ma – major extinction, including dinosaurs; 1Ma ice age; dating principles: superposition, cross-cutting relationships, fossil correlation; radiometric dating; processes occur on a frequency-magnitude spectrum from continuous to catastrophic*
Earth's system comprises interacting spheres -		
- geosphere		
• Earth materials and properties	minerals, fossils, sedimentary, igneous and metamorphic rocks, soil	*definitions of: mineral, fossil, rock sedimentary rock, igneous rock, metamorphic rock, soil; minerals including: quartz, feldspar, mica, garnet, calcite, halite, gypsum, pyrite, galena; fossils including: trilobite, ammonite, dinosaur; fossilisation processes including: burial, replacement, moulds and casts, trace fossils; rock texture, porosity, permeability; sedimentary rocks including: limestone, chalk, conglomerate, sandstone, clay, shale, rock salt; sedimentary features including: layering (bedding), cross bedding, ripple marks; igneous rocks including: granite, basalt, andesite, gabbro, volcanic ash; metamorphic rocks including: slate, schist, gneiss, marble, metaquartzite (quartzite)*

• Earth processes and preserved characteristics	surface processes, sedimentary, igneous and metamorphic processes, deformation (AW)	*weathering (physical/chemical), erosion, transportation, deposition, lithification, metamorphism, intrusion, extrusion, folding, faulting, jointing*
• Structure of the Earth and evidence	crust, mantle, core, lithosphere	*seismic evidence*
• Plate tectonics and evidence	unifying theory, plate construction and subduction, characteristics of plate margins, mechanism, rates of movement; evidence	*constructive, destructive and conservative margins; past and present evidence*
- **hydrosphere**		
• Continental water	location, processes of movement, uses	*surface water, groundwater, ice caps/glaciers; infiltration, downhill flow; water resource management*
• Oceanic water	composition, processes of movement	*salinity; surface flow and waves caused by wind; deep flow due to density differences caused by temperature and salinity*
- **atmosphere**		
• Composition	evolution, current composition	*outgassing by early volcanic activity; nitrogen, oxygen, trace gasses including water vapour and carbon dioxide*
• Flow	processes of movement	*unequal heating of Earth, flow due to density differences caused by temperature, oceanic heat source*
• Change	greenhouse effect, planetary influences, human influence, impact on sea level	*temperature graphs over different time spans; link between temperature change and sea level*
- **biosphere**		
• Evolution	natural selection, fossil evidence, mass-extinction	*palaeogeographical effects on evolution; mass-extinction by volcanic activity and impact*

• Impact on other systems	role of biosphere in Earth systems	*biological weathering; biological deposition*
Earth's system produces resources		
• Raw materials and fossil fuels	naturally concentrated, non-renewable, uses, need careful managing (sustainable development), potentially polluting	*oil/gas; metal ores; bulk raw materials; local examples of mining/quarrying*
• Renewable energy	issues	*low pollution, cost, regularity of supply*
Human/Earth's system interactions		
• Natural hazards	human impact, forecasting, mitigation	*eruption; earthquake; tsunami; landslide*
• Environmental issues	local to global, mitigation	*global human impact (causing erosion, pollution, drainage-changes mining/quarrying); burning fossil fuels and greenhouse effect*
• Impact on human history	resource wars; migration due to climate change	
Earth's system is explored through fieldwork and practical work		
• Observation	observation, measurement and recording	
• Synthesis of observations	interpretation	*environment of rock-formation; geological history; environmental issues*
• Investigation and hypothesis-testing	devising and implementing plans, processing data, drawing conclusions, evaluating results and communicating findings	