

Geology in the Spanish Education System: The Incredible Shrinking Curriculum [†]

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Abstract: The Spanish education system is undergoing a profound transformation due to the implementation of a new education law. In this work, we will make a comparison between the old and new educational laws about content related to Geology in primary education. Moreover, the Spanish curriculum will be compared to the New Generation Science Standards (NGSS), since this is the reference curriculum used by the largest American research institutions (NASA, USGS, NPS, Universities, ...). This study will analyze the specific curriculum that will be implemented in the Canary Islands (Spain). In this sense, we will pay special attention to the treatment of the volcanic phenomenon and the use of Canarian geological resources. The Geology of the 21st century is characterized by its interdisciplinarity, where subjects such as physics, mathematics, chemistry, ethics or engineering play a fundamental role. Is this taken into account in new education laws? Finally, we will offer a series of didactical tips to give students and teachers of primary education a broader, more engaging and motivating vision of geology that awakens their curiosity around Earth sciences.

Keywords: geology; primary education; curriculum



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1. Introduction

We study geology to learn about the world around us, similar to any other science. Geology looks at some of the key issues in modern world, including global change, energy sources and sustainability, human impact on the environment, water management, mineral resources and natural hazards. Geology stands behind fundamental research on how to switch to renewable energies, how to reduce our carbon emissions and their effects of global warming, and how to evaluate the risks related to water pollutions, to properties of the soils, landslides, seismicity, volcanic activity, etc. The exploration of the solar system and the search for habitable planets orbiting other stars are exciting research fields in which geology plays a fundamental role. However, the importance of geology, from professional and academic perspectives, in modern society is not reflected in the educational curriculum of most countries [1–4].

Early exposure to career alternatives is fundamental for students to make informed decisions about their future [2]. However, this is not the case in geology; hence, we must ensure that Earth science is visible in the curriculum. In general, geology is integrated into different subjects, such as geography, social sciences, biology or chemistry, in a disordered manner, wherein teachers feel uncomfortable teaching geological contents and procedures. This has led to a substantial reduction in the number of students interested in academic careers in Earth sciences and hence, the number of prospective geology teachers has declined. This vicious circle seems to grow with time.

In the Spanish case [3,5], geological content in secondary education represents less than 30% of the content related to biology and life sciences. Moreover, geology has little influence in university access exams; hence, students do not take the subject in high school. This trend is also seen in other countries [1,2].

In this work, we are going to analyze the content related to geology in primary education in Spain, in particular in the Canary Islands, where a major change in the education system is taking place, and in the USA, a country that hosts some of the most prestigious research institutions devoted to Earth sciences (NASA, United States Geological Survey, the National Parks Service, and top Universities, etc.). Finally, we will propose a series of didactical tips to give a broader, engaging and motivating vision of geology in primary educations, which will awaken students' curiosity around Earth sciences.

2. A Review of American and Spanish Geological Standards in Primary Education

The science content standards for pre-university students in the USA are contained within The Next Generation Science Standards (NGSS) [6]. These research-based standards set the expectations for what students should know and be able to do. These standards facilitate the design of classroom learning experiences that stimulate students' interests in science and prepare them for college, careers, and citizenship.

As it is defined in Ref. [6], there are three distinct and equally important dimensions to learning science. These dimensions are combined to form each standard (or performance expectation), and each dimension works with the other two to help students build a cohesive understanding of science over time. These dimensions are crosscutting concepts, science and engineering practices, and finally, disciplinary core ideas (DCIs).

Crosscutting concepts help students explore connections across the four domains of science, including physical science, life science, Earth and space science, and engineering design. Among these concepts, we could find "cause and effect", "patterns", "energy and matter" or "stability and change". These concepts can help students develop a coherent and scientifically based view of the world around them. Science and engineering practices describe what scientists do to investigate the natural world and what engineers do to design and build systems. Some of these practices are "engaging in arguments with evidence", "developing and using models" or "analyzing and interpreting data", among others. Finally, the disciplinary core ideas (DCIs) are the key ideas in science that have broad importance within or across multiple science or engineering disciplines. These core ideas are grouped into the following four domains: physical science, life science, Earth and space science, and engineering. Some of these ideas in the domain of Earth and space science are "the history of planet Earth", "Earth materials and systems", and "human impact on Earth systems", among others.

In the new (starting in 2022) Spanish pre-university educational system [7] called LOMLOE and adaptations to the curriculum of the Canary Islands [8], the core standards for each level and subject are composed of a series of contents, skills and attitudes that are called "basic knowledge". The level of performance in each area that is achieved through the work with this basic knowledge is defined by specific competences. As a quantifiable reference to indicate this level of performance, the specific competences are accompanied by evaluation criteria. The acquisition of specific competences in all areas define the "exit profile for each educational level" of the students; in other words, if the students complete the "exit profile", they have developed a series of key competences, as defined in the European educational framework. In this sense, the Spanish educational system has shifted to a competences-based framework. The LOMLOE replaces the former pre-university educational law, the LOMCE [9], and the adaptations to the curriculum of the Canary Islands [10]. From a curricular point of view, the LOMLOE fully implements the competences-based methodology that was started by the LOMCE.

Let us explore how the content related to geology is organized within the three different curricula for primary education, namely NGSS, LOMCE and LOMLOE. In general, NGSS offers the best organization of the science curriculum, under the three dimensions

to learning science, namely crosscuttings concepts, science and engineering practices and finally, disciplinary core ideas. This structure makes it easier for teachers to implement didactical activities with a strong relation to the ideas and processes of science. The two Spanish curricula for primary education, at least in science, lack a global structure and order. They are basically a collection of ideas that teachers should connect to build a competences-based teaching–learning process. However, and surprisingly, when we look carefully at those parts of the three curricula in which geological content and processes are explicit (see Figures 1–3), they look very similar. Although primary school is divided into six years, there is no clear progression in the ideas and concepts that are taught. Within the three curricula, rocks and minerals, the interpretation of reliefs, the effect of water on landscapes, the use of maps, natural resources, sustainability and global changes are randomly distributed throughout the six-year period. There are no clues on how to make connections to other areas, such as physics, chemistry, mathematics, etc. In the case of LOMCE, all the content directly related to geology is found in the social sciences curriculum (under the section ‘The world where we live’), whereas in the LOMLOE curriculum, the geological content is found in both the social sciences (under the section ‘Societies and territories’) and natural sciences (under the section ‘Scientific culture’) curricula.

There is a significant difference between the American and Spanish geological standards; the Spanish curriculum talks about identification and description, whereas the American curriculum introduces the idea of the explanation after the description. It is an important difference, since the idea of geology in the Spanish primary education curriculum looks more closely at geography than at present-day geology.

Curricular code	Disciplinary idea	Course	Expectations
III. Societies and territories	1. Challenges in the actual world	1,2	1.2. The volcanic origin of our archipelago. Approach to volcanism in the Canary Islands (main elements of the volcano and basic security measures in the event of a volcanic eruption).
I. Scientific Culture	2. Life in our planet	3,4	2.5. Identification of the most relevant forms of relief and elemental classification of rocks. Recognition of the geological particularities of the formation of the Canary Islands with respect to other geological processes and the main volcanoes of the Canary Islands.
	2. Life in our planet	3,4	2.6. Identification of water as an essential element for life. Hydrosphere. groundwater. Water cycle, use, forms of saving and responsible consumption, especially in the Canary Islands.
III. Societies and territories	1. Challenges in the actual world	3,4	1.1. Description of the earth and natural catastrophes: elements, movements (translation, rotation and their consequences), dynamics that occur in the universe and their relationship with physical phenomena that affect the earth and have repercussions on daily life and the environment. Recognition of the formation of the Canary Islands, types of volcanism and impact on people's lives.
III. Societies and territories	1. Challenges in the actual world	3,4	1.2. Knowledge of space from the representation of the Earth through the globe, maps and other digital resources, the interpretation of maps and plans at different scales and orientation techniques through the observation of the elements of the physical environment, cardinal points and other means of spatial location (GPS).
I. Scientific Culture	2. Life in our planet	5,6	2.1. Basic classification of rocks and minerals. Uses and sustainable exploitation of geological resources, especially in the Canary Islands.
I. Scientific Culture	2. Life in our planet	5,6	2.2. Identification of the basic geological processes of formation and modeling of the relief, applying knowledge to the natural environment of the Canary Islands. Recognition of the geological peculiarities of the formation of the Canary Islands with respect to other geological processes (tectonics, sedimentology, etc.).
I. Scientific Culture	2. Life in our planet	5,6	2.3. Protection of the environment based on knowledge and appreciation of the main ecosystems and their landscapes. Approach to the fragility of the Canarian ecosystems and the anthropic impact.
III. Societies and territories	1. Challenges in the actual world	5,6	1.3. Assessment of the natural environment, of the geographical diversity of continental and insular Spain and of Europe. Graphic, visual and cartographic representation through analog and digital media and resources using Geographic Information Technologies (GIT).

Figure 1. Summary of the curricular content related to geological concepts in the Spanish LOMLOE educational law. In the column ‘course’, 1 stands for the first year of primary education, 2 for the second year, and so on. The column ‘expectations’ indicates what the students should understand.

Curricular code	Disciplinary idea	Course	Expectations
II. The world where we live		1	6. Recognize the positive and negative effects of human actions in the use and exploitation of natural resources by identifying and explaining the properties and characteristics of some materials in their environment, recognizing water as an essential element for the existence of human beings and other living beings, valuing it as an indispensable and scarce good and making responsible use of it.
II. The world where we live		2	4. Differentiate between natural landscape and humanized landscape from direct observation and description of graphic sources of various types to recognize and explain the relationships between some factors of the physical environment, the different forms of landscape and the evidence of human action on it, valuing ecological attitudes and respect for the landscape as a legacy for future generations.
II. The world where we live		3	5. Identify the stars of the solar system and the location of the Earth and the Moon in it, explaining the main characteristics of the Earth, the movements of rotation and translation and their consequences in nature and in our lives, in order to become aware of the magnitude of the solar system through the observation and treatment of various textual sources, audiovisual, graphic, etc. 6. Describe the importance of rocks and minerals, identifying the properties that differentiate them, and value water as an essential resource for life on the planet, favoring attitudes and behaviors of respect, care and conservation, water in particular, and by extension of the environment in general.
II. The world where we live		4	4. Identify and compare some of the main landscapes of the Canary Islands and the most representative of the rest of the Spanish State from their characteristic elements and analyze the main physical and human agents that make them up, valuing their diversity and indicating examples of the positive or negative impact of human activities on them, in order to promote interest in the conservation of the territory and sustainable development. 5. Use spatial notions of a geographical nature and cardinal points to situate oneself in the territory, locate and describe the situation of objects in delimited spaces and landscape elements in known environments, and interpret plans, photographic images and simple maps to reflect locations, as well as orienting and moving with the help of the compass or any other tracking device (GPS). 6. Indicate respectful behaviors with the environment and with the use of natural resources in daily life, and recognize and identify some damages caused to ecosystems by human action, indicating feasible actions to preserve the ecological balance.
II. The world where we live		5	6. Recognize the layers and internal and external structure of the Earth in different models and representations of it, explaining the components and functioning of the hydrosphere and the lithosphere, and identify and classify some types of rocks and minerals, based on their properties.
II. The world where we live		6	4. Identify, describe and locate on maps the main units of relief in Spain and Europe, their climates and hydrographic slopes, analyzing their impact on different types of landscape in order to assess the diversity and richness of the territory and the importance of promoting its conservation. 5. Make, interpret and use plans and maps, taking into account conventional signs and graphic scale to explain the different ways of representing the earth's surface and locate different points or areas of the planet, handling the concepts of parallels, meridians and geographical coordinates.

Figure 2. Summary of the curricular content related to geological concepts in the Spanish LOMCE educational law. In the column ‘course’, 1 stands for the first year of primary education, 2 for the second year, and so on. The column ‘expectations’ indicates what the students should understand and do.

Curricular code	Disciplinary idea	Course	Expectations
2-ESS1-1	Earth’s place in the Universe	3	Use information from several sources to provide evidence that Earth events can occur quickly or slowly. Examples of events and timescales could include volcanic explosions and earthquakes, which happen quickly and erosion of rocks, which occurs slowly
2-ESS2-1	Earth’s Systems	3	Compare multiple solutions designed to slow or prevent wind or water from changing the shape of the land.
2-ESS2-2	Earth’s Systems	3	Develop a model to represent the shapes and kinds of land and bodies of water in an area.
2-ESS2-3	Earth’s Systems	3	Obtain information to identify where water is found on Earth and that it can be solid or liquid.
4-ESS1-1	Earth’s place in the Universe	5	Identify evidence from patterns in rock formations and fossils in rock layers to support an explanation for changes in a landscape over time.
4-ESS2-1	Earth’s Systems	5	Make observations and/or measurements to provide evidence of the effects of weathering or the rate of erosion by water, ice, wind, or vegetation.
4-ESS2-2	Earth’s Systems	5	Analyze and interpret data from maps to describe patterns of Earth’s features.
4-ESS3-1	Earth and human activity	5	Obtain and combine information to describe that energy and fuels are derived from natural resources and their uses affect the environment.
4-ESS3-2	Earth and human activity	5	Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans.
5-ESS2-1	Earth’s Systems	6	Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact.
5-ESS2-2	Earth’s Systems	6	Describe and graph the amounts and percentages of water and fresh water in various reservoirs to provide evidence about the distribution of water on Earth.
5-ESS3-1	Earth and human activity	6	Obtain and combine information about ways individual communities use science ideas to protect the Earth’s resources and environment.

Figure 3. Summary of the curricular content related to geological concepts in the American NGSS. In the column ‘course’, 1 stands for the first year of primary education, 2 for the second year, and so on. The column ‘expectations’ indicates what the student should understand and do.

3. A Proposal to Teach Geology in Primary Education in Spain

After the revision of the primary education curriculum for both the present-day LOM-LOE and the former LOMCE, we arrived at the conclusion that the included geological content and procedures are closer to geography than to an experimental science. Moreover, the contents are neither structured nor ordered throughout the six years of primary education. In an attempt to solve these problems, we propose the use of the methodology ‘big ideas in science’ [11]. This consists of implementing all didactical activities around a central idea. In the case of geology, the following is the big idea: “the composition of the Earth and its atmosphere and the processes occurring within them shape the Earth’s surface and its climate. Radiation from the Sun heats the Earth’s surface and causes convection currents in the air and oceans, creating climates. Below, the surface heat from the Earth’s interior causes movement in the molten rock. This, in turn, leads to movement of the plates which form the Earth’s crust, creating volcanoes and earthquakes. The solid surface is constantly changing through the formation and weathering of rocks.”

The implementation and translation of this big idea into the primary school curriculum exceed the objective of this work. However, we propose the following general strategy: the interactions between matter and energy work on different spatial and temporal scales, and geological phenomena might be understood as an example of these interactions. In this sense, we have designed a general scheme (see Figure 4) to explain the main properties of matter and energy. This scheme is intended to serve as a reference for teachers to design lessons and activities related to the scientific areas of physics, chemistry and geology. For instance, if a teacher is designing an activity about gravity, the logical path presented in this scheme tells us that mass is a primordial property of matter, and it is related to a force, gravity. A force exerted along a distance is known as work, and is one of the forms of energy transfer. This logical sequence might continue, connecting to other forms of energy transference or transformations.

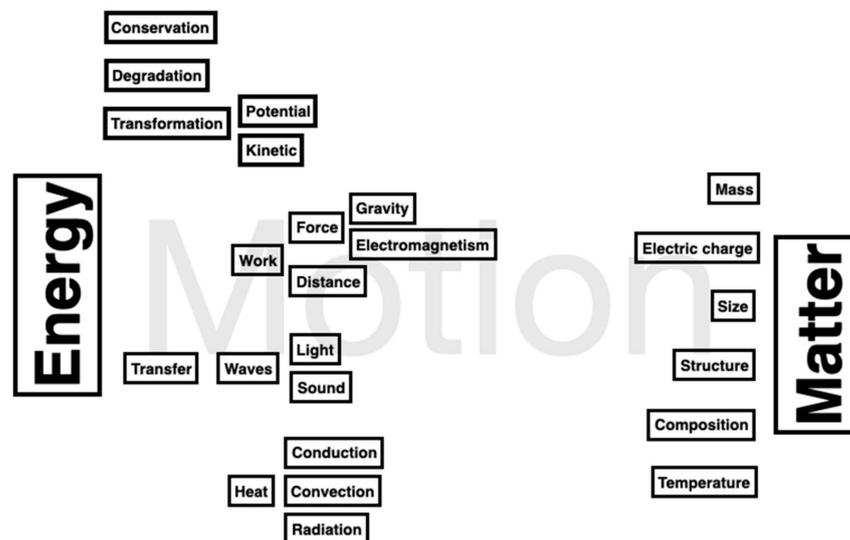


Figure 4. Global scheme about the properties of matter and energy and the interaction between them.

In geology, we may follow different logical paths within this scheme, as in these examples:

- Due to the temperature difference between the Earth’s core and surface, there is a transference of energy in the form of heat, in particular convection. Phenomena such as earthquakes, volcanic activity or plate tectonics are related to the dynamics induced by convection.
- The motion of electric charges within the Earth interior induces magnetic fields. The Earth magnetic shield prevents that lethal forms of radiation coming from the sun from hitting the planet.

- The composition of rocks and/or minerals depends on the temperature and pressure (force per unit of area) of the medium hosting them.

In other words, we will design activities related to geology with the same vocabulary and logic that will be used in activities or lessons related to physics or chemistry. The scheme presented in Figure 4 gives a framework to explain all the scientific concepts that appear in the primary education curriculum through some basic ideas on matter and energy. However, it is also important to emphasize what makes geology unique. We believe students should understand that geologists observe and describe the world around us to try to understand the history behind it and all processes that have taken place.

4. Conclusions

We have analyzed how the Spanish and American primary education curricula explain geological concepts and processes. Surprisingly, although both curricula differ in how they are organized and what their basic objectives are, the treatment of geological content is very similar. In both cases, we lack a sequence of content and a more direct relationship with other areas of knowledge, such as physics, chemistry or biology. The biggest difference is found in the more geographical orientation in the Spanish case, compared with the more scientific orientation in the American case.

We propose that physical, chemical, biological and geological concepts are interconnected through a logical scheme wherein the properties of matter and energy are related. In this way, students understand that geology shares procedures and concepts with other areas, although it works with different time and spatial scales. We believe that it is also essential to design activities that make clear a fundamental aspect that makes geology unique: interpretation of the current landscape can be a tool for understanding its historical evolution.

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