Current state of the Geology Teaching, particulary the cristalography, mineralogy and petrology contents

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Abstract

This paper deals with the current state of the Geology in the compulsory Education and High School and has been divided in the following: a) discuss the current status of the teaching of geology in compulsory education; b) compare this situation with that of other European countries; c) disclose the actions undertaken by the Commission "what geology would be taught" whose main objective is the definition of the "framework for Geoscientific literacy principles" that should be taught in Spanish schools in Secondary Education; d) The first version of a new law being drafted, however, removed the geosciences from the list of required courses taught in secondary schools. Hopefully, after major fighting of the Spanish geological community, the ministry has presented other version of the law, in which the Geosciences are better considered, but not enough.

With this aim in mind, it is first the geological contents taught in compulsory education emphasizing the crystallographic, mineralogical and petrological ones. After that explained what could be understood as “Social Influence of the Geology” and how may it be assessed. Afterwards some hypotheses are proposed that should be validated and, finally, recommendations are provided on the basis of these assumptions.

Resumen

Este artículo pretende analizar el estado actual de la Geología en varios ámbitos. Para ello se ha estructurado en los siguientes epígrafes: a) examinar el estado actual de la enseñanza de la geología en la enseñanza obligatoria; b) comparar esta situación con la de otros países europeos; c) divulgar las acciones emprendidas por la Comisión "Qué geología enseñar", cuyo principal objetivo es la definición del "marco de los principios de alfabetización geocientífica" que deben ser impartidos en la educación obligatoria; y, d) Valorar el "Anteproyecto de Ley Orgánica de Mejora de la Calidad Educativa“ (LOMCE). La primera versión de este anteproyecto no incluía contenidos geológicos en el currciulum de bachillerato. Por suerte, después de la lucha organizada por la comunidad geológica española, el Ministerio ha presentado otra versión de la ley, en el que las Geo-Ciencias están mejor considerados, pero no lo suficiente.

Con el fin de intentar conocer a que obedecen estas circunstancias se analiza, en primer lugar, los contenidos geológicos que se imparten en la enseñanza obligatoria haciendo hincapié en los cristalográficos, mineralógicos y petrológicos. A continuación se explica que se entiende por “Influencia Social de la Geología” y como se puede evaluar. Posteriormente se plantean algunas consideraciones que tendrían que ser validadas y, para terminar, se proponen algunas recomendaciones atendiendo a dichas consideraciones.

Key-words: *Spanish education, teaching geology, Social Influence of the Geology, hypotheses and recommendations.*

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1. Introduction

Over the past few years, several reforms in the educational system have been implemented in compulsory education in Spain. The most recent reform was the General Education Act *(initials in Spanish, LGE)* which implemented compulsory education from 6 to 14 years of age until the current educational system which increased compulsory education until 16 years of age.

These changes in the legislation on education have not been favourable in terms of geology. Crystallography, mineralogy and petrology are traditional branches of geology, for which reason, although this science is dealt with globally in this communication, all the branches of knowledge are included.

At the same time, the low degree of representation of geological contents in secondary education textbooks has caused a decrease in the number of students who take these subjects. We must also add to this fact that, in natural sciences general subjects, geology is not taught at all or it is not taught well. Furthermore, the optional character of subjects with geological content in Bachillerato ("Earth and Environmental Sciences") and the little importance they have in the PAAU *(University Entrance Examinations)*, for entrance to degrees in most universities, leads to these subjects not being taught in many schools.

In this scenario it seems to be reasonable to discuss about geology in pre-university education. In this line of argument, the following scenarios will be analysed in depth:

- Analysis of the current situation of the teaching of Geology in compulsory education.
- Comparison of this situation with other European countries.
- Dissemination of the current proposal on "Which Geology to teach in secondary education".
- Assessment of the "Draft of Organic Law for the Improvement on the Quality of Education" *(initials in Spanish, LOMCE)*.

Secondly and equally important is a reference to geological contents taught within the framework of the new system of areas of authority and science literacy. In this respect, the current Organic Law on Education *(initials in Spanish (LOE)* of 2006 is committed to the development of a new curriculum to improve, among other matters, the results of young people in science. In particular, in Spain scientific competence is separated from mathematical competence and is called "Competence in the knowledge and interaction with the physical world". This competence addresses skills to function appropriately, with autonomy and personal initiative, in life and knowledge (health, science, technology, etc.).

Another main aim of this study involves assessing the influence of Geology in society and analysing to what degree geologists contributed to the current situation of this science. From that moment on, we shall be able to use the necessary resources to remedy the situation.

To complete these considerations, we shall assess the relevance in the past few years of matters related to Geoscience and, in particular, to crystallography, mineralogy and petrology. Teaching methods will be analysed afterwards, what is understood by the phrase "Social Influence of Geology" will explained and how it may be assessed. Based on the above, some final considerations will be exposed.

2. Analysis of the current situation of the teaching of Geology in compulsory education

Education in Spain is compulsory for students under 16 years of age *(LOE, 2006)*. These studies are organised in three stages, as indicated in *figure 1:* Spanish Primary Education *(Ministry of Education and Science, 2006),* some basic geological contents appear scattered in the subjects of "Environmental Knowledge". These contents make reference to materials of the Earth (rocks, such as granite and minerals). At this stage, Science represents approximately 7% of the curriculum and is not considered as an instrumental knowledge area at the same level as maths and language, as it has been recommended by the latest PISA reports *(OECD, 2010)*.

In the case of Secondary Compulsory Education

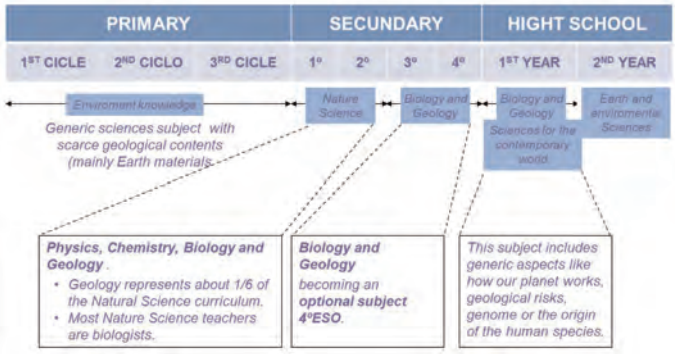

Fig. 1. Comparative analysis of curricula in Spain.

or ESO (12 to 16 years of age) science is not compulsory for the first three years and represents about 18% of the total amount of teaching hours. The first two years include a single scientific subject called *"Nature Sciences" (Figure 1)*. This subject includes contents that comprise: Physics, Chemistry, Biology and Geology *(Calonge, 2010)*. If we focus on Biology and Geology curricula we notice that they represent about 70% of the two Natural Sciences courses, of which geological contents are 1/3 of 70%.

In the second year of ESO *(Ministry of Education and Science, 2007a),* the subject "Biology and Geology" *(Figure 1)* is separated from the other sciences, with the particular feature that, in the last year, it is an optional subject (Calonge, 2010). In the third year of ESO the topics related to Geology comprise external geological processes and sedimentary rocks. Geological topics of the fourth year include traditional contents: origin and structure of the Earth, Earth's dynamics (internal processes), Earth's materials, Earth's history, etc.

In "Bachillerato" (16 to 18 years of age) the core subjects *(Figure 1)* which include geological contents are: "Biology and Geology" in the first year and "Earth and Environmental Sciences" in the second year. We must remember that this stage is divided in two years: First and Second year of Bachillerato and, in the different Autonomous Regions, different models are taught *(Ministry of Education and Science, 2007b).*

Furthermore, since 2008 another compulsory subject is offered to all students of the first year called "Science for the Contemporary World". This subject includes 15% of geological contents *(Pedrinaci, 2008)*.

3. Curriculum comparison in european countries

Although the knowledge of geosciences is important in every-day's life of all European citizens, in most European countries Geology does not exist as a separate subject in

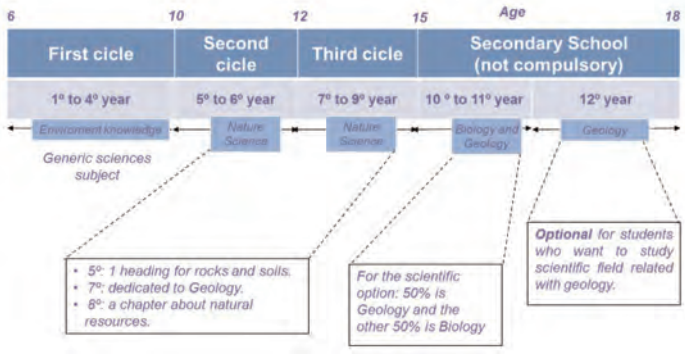

Fig. 2. Curriculum comparison research: Portugal.

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secondary education. Geology is included, indirectly, through other subjects and educational activities such as Environmental Education. In the next *figures (2 a 5)* it is presented a general view of the situation of geosciences teaching in schools in Spain, Portugal, Greece, Austria and Italy.

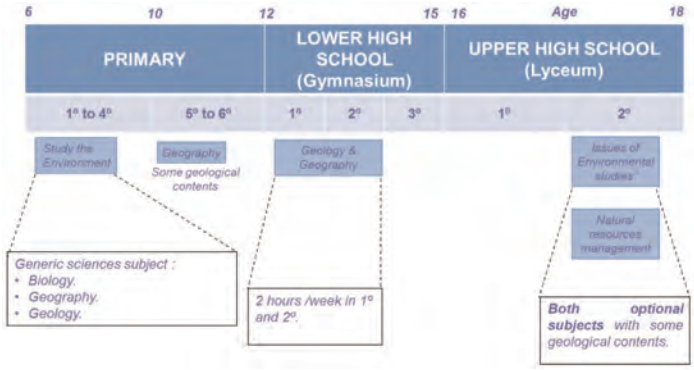

Fig. 3. Curriculum comparison research: Austria.

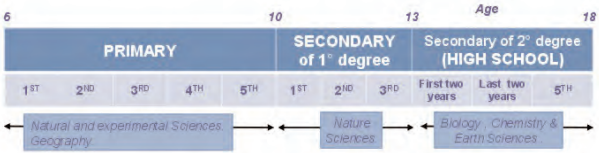

Fig. 4. Curriculum comparison research: Italy.

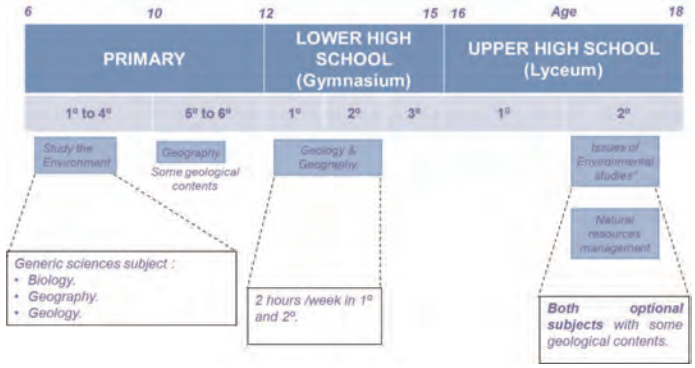

Fig. 5. Curriculum comparison research: Greece.

This analysis shows that, at the lower levels, Geology is studied as a discipline included in a generic Sciences subject, and a single teacher normally teaches all subjects to one class.

At the intermediate levels there are two possibilities:

- «Horizontal approach»: in countries like Spain, Portugal, Austria and Italy, the approach is the classic of Natural Sciences, where a subject includes several scientific disciplines: Biology (the most relevant), Geology or Earth Sciences, Chemistry and Physics.

- «Vertical approach»: the case of Greece where Geology is included with Geography, which is closely related.

Based on this curricular structure, it must be pointed out that, while in Primary Education there is a general structure in all Europe in which science is taught as an integrated subject, in Secondary Education the mixed nature of the Spanish curriculum does not follow the prevailing trend of the rest of Europe.

In the higher educational levels some countries, such as Portugal, show an important presence of Geology in school curricula of Secondary School. But in most European countries, the geological concepts are distributed in other disciplines vaguely related.

In secondary schools, specialist teachers teach the different curriculum subjects. In the case of Science, a single science teacher normally teaches the whole science curriculum to 11-14 year old students (including Biology, Chemistry and Physics with some elements of Earth science, Environmental science and Astronomy). In this way these students are normally taught Science by specialists in Biology, Chemistry and Physics There is a shortage of science teachers, particularly of Geology teachers; in fact in some schools in Spain almost all Science is taught by Biology specialists. In case of Greece the subject of Geology-Geography is taught also by some other specialists like mathematicians and household economy teachers.

En resumen, la inclusión de los contenidos geológicos en otras materias científicas tales como Biología, Ciencias Ambientales, o Geografía, aunque se justifique conceptualmente, significa la subordinación real de la Geología, que se ocupa de la Tierra y la Geosfera, a otras disciplinas vagamente relacionadas y que tratan temas diferentes (de la Biosfera la Biología, de la Tierra en relación con el hombre y el impacto humano en la Tierra la Geografía y Ciencias Ambientales).

In summary, the inclusion of Geology within other “twin” or conceptually close subjects, such as Biology, Environmental sciences, or Geography, although conceptually unjustified, means the actual subordination of Geology, which deals with earth and geosphere, to other separate disciplines that deal with separate subjects of knowledge (Biosphere for Biology; Earth in relation to Man, and human impact on Earth for Geography and Environmental sciences). This subordination has produced a misbalance in teaching regarding: the shared space of text for the different matters, the conceptual accuracy of the Geology explained, and the appropriateness of the teaching staff. Some cases, for instance, the Spanish educational system in which the discipline of Geology is excluded from the university access tests, or Greek’s educational system in which Geology is totally absent in the high cycle of Secondary Teaching *(figure 5)*, are particularly alarming. The progressive decrease of the amount of Geology being taught in schools, both in time assigned and in contents’ share in science programs, could bring highly negative consequences to the university background and future research and knowledge of Earth.

What is happening is that the reduction of geological subjects in secondary schools plus the significant gaps in the training of teachers who deliver these subjects, results in negative impacts on the education. Students do not choose college degrees related with Geology.

4. Dissemination of the current proposal on "Which Geology to teach in secondary education”

Despite the reduction of hours devoted to science subjects, this situation has not brought about a review of the length of the contents to be taught.

In this respect, in May 2011 the Committee "What Geology should be taught in compulsory education and Bachillerato" started. The aim is to have a consistent, updated and educational curricular proposal for teaching geology in ESO and Bachillerato, which takes into consideration social and educational requirements and has maximum support from the relevant organisations and institutions related to Geology and its teaching. The purpose is to become a necessary reference for education authorities and non-university science teachers.

The first step of this Committee composed of

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18 geological institutions was to define the *"Framework of principles of Geoscientific literacy"* which should be taught in Spanish schools for compulsory education.

The Committee agreed, submitted and disseminated a *"Manifesto for scientific literacy"* which aims at achieving an acknowledgement of the relevance of scientific contents in general and, in particular, the role of Geology is claimed.

5. Assessment of the "Draft of Organic Law for the Improvement on the Quality of Education" (initials in Spanish, LOMCE)

The Council of Ministers of 21st September 2012 approved the first draft of the "Draft of Organic Law for the Improvement on the Quality of Education" (LOMCE) which undervalues geological contents.

Just as in Compulsory Secondary Education (ESO) there were minor modifications, Bachillerato included aspects that could be clearly improved. For instance, in this first draft:

1. A student could finish Bachillerato in Sciences without having taken any Geology or Biology subject.

2. There was no subject with scientific content among all common subjects of Bachilleratos (eight, which become ten in the Autonomous Regions which have an official language other than Castilian Spanish).

3. "Geology" disappeared in the second year of Bachillerato and the subject "Earth and Environmental Sciences" became optional in the first year, although until now it is a core subject in the second year of Health Sciences, and could be tested in the university entrance exams.

Furthermore, the optional subjects did not remedy any of these mistakes. The proposal involved a single optional subject per year which, in all types, should be: "Second foreign language" and "Information Technologies and Communication" for the first year and, for the second year, "Second foreign language". It is true that it is pointed out that "Also, schools may offer other optional subjects" and, among them, for Bachillerato in Science there was "Earth and Environmental Sciences" in the first year.

The second version improved the biggest hurdle and Geology appeared on a level of absolute equality as the other scientific disciplines. Nevertheless, the arguments and proposals in defence of sciences, in general, and geology, in particular, carry on and they are focused on claiming:

1. A subject on "Scientific Culture" for all non-scientific Bachilleratos.

2. That all students of first year of Bachillerato must take two scientific subjects ("Physics and Chemistry" and "Biology and Geology"). It would be strange if a student finished Bachillerato in Science without having studied two of the four basic scientific disciplines.

3. The possibility to choose two subjects of the five (the 4 scientific disciplines plus technical drawing) because, as it is organised, the possibility for Geology to be chosen is very low. For this reason, the amendment of the preliminary draft was requested for the chosen subjects to at least be three of the five, which would noticeably increase the possibility for Geology to be a chosen subject.

The coordinators of these actions offered the administration and the parliamentary groups to work with them, to join them during the process of the law and make suggestions to them from the geological group.

At the end of February the Ministry of Education sent to the State Council its proposal to draft the mandatory report. In fact, it was a new version of the LOMCE, the third one, which is not called draft any longer but a "draft bill".

This draft bill virtually maintains the content of the second draft, which means that Geology in Bachillerato is treated the same as the other scientific disciplines.

Unfortunately, the request made for all students in Bachillerato in Science to take "Biology and

Geology" in the first year as well as "Physics and Chemistry" was not included. But where it said "they will choose two subjects" (of the three core subjects in the first year and of the five core subjects in the second year) it now says "they will at least choose two subjects".

The most important changes detected in this third version (draft bill) are related to the distribution of areas of authority between the central and the regional authorities, with the same category as co-official languages are included and with an implementation schedule that, in practice, shall entail a delay of one year in the entry into force of the law which, in the best case scenario, shall apply for the first time to the 2015-2016 academic year.

In short, and as regards geology, there are reasons to be satisfied. However, of this process a positive thing must be highlighted: for the first time geologists as a group were in agreement to address this problem. A situation that damaged the future teaching of geology and, therefore, the profession as a geologist.

We, geologists, have joined efforts: some of us would be needed to visit the authorities, others would be needed to speak to parliamentary groups, some would write to the national and/or local press, several of us would hold meetings with the regional Ministries of Education of the Autonomous Regions, etc. For this reason, we should all congratulate ourselves.

6. Future challenges

A society that is interested in Geology and acknowledges the contribution of this science to the development of its culture is needed to establish the desired levels of geoscientific literacy.

Planet Earth and the changes it is undergoing in the course of time is no specific knowledge of a certain science, but a cultural asset whose knowledge must be transferred to all society. In this respect, the geoscientific community has proposed initiatives such as "Geolodía", "Geology Olympics", Geogynkamas" or "Sponsor a rock", which aim at promoting interest in this discipline.

In the previous sections we have analysed the current situation of geology in pre-university teaching. But, what challenges should be addressed?

For a start, it would be advisable to know the geological contents being taught in compulsory education. In this regard, the reflections below will be focused on the compulsory levels of secondary education, because in primary education very little geological content is taught beyond some rocks and minerals and in Bachillerato it is not a compulsory level and increasingly fewer young people take the scientific path.

Firstly, the geological contents included in the Royal Decree on minimum teaching requirements for secondary education will be analysed; then, the geological contents in textbooks will be analysed, the amount and quality of the information given to students will be examined in depth and, in particular, the contents of crystallography, mineralogy and petrology will be examined. Finally, based on the data above some reflections will be advanced.

6.1. Geological contents in secondary education

The following figures (6 to 10) show the topic segments included in ROYAL DECREE 1631/2006, of 29 December, establishing the core curriculum of compulsory secondary education.

1º	Common contents
2º	**The Earth and the universe**
3º	**Earth materials.**
4º	Biodiversity

Fig. 6. Topic segments of "Nature Sciences". First year.

1º	Common contents
2º	Matter and Energy
3º	Transfer of energy (heat, light, sound)
4º	**Geological changes caused by internal energy**
5º	Life in action (nutrition, respiration, reproduction, life cycles)
6º	Natural environment (ecosystem)

Fig. 7. Topic segments of "Nature Sciences". Second year.

1º	Common contents
2º	Diversity and unity of the matter structure
3º	Internal structure of the substances
4º	Chemical changes and their impact
5º	People and health
6º	People and enviroment
7º	**Geological changes caused by external energy**

Fig. 8. Topic segments of "Biology and Geology". Third year.

1º	Common contents
2º	**Earth, a changing planet (The geological history of the Earth and Plate Tectonics)**
3º	The evolution of life
4º	The changes in ecosystems

Fig. 9. Topic segments of "Biology and Geology". Fourth year.

The following step consists of making an initial diagnoses of the situation in which geological contents in general are and, in particular, mineralogical, petrological and crystallographic contents in textbooks in compulsory education.

It is well-known that teachers use textbooks as the most important teaching resource in non-university educational levels, for which reason the manner in which they present geoscientific contents is a determining factor of subsequent geoscientific education in this educational level.

In our particular case, the relevance of these materials is more significant, as it entails knowledge of little social impact and traditionally lacks something in compulsory education as well as in teacher training.

Contents in the table of contents of secondary education textbooks related to science have been analysed and topics devoted to geology have been identified *(Figure 10).*

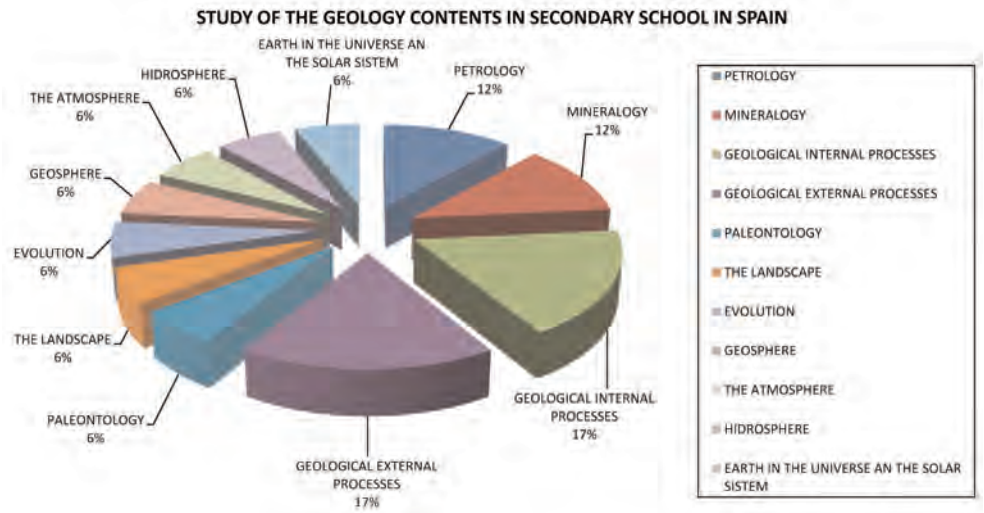

Fig. 10. Percentage of geological contents included in Spanish textbooks.

Based on the data above in Spain *(Figure 10)* the most studied topics are related to geological processes followed by Earth materials:

- Internal geological processes (17%),
- External geological processes (17%),
- Mineralogy (12%) and

- Petrology (12 %).

However, it is known that there are important geoscientific shortcomings among youngsters who complete their compulsory education. Some reasons for these deficiencies are:

1. Late and slow updating of the contents of textbooks.
2. Lack of resources to efficiently teach Geology.
3. Lack of updated geological training of the teachers involved in the teaching of this subject.

But these reflections are worthless if we fail to understand that changing the way Geology is taught must have an impact on the methods applied for its teaching *(Fermeli et al., 2011)*. It is obvious that we must commit to a teaching change towards more active and efficient teaching formulas that involve Geology students and teachers in a new learning approach.

We must pinpoint the dynamic aspects, the relations with the matters that concern society, the links with the physical environment of students and the practical applications, among others. Geology must be perceived as an interesting subject (understood as something that has an impact on a person and remains as part of his personal heritage) and fun (not boring). Teaching the most attractive and tangible geological contents is essential to stimulate students' interest for Geology *(Fermeli et al., 2012)*.

6.2. The specific case of crystallography, mineralogy and petrology

Under this heading we analyse the problem related to transferring knowledge, procedures and attitudes in geology teaching, such as crystallography, mineralogy and petrology, in compulsory education. To assess these contents the legislation and what is included in textbooks has been taken as a reference (the most relevant eleven publishing companies in the market have been selected).

Royal Decree 69/2007 establishes for the first year of compulsory secondary education (initials in Spanish, ESO), in the subject of Nature Sciences, the topic segment "The Universe and the Earth" which includes the unit "Composition of the Earth" structured in three topics: atmosphere, hydrosphere and geosphere (minerals and rocks). Also, under criteria 7 it is stated that students must be able to "know the most frequent rocks and minerals and, in particular, those found in their immediate environment, by using simple keys". Specifically, the contents included in the topic on geosphere are:

Topic 3. Geosphere.

- Internal structure of the Earth.
- Earth's crust: surface, chemical composition and geochemical elements.
- Chemical composition and petrology of the layers of the Earth.
- **Minerals and rocks. Concept of mineral and rock.**
- **Types of rocks: sedimentary rocks, magmatic rocks and metamorphic rocks. Importance and usefulness of rocks.**
- **Usefulness, importance and relative abundance of minerals.**
- **Observation, description and acknowledgement of the most frequent minerals and rocks.**
- **Use of simple keys to identify minerals and rocks.**
- **Exploitation of minerals and rocks.**

Most of the textbooks examined include the contents regulated in the Decree. These books include photos, mainly on the use of minerals, which gives a more practical and attractive sense, instead of only providing a description.

In the second year of ESO, the geological contents are included in section 4:

Section 4. Geological transformations owed to the internal energy of the Earth.

- Transfer of energy in the interior of the Earth.
- Signs of the internal energy of the Earth: volcanic eruptions and earthquakes.
- Assessment of volcanic and seismic risks and importance of their prediction and prevention.
- **Identification of magmatic and metamorphic rocks and relation between their texture and origin.**
- Signs of internal geodynamics in the contours of the Earth.

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And, in the third year of Compulsory Secondary Education (ESO), "Biology and Geology" is divided in two sections; the first section is Biology, mainly human Biology and the second section includes mineralogical and petrological contents in section 7:

Section 7. Geological transformations owed to external energy.

External geological activity of planet Earth:

- Solar energy in the Earth. Atmosphere and its dynamics.
- Interpretation of simple weather maps. Contours of the Earth and their representation. Topographic maps: reading.
- Alteration of rocks caused by air and water. Action of the weather.
- Torrents, rivers and groundwater as geological agents. Over-exploitation of aquifers. Geological action of ice and wind. Marine dynamics.
- **Formation of sedimentary rocks. Origin and usefulness of coal, oil and natural gas. Assessment of the consequences of its use and depletion.**

However, many textbooks increase the contents by including one topic on mineralogy such as:

- **Mineral matter.**
- **Characteristics of mineral matter, crystalline matter and amorphous matter. Concept of crystal.**
- **Crystallisation and its forms.**
- **Physical and chemical properties of minerals. Mineralisation.**
- **Applications and economic interest of minerals.**

This increase is very good as, although it is true that conceptual contents on mineralogy contained in the syllabus of the first year are not included, crystallographic contents are not present in any of the four years that form part of compulsory secondary education.

All textbooks explain the definition of mineral and rock and their classification, types and properties, in more or less detail. However, the law sets forth that these contents should be studied in greater detail and they should deal with their relation with the Earth's crust, the chemical composition, its use (not only the use of fossil fuels), relative abundance, or its acknowledgement and identification. In short, if all this is included in the current legislation, it should be included in the books.

It may be concluded that all publishing houses analysed incorporate basic knowledge, but some important concepts are missing. In other words, rocks and minerals may be defined, but it is not of much use if this information is not contextualised afterwards, if it is not related to the cycle of rocks, to the world around us, both in relation to their presence or their origin, and to their use and their local and global relevance.

The case of the third year of ESO is worth mentioning, in which regulated geological contents are about a third of the total content, while this percentage is reduced to less than 20% in textbooks in some cases (and they are also at the end of the book, knowing that, by the end of the academic year, books have been rarely finished completely for lack of time). Therefore, even if mineralogical and petrological contents are explained and even if these appear in the table of contents, it is obvious that the content of these topics is undervalued compared with biological contents.

What has not been mentioned until now is that all books include experimental activities, which is what is probably missing. Furthermore, in almost all secondary schools there is a science laboratory where there is a collection of rocks and minerals for identification practice.

6.3. Importance of heritage in the teaching of Geology

The aim of this section is to analyse the treatment of the several aspects of the geological heritage, in general, and of the mineralogical and/or petrological heritage, in particular, in secondary education textbooks in Spain.

It is striking that one of the aims repeatedly included in the subjects of biology and geology states: To know the natural heritage of our Autonomous Region, its characteristics and integrating elements and assess the need to preserve it and improve it.

However, paradoxically, one of the most relevant

aspects in Geology books in secondary education is the scarce or absence of information on geological heritage. This may be owed to the fact that this geological heritage is clearly a minority discipline compared with other natural sciences, although this knowledge is a fundamental part of the scientific training of citizens and, therefore, of their basic culture. This absence of references or explicit contents on heritage does not mean that these are not implicitly present in textbooks. In fact, a de facto use of heritage as a fundamental teaching tool to illustrate the main geological processes and the Earth materials is clear, by the frequent use of photographic images of points of geological interest and museum pieces.

We may not ignore that the points of geological interest (initials in Spanish, PIG) best illustrate an element, a geological process or a characteristic form. Likewise, sites protected under a specific legal category have been pointed out and protected owing to their good exposure, their special richness or the exceptional preservation of specimens. In general, almost all geological topics include illustrations of the geological heritage, although in some exceptional cases, a specific teaching unit (Crystallography, Mineralogy, description of rocks, etc.) may include no illustration of clear heritage interest.

On a separate issue, fieldwork is a starting point of any geological study. In this line, it could be stated that Geology is a science which laboratory is found in the environment. For this reason, fieldwork is essential to acquire competence and geological knowledge.

Based on this statement, a deep teaching change is proposed, in other words, to combine traditional teaching methodology with field activities (geological trips) which facilitate a more active and participative way of teaching Geology. A possible proposal consists of proposing geological routes and trips (geo-routes) which include points of geological interest with an educational and scientific value and support and promote the creation of geological parks, interpretation centres, local museums, etc.

However, we must not to forget that the preparation and accessibility of the points of geological interest directly increase their risk of destruction and plundering; for this reason, it is necessary for preparation measures and teaching and tourist adaptation to be implemented along with appropriate protection and maintenance measures. These aspects are fundamental for the protection of the geological heritage and preservation.

7. Social influence of Geology

Characterising the influence in society of a specific activity or science is a complex task in the short term, because it is difficult to be objective. In order to attempt to be objective, we should identify some significant parameters, which may also be measurable based on objective criteria.

In our case, there is an extensive amount of parameters which could be selected and which combination would give rise to multiple models. There is no knowledge about there being a specific model and proposing the development and scientific justification of one model would be excessively delayed in time and, furthermore, it would be of little value, as the idea is to have a perception of the situation. According to the above, the following parameters are proposed:

1. The presence of Geology in the means of communication: defined as the number of hits (news/articles and specific contents) which appear in a certain set of means of communication over a period of time. The following media are taken into consideration: (1) Television, as it is the most popular mass media; (2) printed media (newspapers and magazines), choosing the ones with the highest circulation; (3) Multimedia: as the cinema or the Internet, as these are most popular among youngsters.

2. Professional activity: defined as the number of people devoted to a professional activity related to Geology in its different facets (extraction, public works, environment, etc.) and in the teaching activity.

3. Geological contents in curricula: measured as total credits taught at university by geologists in relation to the total number of enrolled students.

These three magnitudes are closely related, as presented in *figure 11*. In this figure a notation has been used, taken from Systems Dynamics in which relations are represented as "feedback

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cycles" or virtuous cycles, in which the growth of a variable means the growth of another and so on. Thus, we could also assess the social influence of Geology compared with other sciences that

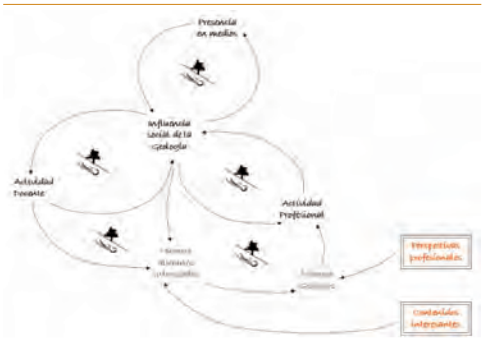

Fig. 11. Interrelation among factors.

compete for a space in the teaching curriculum (Biology, Chemistry, Physics, etc.).

8. Considerations

Based on the above, the following possible considerations are pointed out.

The first consideration is related to the motivation of people to study Geology and work in activities related to this discipline. This motivation is directly related to:

- Interest in the geological contents that are usually acquired via two channels: the number of news related to Geology received from the media and from the immediate surroundings. Some pieces of news arouse people's interest, such as the film Jurassic Park, the findings in Sierra de Atapuerca, the Tsunami in the Indian Ocean, the Tsunami in Japan or the earthquake in Lorca.
- The encouragement of the geological contents taught at the different teaching levels, which are not presented in an attractive manner. If we ask Primary, Secondary and Bachillerato students to arrange a set of subjects according to their interest and perception of relevance, Geology would be in one of the last positions of all subjects.
- Perception of applicability to professional life. Here, we assess the amount of jobs that this discipline generates personal expectations, social recognition and salary associated with them.

Secondly, the number of geologists has decreased in the past few years:

- The degree in Geosciences is not the first option chosen by many students, which some of them end up accepting, if they do not have a higher grade to study something else. This has made many graduates end up working in other fields; therefore, the most efficient way of arousing interest and enthusiasm in others has been lost.
- The professional options for geologists, beyond the most obvious ones related to research, teaching and natural resources, are not clear.
- There is competition with other qualifications which are more prestigious and enjoy better marketing. These qualifications attract students who, potentially, could have studied the Degree in Geosciences or similar degrees.

9. Conclusions

Taking as a starting point the above considerations, it is essential to carry on with the task of teaching, dissemination and arousing awareness in society in general *(Fig. 12)*.

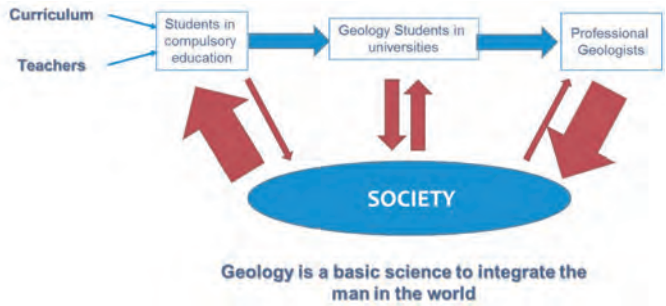

Fig. 12. Final remarks.

For this purpose, we must not forget some comments at different levels:

1. In the past few decades, Geology may have become one of the fastest growing branches of knowledge. However, the real challenge is geologists, not geological contents. In this regard, for instance, we must give our support to the Committee, "What Geology should be taught" to carry on doing its work.

2. Spreading is the second pillar in popularisation and dissemination of geological knowledge. We must disseminate Geology through the media; promote books, articles, information videos; promote talks, conferences, field activities at all educational levels such as, for instance, Geolodías or Science Week; organise geological Olympics in all provinces, integrate the geological aspect in all Environmental Education activities and natural classrooms, etc.; in short, the most important thing is to take Geology to the streets.

In the field of education as well as in the field of spreading Geology it can be seen that:

- the number of people who take part in geological activities is increasing (there is interest and demand),
- the initiatives are clearly insufficient (the offer is insufficient).

Now more than ever, we must create platforms to disseminate Geoscience culture, which should be a priority aim of geologists as a group. It is obvious that it is necessary and a priority:

1. To bring Geology closer to society promoting communication initiatives (TV, radio, press, conferences, courses, field activities, etc.) to explain the role of geologists and Geology.

2. Involve Geology professionals in those activities, productions, materials, publications or information that make scientific knowledge accessible to the general public or to Geology teachers in pre-university levels.

3. Promote actions related to the geological heritage, as it is one of the most efficient formulas to bring Geology to citizens. These actions should include Points of Geological Interest, Theme Parks or Geoparks, and take into account the current legislation (against destruction, plundering and collecting).

4. Increase geological contents in compulsory teaching based on the educational context, taking into consideration the opinion of experts in Geology teaching. In other words, assess the importance of research in Geology teaching, where interesting contributions are made, as there is a field of scientific knowledge between teaching and Geology that should be promoted. A good example is the magazine Enseñanza de las Ciencias de la Tierra, published by AEPECT or Alambique from the publishing house Grao.

These initiatives must be supported in public bodies (Official Professional Association, Geological and Mining Institute of Spain, universities, and others), associations (Spanish Association for the Teaching of Earth Sciences, Geological Society of Spain, Spanish Mineralogical Society, etc.), private companies (Repsol, Cepsa, BP, etc.) and professionals engaged in activities related to Geology.

It is clear that this is not a good time for Geology, for which reason, now more than ever, we must join forces for all of us who are committed to this science. From this perspective, associations and societies are a fundamental platform to channel all types of initiatives leading towards this.

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