

# Earth Sciences in Moroccan Secondary Education: Limited Curricula Coverage and Absence of Fieldwork

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## Abstract

This study investigates the pedagogical orientations, curricula, and textbooks of Life and Earth Sciences (LES) in Moroccan secondary education, with a particular focus on the role of Earth sciences and the integration of field trips. To ensure objectivity, analysis grids based on specific criteria and indicators were employed, allowing for both quantitative and qualitative evaluation of curricula and textbooks. The results reveal that the LES curriculum prioritizes biology, limiting the time devoted to Earth Sciences (ES) and omitting field trips from instructional practices. Such constraints are likely to impede the effective acquisition of geological concepts by restricting opportunities for hands-on and contextualized learning. Based on these findings, recommendations are proposed to enhance the presence of ES and promote the systematic incorporation of fieldwork in secondary-level LES education.

**Keywords:** earth sciences, field trips, pedagogical orientations, analysis grid, curricula, textbooks, Moroccan secondary cycle

## 1. Introduction

In the Moroccan public education system, pedagogical orientations are articulated through a set of official texts that complement specific ministerial decrees. Whereas these decrees establish the structural framework of education—including organization, schedules, and curricula—the accompanying instructional guidelines detail how such decisions are to be implemented. These guidelines outline targeted objectives, recommend teaching methods and pedagogical approaches, and broadly define the principles underpinning school education. In this way, ministerial decrees provide administrative and structural directives, whereas official instructions communicate pedagogical norms. Distributed across all levels of the school hierarchy, these documents reflect the official doctrine of education and are uniformly applied to all institutions. They also serve as a mechanism for centralizing primary and secondary education under a standardized framework. In recent years, educational reforms in Morocco, particularly Framework Law 51.17 (2019) and the Strategic Vision 2015-2030 of the Higher Council for Education, Training and Scientific Research (CSEFRS, 2015), have introduced significant pedagogical changes, including competency-based approaches and learner-centered methodologies (CSEFRS, 2018; Jabri, 2023; El Allaoui et al., 2026). These reforms aim to modernize science teaching, including Earth Sciences (ES), by promoting active learning strategies and field-based inquiry (Iwzane, 2025).

Often regarded as a less appreciated discipline, Earth Sciences (ES) are perceived with limited enthusiasm by both teachers and students, who rarely demonstrate genuine interest in the subject (Bezzi, 1999; Gohau, 2001; Lakhroufi, 2014). In Morocco, similar challenges are observed (Ghalloudi, 2005; Eddif et al., 2016; Chakour et al., 2019), where the teaching and learning of ES are constrained by temporal and spatial limitations. Research indicates that the discipline has not undergone significant development and continues to face persistent challenges (Kaid Rassou et al., 2017). In particular, the scarcity—or even absence—of fieldwork limits opportunities to foster constructive teacher–student relationships and hinders the acquisition of geological concepts. This situation persists despite recent curricular

updates aligned with the Strategic Vision 2015–2030 (CSEFRS, 2015) and Framework Law 51.17 (2019), as fieldwork practices remain underutilized in Moroccan Earth sciences education (Benguitoun et al., 2024; Salahddine, 2026).

The integration of geological field trips represents a scientific approach that enables learners to engage directly with key themes of the Earth Sciences curriculum and to practice methods specific to the discipline. These activities are not merely complementary but constitute an integral component of the Life and Earth Sciences program at both middle and high school levels. Teachers are encouraged to organize them in alignment with curricular requirements, in accordance with ministerial directives issued over several decades (circulars no. 57 of November 25, 1971; no. 318 of November 6, 1973; no. 213 of November 1, 1975; no. 244 of November 13, 1979; no. 42 of July 11, 1999; and no. 55/15 of April 28, 2015). Nevertheless, many Moroccan teachers consider such practices increasingly unrealistic and anticipate their gradual abandonment, owing to persistent constraints (Sibari et al., 2020).

## 2. Materials and Methods

### 2.1 Materials

The corpus for this analysis comprises two types of documents: official reference texts and school textbooks, selected for their relevance to the study.

#### 2.1.1 Official Texts and Pedagogical Orientations

The analysis is based on framework documents published by the Moroccan Ministry of National Education, which set out the curricular requirements and define the expected pedagogical approaches. The principal reference is the Official Curriculum for Life and Earth Sciences in the Secondary Cycle (July 2007), which serves as the primary benchmark for assessing the alignment of textbook content with national learning objectives.

#### 2.1.2 Selection of Textbooks

In Morocco, secondary school LES textbooks, all published in French, include multiple ministry-approved editions, with different regions or schools often adopting different versions. To identify the most widely used editions, a preliminary selection was carried out through a questionnaire distributed to 200 LES teachers in Moroccan secondary schools. The survey consisted of 13 questions organized into four themes: demographic information, the perceived importance of ES in teaching, the types of textbooks used, and general perceptions of thematic coverage. Data were collected online through Google Forms from respondents across different regions of Morocco and analyzed using descriptive statistics (percentages and averages) to identify prevailing trends and perceptions.

Findings from the survey indicate varied patterns of textbook use. While teachers remain primarily attached to official textbooks, many also draw on supplementary materials and digital resources, reflecting diverse approaches shaped by personal initiative and pedagogical context. Textbook choice further depends on the level taught. In middle school, *Al Moufid* dominates across all grades, with *Étincelle* also widely used. At the high school level, teachers diversify their choices according to grade and specialization, often selecting *SVTPlus*, *Archipel*, and *Étincelle*. This variation reflects teacher adaptation of resources to curricular demands and demonstrates considerable pedagogical autonomy.

Based on the results of this survey, three textbooks covering both middle and high school levels were selected for detailed analysis (Table 1).

**Table 1.** Selected LES Textbooks for Qualitative Evaluation

Textbook	Level	Track/option	Edition year	Publishing house
<i>Étincelle</i> SVT– Life and Earth Sciences	2nd year of Middle School	N/A	2020	Apostrophe
<i>Archipel</i> SVT– Life and Earth Sciences	2nd year of High School	Experimental Sciences	2021	Moynier
<i>Étincelle</i> SVT– Life and Earth Sciences	3rd year of High School	Experimental Sciences- Physics option	2019	Apostrophe

With regard to the *Étincelle* textbooks, although they belong to the same series published by the same publisher, they correspond to two distinct grade-level editions with different content, structure, and pedagogical progression. Consequently, they were treated as separate samples in the analysis.

## 2.2 Methods

This study employs a systematic mixed-methods design, combining quantitative and qualitative perspectives using analysis grids. To ensure validity and reliability, the grids were reviewed by five specialists in science education and ES from the Regional Center for Education and Training Professions (CRMEF). They evaluated clarity, relevance to the research objectives, and comprehensiveness. Their suggestions on phrasing and scale granularity were incorporated into the final grids, improving their rigor and credibility.

### 2.2.1 Quantitative Analysis Grid

#### Purpose of the Grid

The objective of the quantitative grid is to assess the presence of geological concepts and field trips in LES teaching in the Moroccan secondary level. It evaluates their inclusion, significance, and treatment in the official curricula. Prior to this, a quantitative assessment of time allocation in LES and ES units (Tables 2 and 3) provided a foundational overview of the curricular structure. The analysis is conducted on two complementary levels: at the global level, it examines the position of Earth Sciences within educational orientations and school curricula (Table 4 and 5), while at the thematic level, it focuses on the inclusion of field trips in the teaching of Earth Sciences at the secondary level (Table 6 and 7).

#### Evaluation Indicators

The analysis is based on a grid structured around five quantifiable indicators, designed to assess the integration of ES and field trips at different levels:

- Presence in the curriculum: Binary indicator (Yes/No) determining whether ES or field trips are explicitly included.
- Allocated instructional time: Categorical indicator (Reasonable/Unreasonable) evaluating the adequacy of the time devoted to ES lessons or to field trips.
- Curricular approach: Categorical indicator (Satisfactory/Unsatisfactory) assessing the recommended pedagogical methodology for teaching ES or conducting field trips.
- Curriculum–textbook alignment: Binary indicator (Yes/No) verifying whether the textbook follows official prescriptions.
- Presence in targeted competencies: Binary indicator (Present/Absent) examining whether ES-related skills or field trip activities are included among the competency objectives for students.
- Necessity of implementation: Categorical indicator (Direct/Implicit) analyzing if the program explicitly mandates the field trip, or whether it is merely recommended.
- Relevance: Categorical indicator (Direct/Implicit) evaluating the educational value and pedagogical justification of the proposed field trip.

All categorical judgments were based on predefined criteria derived from official Moroccan pedagogical orientations and curriculum guidelines. These criteria were applied by subject-matter specialists in Earth Sciences education to ensure consistency and reliability across all school levels. The experts refined the interpretation framework for each indicator, which improved analytical coherence and reduced subjectivity in the coding process.

In parallel, other indicators relied on quantitative measures directly extracted from official curriculum documents. The “presence in the program” indicator was established through systematic identification of Earth Sciences content across units and grade levels and expressed as frequency and percentage distributions. Similarly, “teaching hours” were calculated from the officially allocated instructional time for each unit and subtopic. This allowed a proportional analysis of the weight of Earth Sciences within the curriculum. These quantitative results presented in Tables 2–3 complement the qualitative judgments by providing objective evidence of curriculum content distribution.

The structure of the quantitative analysis grid is provided in Appendix A1 and A2.

### 2.2.2 Qualitative Analysis Grid

#### Purpose of the Grid

To complement the quantitative analysis and gain a deeper understanding of the pedagogical and scientific quality of the textbooks, a qualitative evaluation was carried out. The goal was not simply to determine whether ES was included in Moroccan LES textbooks, but to examine how it was presented, with attention to narrative, pedagogical, and visual dimensions that cannot be reduced to numerical data.

### Evaluation Indicators

A detailed qualitative analysis grid (Table 8) was developed to collect nuanced evaluative judgments using a five-level Likert scale: 1 (Very Poor), 2 (Poor), 3 (Fair), 4 (Good), and 5 (Excellent). The grid is organized into five main categories, each comprising several specific criteria:

- Educational content: Assesses thematic completeness, logical progression, curriculum alignment, clarity, level-appropriate complexity, currency, and interdisciplinary connections.
- Pedagogical approaches: Evaluates the variety and relevance of teaching methods, the feasibility of practical activities, and the promotion of inquiry-based learning and problem-solving.
- Illustrations and visual aids: Analyzes the quality, relevance, and appeal of illustrations, the use of digital media, and the incorporation of Moroccan geological heritage.
- Assessment and monitoring: Examines the variety of evaluation tools (multiple-choice, open-ended questions, projects) and the presence of remediation and progress-tracking measures.
- Linguistic aspects: Assesses the accuracy and clarity of geological vocabulary and the quality of definitions.
- International alignment: Evaluates the alignment of content with international standards. This indicator was developed with reference to widely recognized principles in science education, as reflected in international frameworks such as UNESCO guidelines for Earth science education (UNESCO, 2015), the OECD PISA 2015 science framework, and the Life and Earth Sciences curricula of the French Ministry of Education (MEN, 2020).

The structure of the qualitative analysis grid is provided in Appendix B.

### Rating Process and Rater Information

The qualitative analysis was conducted by four independent raters, all secondary school teachers (two from middle school and two from high school) with over five years of experience in teacher training. None of the raters were involved in the selection of textbooks or the design of the grid, thereby minimizing confirmation bias.

The evaluation was conducted as follows:

**Familiarization:** All raters independently read and familiarized themselves with the entire geological content of each textbook.

**Calibration:** The raters initially applied the grid to a sample chapter not included in the final study to calibrate their understanding of the Likert scale and criteria.

**Independent Rating:** Each rater then independently evaluated the textbooks using the final grid, providing a score from 1 (Very Poor) to 5 (Excellent) for each of the specific criteria. Notes and justifications for each score were documented.

**Consensus Building:** For the few criteria where discrepancies occurred (scores differing by more than one point on the Likert scale), the raters discussed their justifications until a consensus score was reached. The final results reported in the study are based on these consensus scores.

### *2.3 Ethic Statement*

This study combines analysis of publicly available curriculum and textbook documents with questionnaire data from Life and Earth Sciences teachers and subject-matter experts. Participation was voluntary, informed consent was obtained, and all responses were anonymized. Predefined coding criteria based on official curricular guidelines were used within a structured analytical framework, with expert validation contributing to consistency and reduction of subjectivity.

## **3. Results**

This section presents the findings from the systematic application of the quantitative and qualitative analysis grids to the Moroccan LES curricula and the selected textbooks.

### *3.1 Quantitative Analysis: The Marginalized Status of ES in Curricula*

The evaluation of the official curricula against quantitative indicators confirms that ES is systematically underrepresented and confined to science-oriented tracks.

#### **3.1.1 Distribution of Teaching Time Across LES and ES subtopics**

The following tables (Tables 2-3) report the distribution of Earth Sciences content in terms of presence in the program,

allocated instructional time, and percentage of curriculum coverage across middle and high school levels.

**Table 2.** Distribution of Teaching Time Across LES Units in Moroccan Secondary School

	Levels	Units	Allocated teaching time per semester (Hours)	Percentage of time allocated per LES unit (%)	
<b>Middle school</b>	First year	Unit 1: Interactions Between Living Organisms and Their Environment	34h	50%	
		Unit 2: External Geological Phenomena	34h	50%	
	Second year	Unit 1: Internal Geological Phenomena	34h	50%	
		Unit 2: Reproduction in Living Beings and Inheritance of Genetic Traits in Humans	34h	50%	
	Third year	Unit 1: Functional Unit of The Body	34h	50%	
		Unit 2: Health Education	34h	50%	
<b>High School</b>	First Year	Literature and Human Sciences track	Unit 1: Water, the Source of Life	15h	50%
			Unit 2: Humans and the Environment	15h	50%
		Science track	Unit 1: Ecology	45h	50%
			Unit 2: Plant Reproduction	45h	50%
	Second Year	Literature and Human Sciences track	Unit 1: Human Reproduction	15h	50%
			Unit 2: Human Genetics	15h	50%
		Experimental Sciences Track	Unit 1: External Geological Phenomena	32h	25%
			Unit 2: Organic Matter Production and Energy Flow	32h	25%
	Unit 3: Hormonal and Neural Communication		32h	25%	
	Unit 4: Neuro-Hormonal Integration		32h	25%	
	Third Year	Mathematical Sciences Track	Unit 1: External Geological Phenomena	32h	50%
			Unit 2: Nature of Genetic Information and Mechanisms of Gene Expression - Genetic Engineering	32h	50%
		Physical sciences Track	Unit 1: Consumption of Organic Matter and Energy Flow	32h	25%
			Unit 2: Nature and Expression of Genetic Information and Mechanisms of Its Transmission	32h	25%
			Unit 3: Use of Organic and Inorganic Substances	32h	25%
			Unit 4: Geological Phenomena Associated with the Formation of Mountain Chains and Their Relationship with Plate Tectonics	32h	25%
		Life and Earth Sciences track	Unit 1: Consumption of Organic Matter and Energy Flow	32h	16%
			Unit 2: Nature and Mechanism of Genetic Material Expression - Genetic Engineering	32h	16%
Unit 3: Transmission of Genetic Information During Sexual Reproduction - Human Genetics			32h	16%	
Unit 4: Variation and Population Genetics			32h	16%	
Unit 5: Immunology	32h		16%		
Unit 6: Geological Phenomena Associated with the Formation of Mountain Chains and Their Relationship with Plate Tectonics	32h		16%		
Agricultural Sciences Track	Unit 1: Nature and Mechanism of Genetic Material Expression - Genetic Engineering, and Gen Transmission	45h	50%		
	Unit 2: Water Resource Management and Agricultural Production Improvement	45h	50%		

**Table 3.** Distribution of ES Teaching Time and Percentage Allocation Across Subtopics in Moroccan Secondary Curriculum

	Levels	Units	Content topics	Allocated teaching time per semester (Hours)	Percentage of time allocated per ES unit (%)	
Middle school	First year	External geological phenomena	Geological Field Trip	8h	29%	
			Sedimentary Cycle	12h	43%	
			Sedimentary Rocks	2h	7%	
			Water Resources	6h	21%	
			Plate Tectonics	4h	14%	
	Second year	Internal geological phenomena	Relationship Between Plate Tectonics and Internal Geological Phenomena	12h	43%	
			Formation of Igneous Rocks	6h	21%	
			Formation of Mountain Ranges	4h	14%	
			Structure of The Earth	2h	7%	
	Third year	NA	NA	NA	NA	
High School	First year Literature and Human Sciences track	Unit 1: Water, the Source of Life	Water Exploitation and Pollution	4h	23%	
			Formation of water Reserves	3h	18%	
			Drinking Water	4h	23%	
			Water Cycle	2h	12%	
	Second year Experimental Sciences Track	Unit 1: External Geological Phenomena	Creation of a Paleogeographic Map of a Region	11h	32%	
			Reconstruction of The Geological History of a Sedimentary Region	13h	38%	
			Geological Map	06h	18%	
	Second Mathematical Sciences Track	Unit 1: External Geological Phenomena	Creation of a Paleogeographic Map of a Region	12h	35%	
			Reconstruction of The Geological History of a Sedimentary Region	12h	35%	
			Geological Map	06h	18%	
			Recent Mountain Ranges and Their Relationship with Plate Tectonics	04h	12%	
	Third Life and Earth Sciences track	Unit 6: Internal Geological Phenomena	Nature of Tectonic Deformations Associated the Formation of Subduction and Collisional Mountain Chains	04h	12%	
			Metamorphism and its Relationship with Plate Tectonics	11h	32%	
			Granitization and its Relationship with Metamorphism	08h	24%	
			Recent Mountain Ranges and Their Relationship with Plate Tectonics	05h	15%	
			Third year Physical sciences Track	Unit 4: Internal geological phenomena	Nature of Tectonic Deformations Associated the Formation of Subduction and Collisional Mountain Chains	04h
Metamorphism and its Relationship with Plate Tectonics					11h	32%
Granitization and its Relationship with Metamorphism	08h	24%				

A quantitative analysis of instructional time allocation shows that ES content is systematically embedded within biology-dominated units. Table 2 indicates that the proportion of ES-specific content relative to total LES instructional time varies across tracks, ranging from 0% in non-scientific tracks to a maximum of 16% in the Third Year Life and Earth Sciences track, where ES constitutes one of six units. In middle school, ES-related topics account for 50% of instructional time in the first two years; however, ES is absent from the third-year curriculum (0% allocation). In upper secondary education, non-scientific tracks allocate 15 hours to the sole ES-related unit, which focuses primarily on descriptive environmental themes such as Water, the Source of Life.

Table 3 provides a more fine-grained analysis of ES-specific instructional time across geological subtopics. In middle school, the unit External Geological Phenomena allocates 8 hours (29%) to field-based activities, while 12 hours (43%) are devoted to theoretical instruction on the sedimentary cycle, corresponding to a fieldwork-to-theory ratio of 1:1.5. In the Second Year Experimental Sciences track (high school), 13 hours (38%) are allocated to reconstructing geological history, whereas 6 hours (18%) are dedicated to geological map interpretation, corresponding to an approximate ratio of 2:1. In the Third Year Life and Earth Sciences track, advanced topics such as metamorphism account for 11 hours (32% of ES instructional time) and are not accompanied by laboratory or fieldwork activities, as reported in the qualitative analysis (Section 3.2).

3.1.2 Integration of Geological Concepts

**Table 4.** Evaluation of Earth Sciences Integration in High School LES Curricula by Track

School levels	Indicators									
	Presence in the program		Teaching hours		Curricular approach		Compliance between the curriculum and the textbook		Presence in the targeted skills	
	Yes	No	Reasonable	Unreasonable	Satisfactory	Unsatisfactory	Yes	No	Present	Absent
First year Science track	✓			✓		✓		✓		✓
First year Literature and Human Sciences track	✓			✓		✓		✓		✓
Second year Experimental Sciences Track	✓			✓		✓		✓		✓
Second year Mathematical Sciences Track	✓			✓		✓		✓		✓
Second year Literature and Human Sciences Track		✓								✓
Third year Life and Earth Sciences track	✓			✓		✓		✓		✓
Third year Physical sciences Track	✓			✓		✓		✓		✓
Third year Mathematical Sciences Track		✓								

As summarized in Table 4, geological concepts in high school curricula are present in the science tracks but receive inadequate attention. For instance, in the Second Year Experimental Sciences Track, ES is present in the program and allocated time is deemed "Reasonable." However, the pedagogical approach is "Unsatisfactory," focusing on rote memorization rather than investigative skills. While textbooks align with the curriculum, ES-related skills are only implicitly "Present" in targeted competencies, not explicitly stated.

Conversely, in non-scientific tracks, such as the Second Year Literature and Human Sciences Track, ES is entirely "Absent" from the program, resulting in zero allocated instructional time and no inclusion in competency objectives.

A similar trend was observed at the middle school curricula (Table 5), where ES disappears from the curriculum in the Third Year.

**Table 5.** Evaluation of Earth Sciences Integration in Middle School LES Program

School levels	Indicators									
	Presence in the program		Teaching hours		Curricular approach		Compliance between the curriculum and the textbook		Presence in the targeted skills	
	Yes	No	Reasonable	Unreasonable	Satisfactory	Unsatisfactory	Yes	No	Present	absent
First year	✓		✓		✓		✓		✓	
Second year	✓		✓		✓		✓		✓	
Third year		✓								

### 3.1.3 Status of Geological Field Trips

The analysis of fieldwork integration reveals a profound deficit across the entire secondary system (Table 6 and 7). Field trips are never explicitly mandated in any track or level. Their "Presence in the program" is marked as "No" for nearly all tracks, except for an "Implicit" mention in the first two years of high school science tracks.

For example, in the First Year Science track, the necessity of implementation is "Implicit," and the activity is considered "Useful," yet the curricular approach for its execution is "Unsatisfactory," and it is "Present" from the targeted skills. In all literary and humanities tracks, as well as the final year of most scientific tracks, field trips are completely absent from all evaluated indicators.

**Table 6.** Status of Field Trip in the High School LES Program by Track

School levels	Indicators											
	Presence in the program		Teaching hours		Necessity of implementation		Relevance		Curricular approach		Presence in the targeted skills	
	Yes	No	Reasonable	Unreasonable	Direct	Implicit	Useful	Useless	Satisfactory	Unsatisfactory	Present	Absent
First year Science track	✓		✓		✓		✓			✓		✓
First year Literature and Human Sciences track		✓	-	-	-	-	✓			✓		✓

**Table 6.** Status of Field Trip in the High School LES Program by Track(continued)

School levels	Indicators											
	Presence in the program		Teaching hours		Necessity of implementation		Relevance		Curricular approach		Presence in the targeted skills	
Second year Experimental Sciences Track	✓		✓		✓		✓		✓		✓	
Second year Mathematical Sciences Track	✓		✓		✓		✓		✓		✓	
Second year Literature and Human Sciences Track		✓	-	-	-	-	-	-	-	-	-	✓
Third year Life and Earth Sciences track		✓		-	-	-	✓			✓		✓
Third year Physical sciences Track		✓		-	-	-	✓			✓		✓
Third year Mathematical Sciences Track		✓		-	-	-	-	-	-	-	-	-

**Table 7.** Status of Field Trip in the Middle School LES Program

School levels	Indicators											
	Presence in the program		Teaching hours		Necessity of implementation		Relevance		Curricular approach		Presence in the targeted skills	
	Yes	No	Reasonable	Unreasonable	Direct	Implicit	Useful	Useless	Satisfactory	Unsatisfactory	Present	Absent
First year	✓			✓	✓		✓			✓		✓
Second year		✓	-	-	-	-	✓			✓		✓
Third year		✓	-	-	-	-		✓		✓		✓

### 3.2 Qualitative Analysis: Pedagogical Shortcomings in Textbooks

The qualitative evaluation of the three textbooks, including both editions of *Étincelle* (second year of middle school and third year of high school, Experimental Sciences – Physics option) and *L'Archipel* (second year of high school, Experimental Sciences), was conducted using a Likert scale (1: Very Poor to 5: Excellent). The results indicate that although these textbooks formally address the required geological themes, they exhibit substantial pedagogical and content-related weaknesses. A summary of the key indicator ratings is presented in Table 8.

**Table 8.** Summary of Qualitative Evaluation Ratings for Selected Textbooks

Category	Indicator	Étincelle (2nd Year Middle School)	L'Archipel (2nd Year High School)	Étincelle (3rd Year High School)
Educational Content	Thematic Coverage	5 (Excellent)	5 (Excellent)	5 (Excellent)
	Compliance of the educational program with educational guidelines and curricula	5 (Excellent)	5 (Excellent)	5 (Excellent)
	Depth and complexity	3 (Fair)	4 (Good)	3 (Fair)
	Updated Concepts	2 (Poor)	2 (Poor)	1 (Very Poor)
	Interdisciplinary Links	2 (Poor)	3 (Fair)	1 (Very Poor)
Pedagogical Approaches	Teaching methods	2 (Poor)	2 (Poor)	2 (Poor)
	Practical Activities	1 (Very Poor)	1 (Very Poor)	1 (Very Poor)
	Inquiry-based Learning	2 (Poor)	2 (Poor)	2 (Poor)
Illustrations and Visual Aids	Varied, adapted, relevant, and attractive illustrations	4 (Good)	4 (Good)	4 (Good)
	Quality of Illustrations	5 (Excellent)	4 (Good)	5 (Excellent)
	Use of Digital Media	1 (Very Poor)	1 (Very Poor)	1 (Very Poor)
	Use of Moroccan Geoheritage	2 (Poor)	4 (Good)	1 (Very Poor)
Assessment and Monitoring	Diversity of Assessments	2 (Poor)	3 (Fair)	2 (Poor)
	Feedback and Remediation	1 (Very Poor)	1 (Very Poor)	1 (Very Poor)
Linguistic Aspects	Geological vocabulary:	5 (Excellent)	4 (Good)	4 (Good)
	Definition and illustration of technical terms:	4 (Good)	1 (Very Poor)	4 (Good)
International Alignment	Compliance with International Standards	3 (Fair)	2 (Poor)	2 (Poor)

#### 3.2.1 Strengths: Coverage and Foundational Clarity

All three textbooks received high ratings (5/5 - Excellent) for "Thematic Coverage" and "Compliance with the educational program," confirming their formal alignment with the national curriculum. The quality of illustrations was also a strength, rated 5/5 (Excellent) for both *Étincelle* editions and 4/5 (Good) for *L'Archipel*, aiding in the comprehension of complex concepts like plate tectonics. Furthermore, the "Geological vocabulary" was found to be precise and age-appropriate, scoring 5/5 in the middle school *Étincelle* and 4/5 in the other two textbooks. The "Definition and illustration of technical terms" was generally well-handled in the *Étincelle* series (4/5), though it was

a notable weakness for L'Archipel (1/5).

### 3.2.2 Weaknesses: Outdated Content, Passive Pedagogy, and Inadequate Assessment

The analysis uncovered more profound deficits in content depth, modernity, pedagogical approach, and evaluation methods. The "Depth and complexity" of geological concepts were only rated as "Fair" (3/5) in the *Étincelle* textbooks, indicating room for improvement in conceptual clarity. More critically, the "Updated Concepts" indicator was rated 2/5 (Poor) or lower across all books, with no substantial references to recent research or geological events. "Interdisciplinary Links" were also weak, rated "Poor" to "Very Poor" (1-2/5), failing to connect ES to chemistry, physics, or contemporary environmental issues.

The pedagogical approaches were a major area of concern. "Teaching methods" were uniformly rated as "Poor" (2/5), promoting passive learning rather than conceptual understanding. Consequently, the "Inquiry-based Learning" approach was also rated low (2/5 - Poor), as students are rarely prompted to formulate hypotheses. Critically, the "Practical Activities" indicator was unanimously rated 1/5 (Very Poor), with no textbooks providing feasible, hands-on experiments for geological investigation.

This passive approach extends to assessment. The "Diversity of Assessments" was limited (2/5 "Poor" to 3/5 "Fair"), relying primarily on rote-recall exercises. Furthermore, "Feedback and Remediation" tools for ES were entirely absent, receiving a score of 1/5 (Very Poor) across all textbooks.

### 3.2.3 Underutilization of Local and Digital Resources

The analysis revealed a missed opportunity to leverage local context and modern tools. The "Use of Moroccan Geoheritage" was rated 2/5 (Poor) for the middle school *Étincelle* and 1/5 (Very Poor) for the high school *Étincelle*, indicating a preference for generic or foreign case studies. While L'Archipel scored better (4/5 - Good) on this indicator, all textbooks scored 1/5 (Very Poor) for "Digital Media," completely lacking links to videos, simulations, or interactive maps.

Finally, "Feedback and Remediation" tools for ES were absent (1/5 - Very Poor in all cases), and the "Diversity of Assessments" was limited, relying primarily on rote-recall exercises rather than competency-based evaluation. This contributes to an overall "International Alignment" score that is, at best, 3/5 (Fair), failing to meet the standards of inquiry-based and technology-integrated geoscience education seen in international frameworks.

## 4. Discussion

This study offers a systematic, evidence-based diagnosis of Earth Sciences education in Moroccan secondary schools. Both quantitative and qualitative analyses reveal that ES is marginalized, detached from field-based practices, and taught through textbooks emphasizing theory over pedagogy. These findings are interpreted against international benchmarks to underscore the gaps between Moroccan practices and global standards.

### 4.1 A Curricular Divide: Quantitative Evidence of Marginalization and Its Implications

Our quantitative analysis reveals a stark curricular divide, with Earth Sciences being explicitly absent from all literary and humanities tracks (Table 4). This is not merely a difference in emphasis but a complete exclusion, denying a significant portion of the student population any foundational knowledge in geoscience. This approach stands in sharp contrast to countries like Finland, where the core educational objective is to build "scientific literacy" for all future citizens through transdisciplinary science education, regardless of their specialization (Lavonen et Laaksonen, 2009). By assuming that geoscience literacy is unnecessary for non-scientific tracks, the Moroccan curriculum creates a significant gap. In the context of pressing challenges such as climate change, water scarcity, and natural hazards, this gap undermines students' understanding of the geological processes behind these risks and limits their capacity for informed civic engagement.

### 4.2 The Fieldwork Paradox: Between Implicit Suggestion and Pedagogical Impossibility

The most striking quantitative finding is the near-total absence of fieldwork as a mandated pedagogical activity (Tables 6 and 7). While ministerial circulars have historically encouraged field trips, our analysis of the official curricula shows that their implementation is, at best, "Implicit" and their pedagogical approach is consistently "Unsatisfactory." They are never a "Direct" requirement and are consistently "Absent" from targeted skills. This creates a fundamental paradox: a discipline rooted in observation and inference is taught almost entirely through indirect means.

This situation diverges profoundly from systems where geoscience education excels. In the United Kingdom, through the Earth Science Teachers Association (ESTA) program, fieldwork is a compulsory and structuring element of the

curriculum, designed explicitly to develop in-situ observational and analytical skills (King, 2008). Similarly, in France, official guidelines explicitly recommend several outings per year (Ministry of National Education, circular no MENE2310475C of 13-6-2023). The Moroccan "implicit suggestion" model, devoid of clear protocols, safety guidelines, or assessment criteria, renders fieldwork logistically and pedagogically unfeasible for most teachers, confirming the perceptions of impracticality reported by Sibari et al. (2020).

Furthermore, our qualitative results expose a critical missed opportunity that exacerbates this problem: the failure of textbooks to valorize Morocco's rich and diverse geoheritage. The ratings for "Use of Moroccan Geoheritage" were "Poor" (2/5) or "Very Poor" (1/5) in two of the three textbooks analyzed (Table 8). When textbooks prioritize foreign case studies and generic diagrams over local examples (e.g., the Rif orogeny, Atlas Mountain formations), they miss a crucial chance to root geological learning in the students' immediate environment, thereby reducing the perceived relevance and ease of organizing local field excursions.

#### *4.3 Textbooks of Uneven Quality: Between Formal Compliance and Pedagogical Shortcomings*

The qualitative evaluation of textbooks highlights a dissonance between formal compliance and pedagogical effectiveness. While the textbooks scored "Excellent" (5/5) on "Thematic Coverage" and "Compliance with the educational program," they displayed severe deficiencies in indicators that reflect modern science education.

The "Very Poor" (1/5) ratings for "Practical Activities" and "Digital Media" across all textbooks (Table 8) are particularly concerning. This contrasts sharply with practices in countries like Canada and Australia, where ES textbooks are dynamic portals, integrating links to online databases, interactive geological maps, and simulations of plate tectonics (Senger et al., 2021; Gregory et al., 2021). The static, academic vision of ES conveyed by Moroccan textbooks fails to connect with the reality of modern geoscience professions—such as geomatics, natural hazard management, or geothermal energy—which are highly applied and technology-oriented.

Similarly, the "Poor" (2/5) ratings for "Inquiry-based Learning" and "Updated Concepts" (Table 8) reveal a pedagogical model that is passive and outdated. International standards like the NGSS and IB curricula encourage students to "think and act like geologists," constructing knowledge through investigation and problem-solving. The Moroccan textbooks, however, present pre-digested facts with minimal emphasis on hypothesis formulation or critical analysis. This pedagogical gap, combined with the lack of updated content, means that students are not exposed to contemporary issues like earthquake-resistant urban planning or recent seismic data, further widening the disconnect between their education and the world they inhabit.

#### *4.4 Limitations of the Study*

Despite the methodological rigor of the mixed-methods approach employed, this study presents several limitations that warrant consideration. The analysis is based primarily on official curricular documents and a limited corpus of school textbooks, which, although representative of institutional orientations, do not fully capture the diversity of classroom practices across regional and local contexts. As a result, pedagogical adaptations made by teachers, often context-dependent, remain only partially accessible. In addition, although the textbook evaluation is guided by an explicit analytical framework, it inevitably involves an interpretative dimension inherent to didactic research, which may introduce a degree of subjectivity.

The absence of empirical data from classroom observations, teacher interviews, or student feedback further limits understanding of how fieldwork and inquiry-based approaches are implemented in practice. Finally, the national scope of the study constrains the generalizability of the findings, although the identified dynamics may also be relevant to other educational systems facing similar structural constraints.

Future research should adopt multi-level and multi-sited empirical designs combining curricular analysis, classroom observation, and stakeholder perspectives to better understand the conditions that support the integration of field-based and active learning approaches in Earth Sciences education.

## **5. Conclusion and Recommendations**

This study provides a systematic diagnosis of Earth Sciences education in Moroccan secondary schools, revealing three critical areas of deficiency: a marginalized curricular status, a profound absence of fieldwork, and pedagogically outdated textbooks. The evidence clearly indicates that the current approach impedes the effective acquisition of geological knowledge and skills. To address these specific shortcomings, the following concrete, evidence-based recommendations are proposed:

- Mandate the inclusion of a foundational, applied ES module across all academic tracks in all secondary cycle

levels. This module should focus on topics of universal citizenship relevance, such as "Water Resources and Management in Morocco" and "Understanding Natural Hazards (Seismic and Climatic)."

- Increase the allocated instructional time for ES in scientific tracks by at least 30% to allow for depth beyond rote memorization and to incorporate practical, inquiry-based activities.
- Formally integrate at least one mandatory, locally relevant geological field trip per year into the curriculum for all science-track classes from middle school through high school.
- Develop and distribute a "National Fieldwork Pedagogical Kit" to all schools. This kit should include a catalog of vetted, accessible field sites for each region, standardized safety-approved protocols for conducting field observations and measurements, and ready-to-use worksheets and assessment rubrics aligned with curricular competencies.
- Launch a "Moroccan Geoheritage in the Classroom" initiative, commissioning the creation of video libraries, 3D virtual field tours, and case studies based on specific Moroccan geological sites (e.g., the Souss-Massa basin, the Middle Atlas volcanoes, etc.) to be used as preparatory or supplementary materials.
- Revise the official textbook approval criteria to integrate mandatory, evidence-based ratings for pedagogical indicators. Future editions must include at least two feasible, hands-on experiments or modeling activities in each geological chapter. They should also provide QR codes or direct links to digital resources, such as plate tectonic simulations, Moroccan seismic activity databases, and satellite imagery of landscape evolution. In addition, each unit should contain a dedicated section that connects geological concepts to contemporary Moroccan environmental challenges, including soil erosion and coastal management.
- Establish a continuous professional development program for LES teachers, focused on inquiry-based teaching methods, the use of digital geoscience tools, and the effective execution of the fieldwork protocols from the national kit.
- Diversify the national examination framework to include questions that assess field-based reasoning and data interpretation skills, moving beyond factual recall.
- Incentivize the creation of digital assessment tools that provide immediate, personalized feedback to students on ES exercises, addressing the critical lack of remediation identified in the textbooks.

Ultimately, strengthening ES education in Morocco is not merely an academic reform but a societal imperative. By implementing these targeted, actionable recommendations derived directly from our findings, Morocco can transform its Earth Sciences education. This will equip future generations with the knowledge, skills, and geological literacy necessary to understand, preserve, and sustainably manage their environment in an era of unprecedented global change.

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**Appendix A**

Table A1. Analysis Grid of Earth Sciences Integration in Middle and High School LES Curricula Across Tracks

School levels	Indicators										
	Presence in the program		Teaching hours		Curricular approach		Compliance between the curriculum and the textbook		Presence in the targeted skills		
	Yes	No	Reasonable	Unreasonable	Satisfactory	Unsatisfactory	Yes	No	Present	absent	

Table A2. Analysis Grid of Field Trip status in Middle and High School LES Curricula Across Tracks

School levels	Indicators											
	Presence in the program		Teaching hours		Necessity of implementation		Relevance		Curricular approach		Presence in the targeted skills	
	Yes	No	Reasonable	Unreasonable	Direct	Implicit	Useful	Useless	Satisfactory	Unsatisfactory	Present	Absent

Appendix B. Analysis Grid for the Qualitative Evaluation of Middle and High School LES Textbooks

Category	Indicators	Rating				
		1	2	3	4	5
Educational content	Thematic: Are the main geological themes well covered? (Plate tectonics, volcanism, etc.)					
	Are the concepts presented in a logical and progressive manner?					
	Compliance of the educational program with educational guidelines and curricula					
	Depth and complexity: Are geological concepts explained clearly and simply?					
	Is the level of detail appropriate for the students' level?					
	Updated concepts: Does the content reflect current geological knowledge?					
	Are references to recent research or recent geological events included?					
Pedagogical approaches	Interdisciplinary Links: Are connections made with other disciplines (chemistry, biology, physics)?					
	Does the textbook link ES to contemporary environmental issues?					
	Teaching methods: Does the teaching method promote understanding of geological concepts (inductive method, etc.)?					
	Are the proposed activities varied and adapted to different learning styles?					
	Practical Activities: Does the textbook offer experiments or practical activities related to ES?					
	Are the activities feasible with the resources available in Moroccan institutions?					
	Inquiry-based learning: Are students encouraged to formulate hypotheses and explore geological solutions?					
Illustrations and Visual Aids	Are problem-solving situations used to stimulate students' critical thinking?					
	Varied, adapted, relevant, and attractive illustrations: (graphs, maps, etc.)					
	Quality of illustrations: Are the diagrams, photos and other illustrations clear and useful for understanding the concepts?					
	Digital media (videos, animations, simulations, etc.)					
Assessment and Monitoring	Use of Moroccan geoheritage in teaching ES					
	Diversity of assessments (MCQs, open questions, projects, etc.)					
	Feedback and Remediation: Does the textbook provide remediation exercises to correct ES-related errors?					
Linguistic Aspects	Are there sections dedicated to tracking ES progress?					
	Geological vocabulary: Is the geological vocabulary precise and adapted to the students' level?					
International alignment	Definition and illustration of technical terms: Are the technical terms well defined and illustrated?					
	Compliance with international ES standards: Is the textbook's geological content consistent with international ES standards?					
	How does it compare with ES textbooks from other countries?					

Rating Legend (1-5): 1: Very Poor; 2: Poor; 3: Fair; 4: Good; 5: Excellent

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