

Research Article

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Challenges and Obstacles Encountered in the Teaching and Learning of Earth Science in Moroccan Secondary Education: Teachers' Perspectives

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Abstract

Background/Objective. The teaching and learning of geology in Morocco's secondary education system seems to face various challenges. This research aims to recognize and analyze these challenges so as to develop a deeper understanding of the problems faced in middle and high school classrooms.

Materials/methods. To this end, a survey was conducted among Life and Earth Sciences teachers working in secondary education in Morocco using an online questionnaire (via Google Forms). Participants were selected using a non-probability sampling method based on self-selection; only teachers who voluntarily agreed to respond to the questionnaire were included in the sample. The sample comprised 142 Life and Earth Sciences teachers from public secondary schools under various provincial education directorates across Morocco. The questionnaire was divided into two parts: the first part, comprising four items, gathers general information about the respondents; the second part, composed of 17 items, explores the specific difficulties encountered in the teaching and learning of geology. Data analysis was carried out using Excel for descriptive statistical processing and SPSS software to apply the Chi-square test to examine relationships between certain variables.

Results. The data analysis reveals numerous challenges from both teachers' and students' perspectives. These challenges are mainly related to the characteristics of the subject, particularly its use of abstract concepts and the intricate ideas of geological time and spatial relationships.

Conclusion. The study found that there are also obstacles related to teaching methods, pedagogy, administration, and individual circumstances. To address these setbacks, the teachers surveyed suggested several solutions to improve the teaching of geology and facilitate student learning.

1. Introduction

Earth sciences aim to reconstruct the history of the terrestrial globe, from its genesis to the present day, as well as the evolution of life that has developed within it. This quest involves established theories, testable hypotheses, careful observation, controlled experiments, and the methodical study of geological formations (Rassou et al., 2017). As a diachronic science that studies events occurring across several temporal and spatial scales, this discipline is organized around three core categories:

- The study of the Earth's crust's constituent materials, including mineralogy and petrology.
- The examination of geological processes, whether they occur inside the Earth (internal geodynamics), such as volcanism, tectonics, and seismology, or at the surface (external geodynamics), such as sedimentology and erosion.
- The reconstruction of geological history, a field of historical geology, particularly through the use of stratigraphy and palaeogeography (Boughanmi, 2009).

1.1. Challenges in Teaching Geology at the Secondary Level in Morocco

In Morocco, teaching geology at the secondary school level presents a significant difficulty for both teachers and students. This discipline requires students to interact with abstract and complicated ideas, the assimilation of which proves arduous for them. In fact, understanding geological phenomena is essentially dependent on mastering notions of geological time and spatial relationships, demanding creative and mental modelling abilities that are frequently challenging for learners to develop (Rassou et al., 2017; Chakour et al., 2019).

According to research, learners' perceptions of geological time and the protracted processes that shape the planet are the main challenges they face when studying Earth sciences. Learners' understanding is made further complicated by the fact that these phenomena, which unfold over millions or even billions of years, are far removed from their daily lives. Geology is so often viewed as an intellectually demanding scientific discipline, potentially fostering a lack of interest among learners.

Nevertheless, despite these observations, limited didactic research has been done in Morocco to analyze the specific challenges in the teaching and learning of geology, particularly when compared to other scientific disciplines like physics or biology (Rassou et al., 2017; Chmanti-Houari et al., 2017).

1.2. Problems and the Study's Objectives

The teaching of Earth Sciences, an essential component of Life and Earth Sciences, is a key part of the scientific education of Moroccan secondary school learners. Its goal is to equip learners to comprehend the problems related to Earth and its environments. However, this teaching faces several challenges that hinder the effective transmission of knowledge. Among these challenges are the complexity and abstraction of geological concepts, the lack of prerequisites among students, the persistence of misconceptions about geological phenomena, overcrowded classrooms that limit the possibility of carrying out practical work in class and field trips, as well as the lack of adapted pedagogical and didactic resources (Laouali Idi et al., 2024).

In addition to that, the shortage of teachers specialized in geology, caused by the predominance of biologists in the teaching of Life and Earth Sciences, the preference for traditional teaching methods, and administrative constraints, such as overloaded curricula and the lack of ongoing teacher training, worsen these difficulties (Chamanti-Houari et al., 2017; Chakour et al., 2019; Laouali Idi et al., 2024; Rassou et al., 2017).

While international studies have examined these difficulties (Boughanmi, 2009; Chalak & El Hage, 2011; Chamanti-Houari et al., 2017), few studies have specifically targeted the Moroccan context, which is, however crucial for identifying the real obstacles encountered in the classroom and suggesting adapted solutions (Rassou et al., 2017). These obstacles impact both teachers and learners. The majority of teachers face difficulties related to their training, often insufficient or not specific to the teaching of geology, and to the heavily burdened school curricula, which leaves them little time to delve deeper into this discipline with their learners. As for the learners, they are often less engaged in geology classes, generally favouring biology (Gohau, 1990; Gohau, 2001; Chalak et al., 2011), which consequently manifests in their poor academic results. These combined factors make the teaching of geology in Morocco particularly intricate and necessitate a thorough examination to identify relevant solutions. Consequently, it appears relevant to investigate the causes of these hurdles, focusing on two fundamental research questions: what are the principal obstacles to the teaching and learning of geology at the secondary education level in Morocco, and what strategies can be implemented to address them?

By addressing these questions, this study aims to explore the perceptions of Life and Earth Sciences teachers regarding the challenges encountered in the teaching of geology. This overall objective is further delineated into several specific objectives:

- To highlight the difficulties in the teaching and learning of geology as observed within the pedagogical practices of teachers in the field.
- To identify the origin and causes of these difficulties.
- To suggest solutions for the improvement of pedagogical practices, curricula, and resources intended for teachers, teacher trainers, and educational policymakers.

2. Literature Review

2.1. Challenges in the Teaching of Geology: Current Status and Bibliographic Synthesis

Based on an established bibliographic synthesis, the teaching of geology constitutes a significant challenge. Numerous prior studies have pointed out the complexity and abstract nature of geological concepts, which makes this discipline difficult for learners to assimilate. In fact, Earth Sciences relies on notions of space and time that transcend the individual imagination of learners.

Several studies have demonstrated that the learning difficulties in Earth Sciences are principally linked to the comprehension of temporal and spatial scales. Gohau (1990) emphasizes that "one of the difficulties in teaching Life and Earth Sciences is our inability to recognize the immense durations of Earth's past." For his part, Orange (1999) points out the obstacles encountered by students when they must integrate empirical data with theoretical concepts during fieldwork (Orange et al., 1999).

2.2. Difficulties Related to the Scales of Time and Space

Trend (2000) has highlighted the challenges associated with understanding the diverse temporal scales involved in geological processes. Indeed, learners struggle to grasp the immensity of the timeframes required for geological phenomena as well as the variable rates at which these phenomena proceed (Sanchez et al., 2006; Raab & Frodeman, 2002).

Orange (2003) highlighted that learners experience difficulties in mobilizing the concepts of time and space when explaining geological phenomena such as seafloor spreading. Monchamp and Sauvageot-Skibine (1995) explain that this lack of comprehension is partly linked to fixism, which leads students to perceive dynamic phenomena as static on a human timescale.

For example, learners imagine that the subduction of one tectonic plate beneath another, less dense one, in subduction zones is a rapid process, whereas it extends over several million years. Similarly, volcanic eruptions, although sudden on a human timescale, are manifestations of a long-term process on the geological timescale. This difficulty lies in the learners' inability to bridge the gap between human and geological timescales (Laperrière-Tacussel, 1995).

Earthquakes constitute another striking example of this lack of comprehension. On a human timescale, a seismic event lasts a few seconds or minutes. However, its formation is a long-duration process involving a gradual accumulation of energy within rocks over years or even centuries. After that, this energy is released abruptly through a rupture along a fault line. Boughanmi (2009) has demonstrated that catastrophism influences students' perceptions: they view the earthquake as a sudden and destructive event without considering its geological history and the immensity of time required for its preparation (Boughanmi, 2009).

2.3. Didactic and Pedagogical Factors Limiting the Teaching of Geology

The effective teaching of geology is hindered not only by the inherent difficulty of its concepts but also by didactic factors. Research from the Educational Technology Research Team in 2004 (Sanchez et al., 2004) pinpointed three main challenges in this regard:

- Firstly, opportunities for students to directly examine geological training in the field are scarce despite the crucial role such firsthand experience plays in understanding geological processes.
- Secondly, the lack of laboratory activities involving sample manipulation and experimentation hampers students' ability to grasp geological concepts. This is often due to insufficient facilities.
- Thirdly, many teachers in Life and Earth Sciences lack comprehensive initial and continuous training in geology, which limits their ability to teach the subject effectively.

Findings from a study in Saudi Arabia echoed these concerns, identifying the shortage of geology laboratories and field trips as major obstacles to geology education. Similarly, the teaching of Earth Sciences in Lebanon is challenged by a range of epistemological, ideological, didactic, professional, and curricular obstacles (Chalak & El Hage, 2011).

2.4. The Teaching of Geology in Morocco: A Marginalized Discipline

According to official Moroccan pedagogical guidelines, geology is taught in the first and second years of middle school and in the first and second years of baccalaureate. However, an analysis of the time allocated to the teaching of Life and Earth Sciences reveals a marginalization of Earth Sciences, which receive significantly less attention than other scientific disciplines.

This limited representation of geology in the school curricula restricts learners' exposure to this discipline and reinforces learning difficulties.

- In middle school, the teaching of geology is limited to the first and second years.

Table 1. Distribution of allocated time for geology in Middle School (Note 132, 2011).

Level	1st year of middle school	2nd year of middle school
Content taught	External Geodynamics ✓ The genesis and formation of rocks ✓ Notion of fossil and fossilization ✓ Introduction to the concept of stratigraphic scale	Internal Geodynamics ✓ Notion of lithospheric plates ✓ Earthquakes, volcanoes, and their relationships with plate tectonics ✓ Tectonic deformations ✓ Formation of magmatic rocks ✓ Formation of mountain ranges
Allocated time	32 hours of geology (50%) 32 hours of biology	32 hours of geology (50%) 32 hours of biology

It is important to note that in the third year of middle school, no geology lesson is included in the curriculum, with the entire semester being exclusively dedicated to biology.

2.5. At the Upper Secondary Level

The chapters dedicated to geology are distributed across the final two years of this cycle: the first year of the baccalaureate and the second year of the baccalaureate. The table below presents a synthesis of the taught content.

Table 2. Distribution of Allocated Time for Geology at the Upper Secondary Level (Pedagogical guidelines, 2007).

Level	1st year of baccalaureate, Experimental Sciences Stream	2nd year of baccalaureate, Experimental Sciences Stream, field: Life and Earth Sciences
Content taught	External Geodynamics ✓ Reconstruction of geological history ✓ Notion of biozone, notions of facies fossils and stratigraphic fossils, and the significance of fossils for the construction of the biostratigraphic scale	Internal Geodynamics ✓ Internal Geodynamics ✓ Recent Mountain ranges and their relationship with plate tectonics ✓ Nature of tectonic deformations characteristic of subduction and collision chains ✓ Metamorphism and its relationship with plate tectonics ✓ Granitization and its relationship with metamorphism
Allocated time	34 hours of geology (25%), 102 hours of biology	34 hours of geology (16.7%), 170 hours of biology

It is important to note that, in the Common Core class, the curriculum is exclusively dedicated to ecology and biology, with no geology lessons (Pedagogical guidelines, 2007).

This distribution highlights the significant disparity between the allocated time for geology and that dedicated to biology. Such marginalization negatively affects both learners' motivation and interest, as well as teachers' engagement with this discipline.

The teaching of geology in Morocco faces numerous challenges, both conceptually and didactically. The notions of time and space, which are essential for understanding geological phenomena, are considered a major obstacle for learners. Furthermore, the absence of field trips, the lack of laboratories, and the insufficient training of teachers worsen these difficulties.

In light of these observations, it seems necessary to adopt innovative pedagogical strategies, such as the integration of interactive digital resources, an increase in experimental activities, and the implementation of continuous professional development for teachers. These measures would enhance learners' understanding and interest in geology, a discipline essential for comprehending the functioning of our planet.

3. Methodology

3.1. Sample Presentation

To study the difficulties encountered in the teaching and learning of Earth Sciences at the secondary school level in Morocco, we conducted a survey among a sample of 142 Life and Earth Sciences teachers from various Provincial Directorates across the country. The participants were selected using a non-probability sampling method based on self-selection. The questionnaire was distributed online via the Google Forms platform, allowing for voluntary participation. The link was shared through professional networks, discussion groups, and direct contacts. Only teachers who voluntarily agreed to participate were included in the sample.

Logistical constraints, such as the geographical dispersion of teachers and time limitations justified this approach. It also aligned with the objective of reaching as many teachers as possible across Morocco to ensure a diverse representation of field realities.

3.2. Data Collection Tool

This questionnaire allows us to collect data in order to identify the difficulties related to the teaching and learning of geology, as well as to gather suggestions from teachers to improve the quality of instruction within this educational cycle.

3.2.1. Development of the Research Instrument

The questionnaire items were formulated based on a thorough review of the literature on the teaching of Life and Earth Sciences, as well as on previous studies addressing similar challenges. The questionnaire is divided into two main parts:

1. Part One (4 items): This section focuses on general information about the respondents (age, academic background, teaching experience, etc.).
2. Part Two (17 items): This section explores the difficulties related to the teaching and learning of geology at the secondary level, as well as the solutions proposed by the respondents.

The questionnaire incorporates various question types—closed-ended, open-ended, short-answer, and long-answer—enabling both quantitative and qualitative analysis of the teachers' perceptions and experiences.

3.2.2. Instrument Validity

3.2.3. Content Validity

A content evaluation was conducted with four experts in science education and pedagogy to ensure that the questionnaire items thoroughly addressed the various challenges encountered in the teaching of Earth sciences. The experts validated each question, and adjustments were made based on their feedback.

3.4. Data processing tools

We used Excel and SPSS (version 25) software for data processing and analysis, enabling us to perform various statistical analyses.

3.4.1. Descriptive analysis with Excel

The data were first organized in Excel to conduct a descriptive analysis and generate clear statistical summaries. This facilitated the calculation of descriptive statistics such as frequencies, percentages, and means, allowing for a better understanding of the teachers' responses regarding various aspects of Earth sciences teaching. These results were used to provide an overview of the obstacles faced by the teachers and their responses to the questionnaire items.

3.4.2. Pearson's Chi-square test

A Pearson's Chi-square test was used to analyze the relationships between the variables. This test helped determine whether statistically significant associations existed between these them. The choice of the Chi-square test was based on the nature of the data, which was primarily categorical (e.g., the relationship between the difficulties encountered in teaching geology and the perception of the courses).

4. Results

The results of the questionnaire are presented below:

4.1. General information about the surveyed participants

The results of the questionnaire are as follows:

Based on the data collected, 66.9% of the 142 teachers surveyed are women, while 33.1% are men. An analysis of the respondents' experience reveals that 43.7% have more than 10 years of experience, 35.9% have between 5 and 10 years, and 20.4% have less than 5 years.

In terms of teaching level, 52.1% of the respondents teach in the upper secondary cycle (high school), while 47.1% teach in the lower secondary cycle (Middle school).

Regarding subject preference, 56.3% of the respondents prefer teaching biology, 40.1% prefer teaching both subjects, and 3.6% prefer teaching geology.

Table 1. Characteristics of the Surveyed Sample

Question 1		Question 2			Question 3		Question 4		
Your Gender		Seniority			Teaching cycle		Do you prefer to teach?		
Female	Male	Less than 5 years	Between 5 and 10 years	More than 10 years	Upper Secondary	Lower Secondary	Biology	Geology	Both
66.9%	33.09%	35.9%	43.7%	20.4%	52.1%	47.9%	56.3%	3.6%	40.1%
Percentage									

According to the data in Table 3, more than half of the teachers surveyed prefer teaching biology over geology. To better understand the reasons behind this preference, the following section presents the questionnaire results regarding the relative difficulties in teaching and learning geology at the secondary level.

4.1.1. Teachers' educational level:

This section provides an overview of the academic qualifications of the Life and Earth Sciences teachers who participated in the survey, specifically focusing on their diplomas and educational attainment.

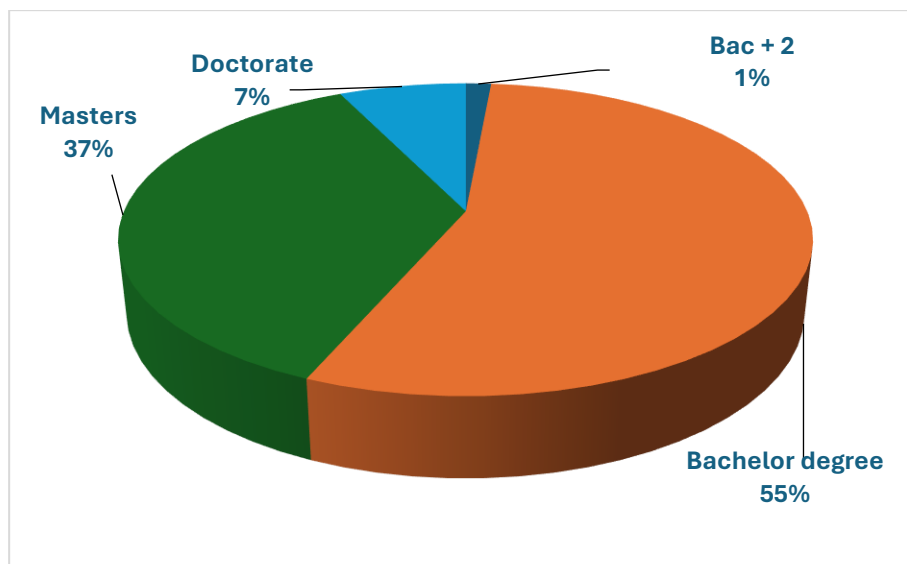


Figure 1. Teachers' educational level

Figure 1 illustrates the academic qualifications of the surveyed teachers. The majority of respondents hold a bachelor's degree (55%), while 37% have a master's degree, and 7% possess a doctoral degree.

4.1.2. Training Undertaken:

Continuous professional development plays a crucial role in enhancing teaching practice and fostering the development of teachers' professionalism.

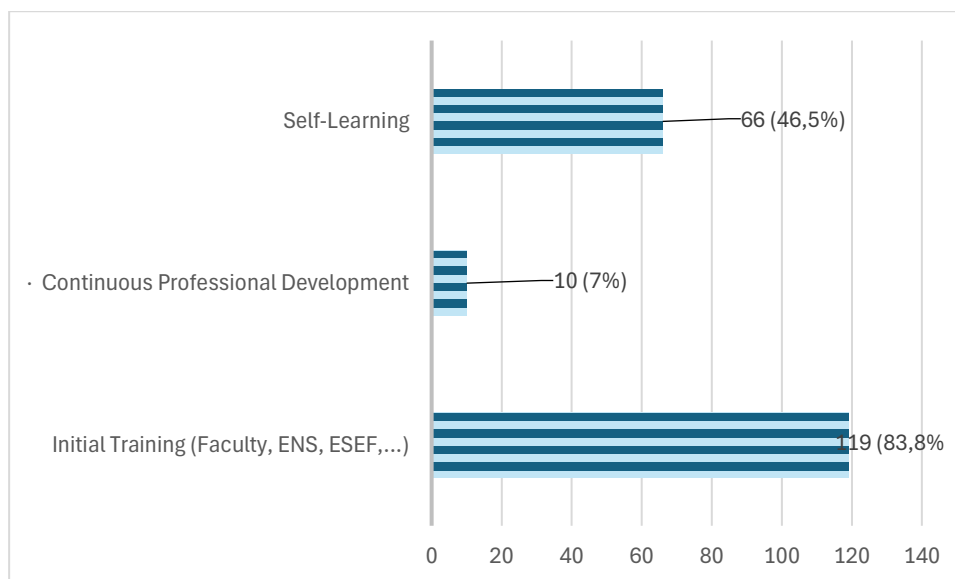


Figure 2. Types of training undertaken by Teachers

The majority of the surveyed teachers (83.8%) received initial training at their institutions (faculties or higher education schools). Additionally, 46.5% of respondents reported engaging in self-directed learning. However, only 10 out of 142 teachers have participated in continuous professional development.

This finding suggests that the limited availability of continuous professional development may be one of the factors contributing to the challenges associated with teaching Earth Sciences in Moroccan secondary schools.

4.2. Difficulties in the Teaching and Learning of Geology at the Secondary Level

4.2.1. Difficulties in Teaching Geology

Out of the 142 teachers surveyed, 114 teachers (80%) reported encountering difficulties in teaching geology, whereas only 28 (20%) indicated they experienced no such challenges.

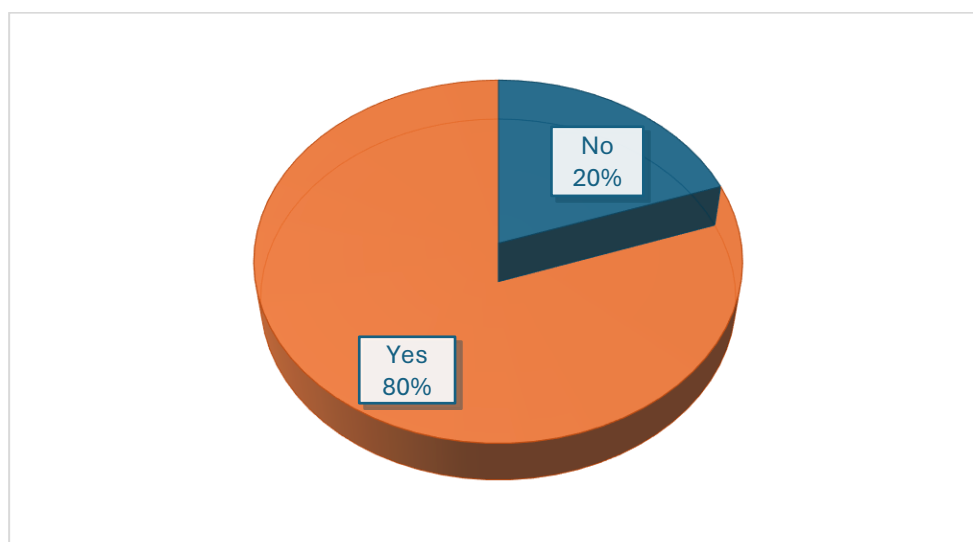


Figure 3. The percentage of teachers reporting difficulties in teaching geology.

4.2.2. Which aspects of geology do teachers find most difficult for learners to understand?

According to the teachers, the geological aspects that are considered most difficult for learners to understand are presented in the figure below (Figure 4).

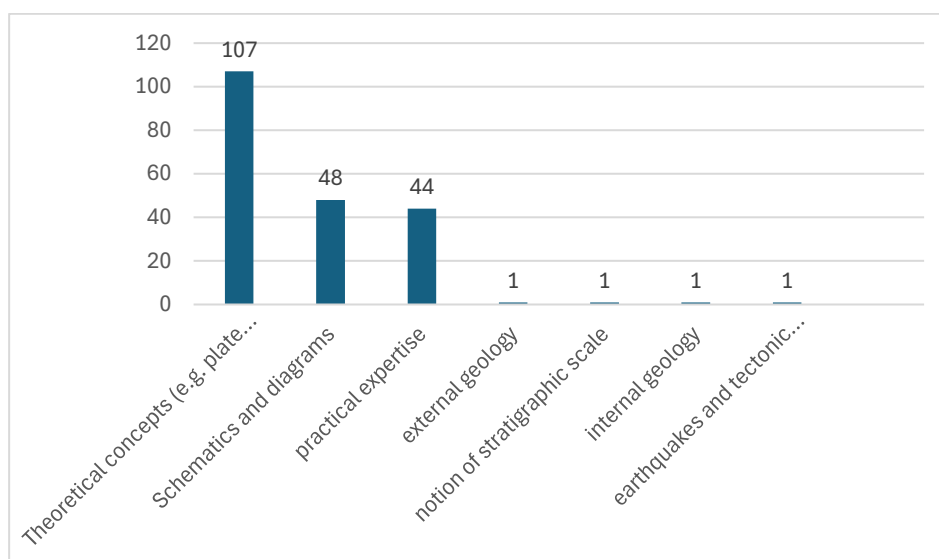


Figure 4. Geological Aspects Difficult for Learners to Understand

According to the teachers, the geological aspects that learners find most difficult to understand are mentioned in Figure 4 above.

The majority of respondents report that their learners struggle with theoretical concepts in geology, such as plate tectonics, diagrams and schematics, and external geology, primarily due to the lack of field trips. Additionally, they highlight the difficulty learners have in understanding stratigraphic scales.

4.2.3. Prerequisites for learners in Geology

The teachers' responses concerning their learners' prerequisites are presented in Figure 5 below.

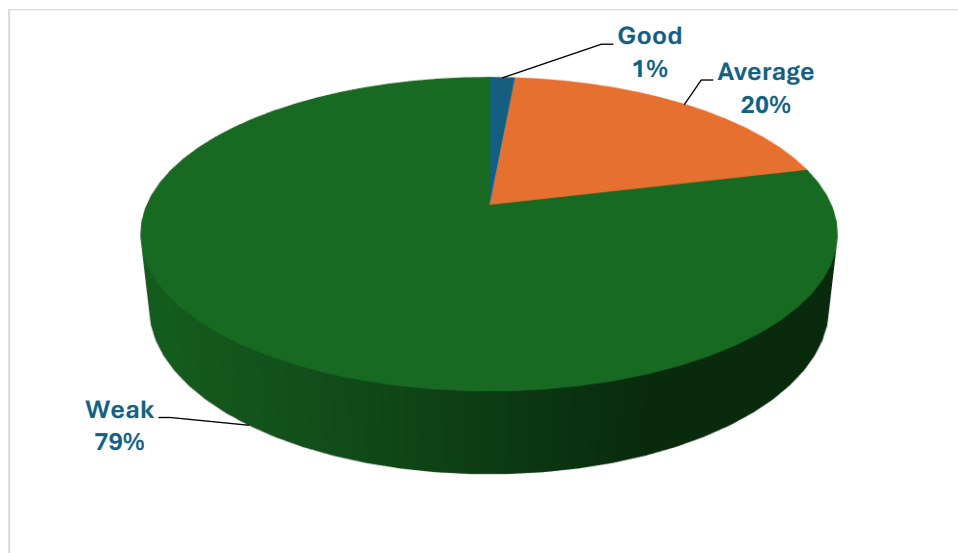


Figure 5. Learners' level of Geological prerequisites

According to the teachers, 79% assess their learners' Knowledge in geology as weak, 20% as average, and only 1% consider their learners' prerequisites to be good or very good.

4.2.4. Evaluation of Taught Geological Programs

The geological program taught in Moroccan middle and high schools (lower and upper secondary) is based on two main units: geological phenomena related to both external and internal Earth dynamics. Figure 6 illustrates the teachers' evaluation of these programs.

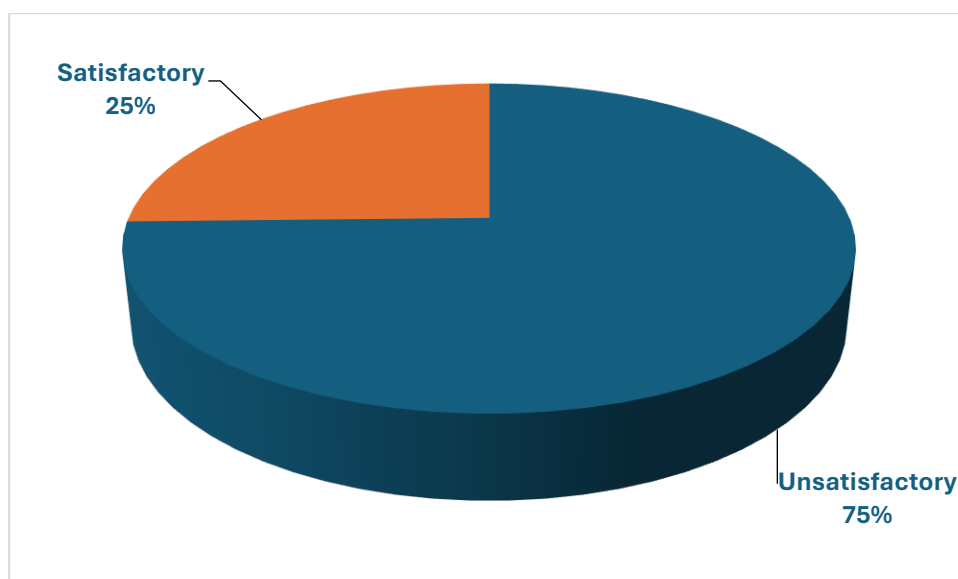


Figure 6. Teachers' Evaluation of Geological Programs Taught

75% of the respondents believe that the geology teaching program is not satisfactory, while 25% consider it to be satisfactory.

4.2.5. *The Highest Grades Obtained by Learners*

Figure 7 indicates the highest grades obtained by learners, according to the teachers surveyed.

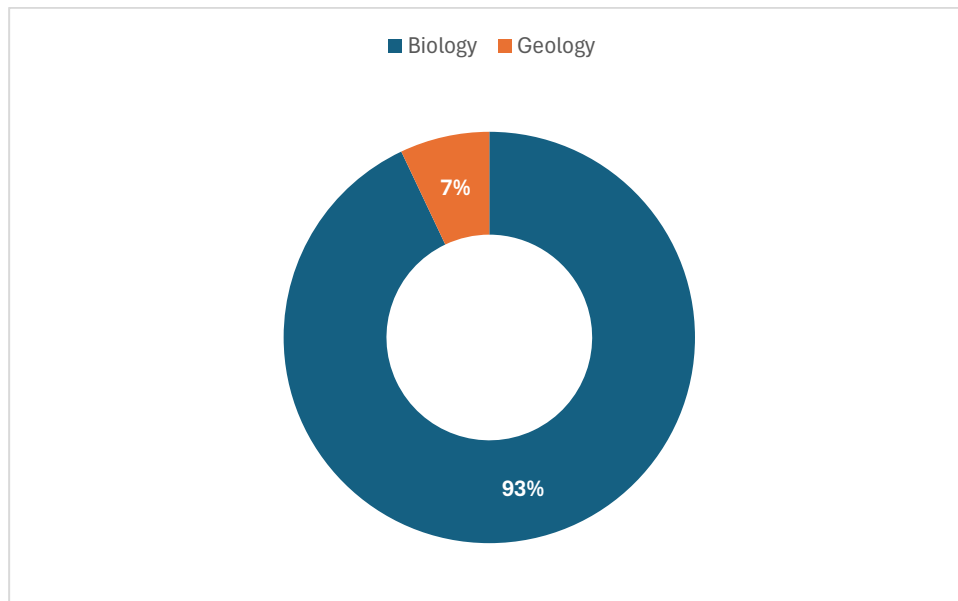


Figure 7. Percentage of Learners with the Highest Grades in Biology/Geology

Almost all the teachers surveyed (132), or 93%, state that their students achieve the highest grades in biology compared to geology (only 10 teachers). This clearly indicates that there is a real problem in learning this discipline. This may be explained by the difficulty in teaching certain geological concepts, as previously mentioned.

4.2.6. *How Teachers Perceive Geology Lessons*

As shown in Figure 8, teachers report that geology lessons are boring (56.3%), 36.6% find them interesting, and only 7% consider them motivating.

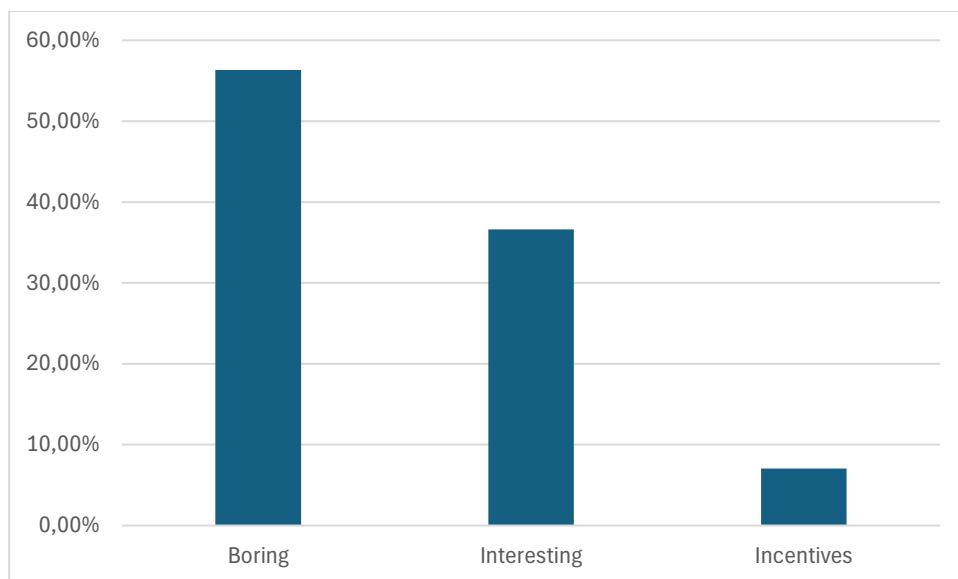


Figure 8. Teachers' Evaluation of Geology Lessons

4.2.7. Learners' Engagement During Geology Lessons

Figure 9 below provides an overview of learners' activity during geology lessons.

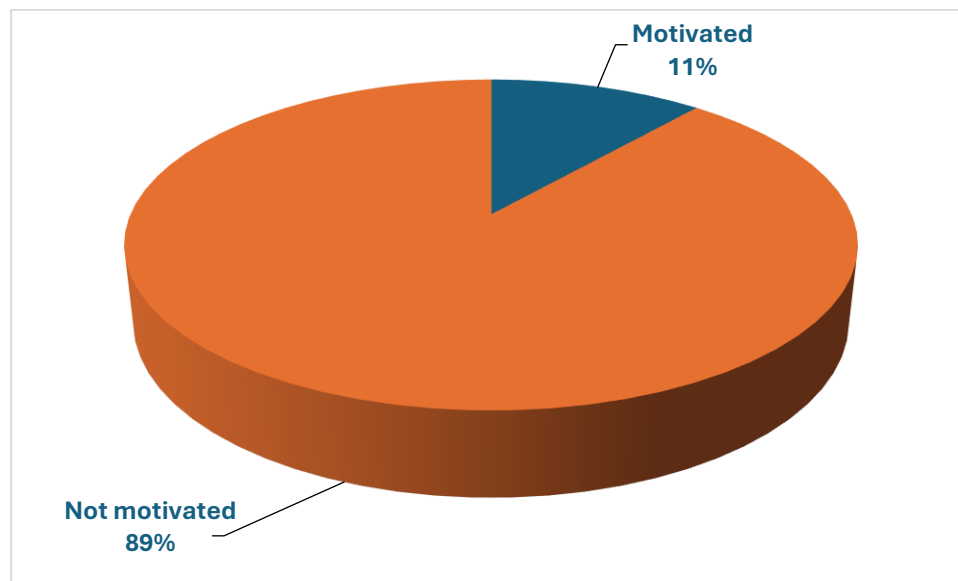


Figure 9. Learners' Activity in Geology Classes

As indicated in Figure 9, 89% of the teachers surveyed believe that learners are poorly motivated during geology lessons, while 11% state the opposite. Following these observations, we asked the teachers about the reasons why learners are poorly engaged in these lessons.

4.2.8. Reasons Preventing Learners from Being Motivated to Study Geology

Teachers stated several reasons that hinder learners' ability to learn geology. These reasons are listed in Figure 10 below.

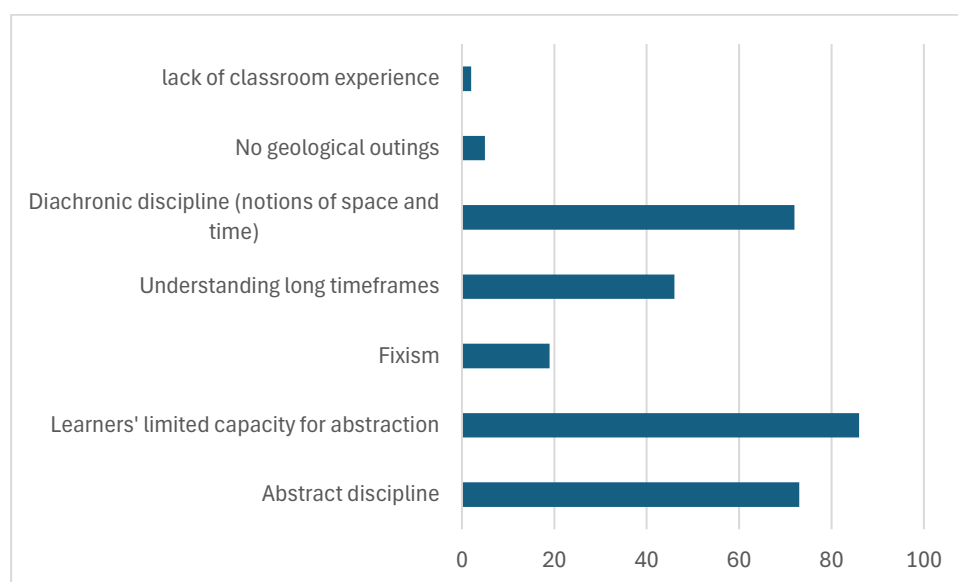


Figure 10. Reasons Preventing Learners from Being Motivated to Study and Learn Geology

Most teachers (51.4%) believe that discipline is abstract, requiring a high capacity for abstraction, while 60.6% state that their learners have a limited capacity for abstraction. Furthermore, the discipline is diachronic (50.7%), relying on notions of time and space, which makes it difficult for learners to understand geological timeframes (32.4%). All these reasons, along with many others, hinder learners from effectively engaging in geology lessons.

4.2.9. Time Allocated to Geology Lessons in the Secondary Life and Earth Sciences Curriculum

The time allocated to teaching the Life and Earth Sciences curriculum is determined by the pedagogical guidelines for Life and Earth Sciences. Is this time sufficient for implementing the program? The answer is presented in Document 11.

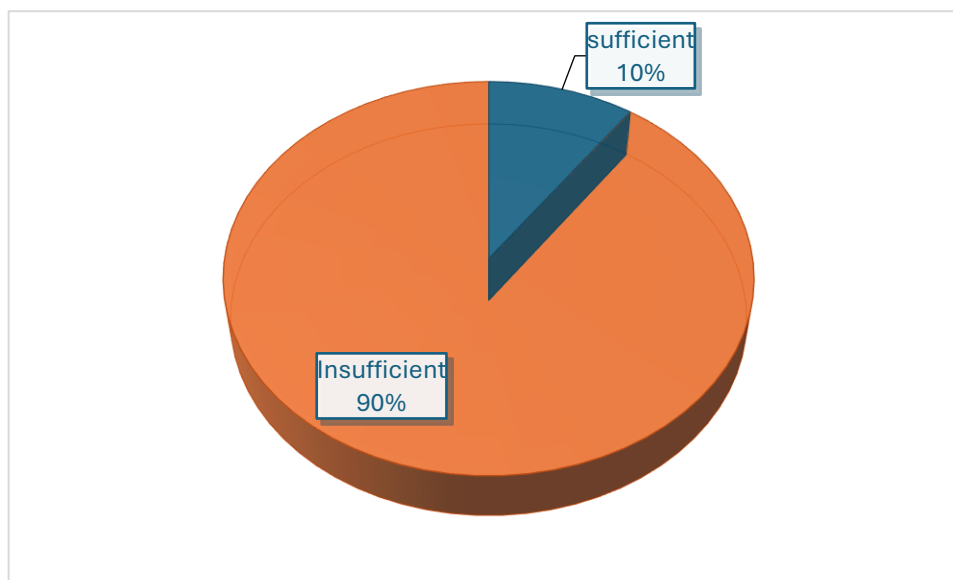


Figure 11. Time Allocation for Geology Lessons

The majority of respondents (90%) state that the time allocated to geology lessons is insufficient to teach and, therefore, to properly understand geological concepts. The results of this question reveal that almost all the teachers surveyed confirm that the time dedicated to geology lessons is not aligned with the content being taught, making it insufficient for the implementation of the geology program. This creates difficulties for both teachers and their learners, who face obstacles in mastering this discipline.

4.2.10. Implementation of Practical Work

Practical work is one of the most important components of teaching and learning geology. We asked teachers about the reality of this practice, and the results are presented in Figure 12.

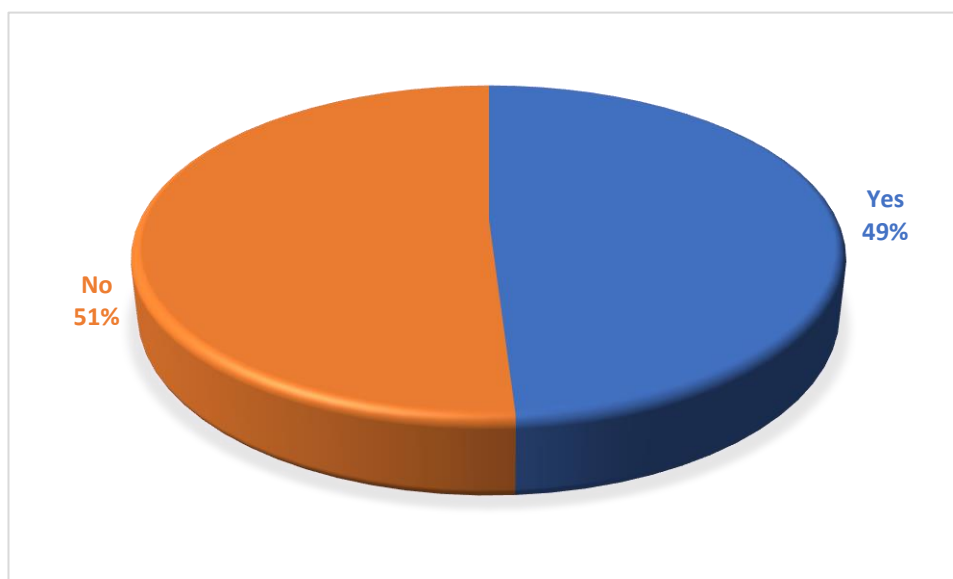


Figure 12. Percentage of Teachers Engaging in Practical Work

48.6% of respondents use practical work in teaching geology, while 51.4% do not. According to the respondents, the reasons for not implementing it include a lack of equipment, overcrowded classes, insufficient time, and the constraints of an overloaded program.

4.2.11. Organization of Geological Field Trips

Geological field trips are essential for bridging the gap between theory and practice, as well as for developing learners' practical skills in understanding geological phenomena. Nevertheless, such trips are not feasible. Figure 13 presents the percentage of teachers who organize them.

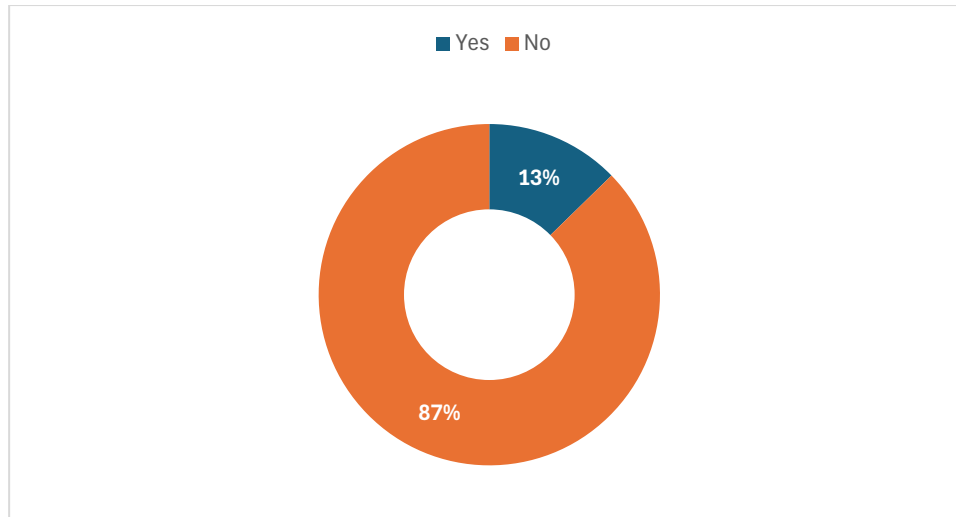


Figure 13. Percentage of Teachers Who Organize Geological Field Trips

Among the 142 teachers surveyed, 124 state that they do not organize field trips. The main reasons are generally related to a lack of resources, logistical issues (transportation, approval from the administration and parents, etc.), safety concerns, overcrowded classes, insufficient time to combine theory with practice, and various administrative obstacles.

4.2.12. Use of Digital Tools and Technologies in Geology Class

ICT (Information and Communication Technologies for Education) has a significant impact on improving academic performance and can help increase learners' success rates by enabling them to assimilate studied phenomena, especially when practical work or geological field trips are not feasible. For these reasons, we asked teachers about the actual integration of these tools into their teaching and learning practices. The results are presented in Figure 14.

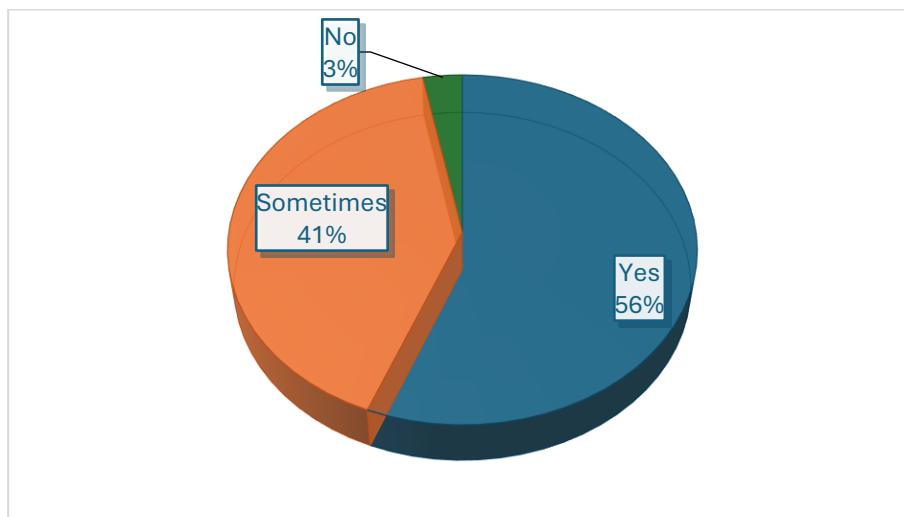


Figure 14. Percentage of Teachers Using ICT in Geology Classes

56% of the teachers surveyed regularly use digital tools during teaching and learning situations, 41% use them occasionally, and only 3% never use such tools. The respondents indicate that the most commonly used ICT tools include flash animations (58.8%), video projectors (81%), images (78.9%), interactive whiteboards (11.3%), modelling software (46.5%), and digital resources (47.9%).

4.2.13. Does the French Language Pose an Obstacle to Learning Geology?

After its independence, Arabic became Morocco's official language in all sectors, including education. However, since 2013, Morocco has reformed its education system by reinstating the teaching of scientific subjects in French despite learners' insufficient mastery of the language. This is why we posed the following question: Does the French language pose an obstacle to learning geology? The answer is presented in Figure 15.

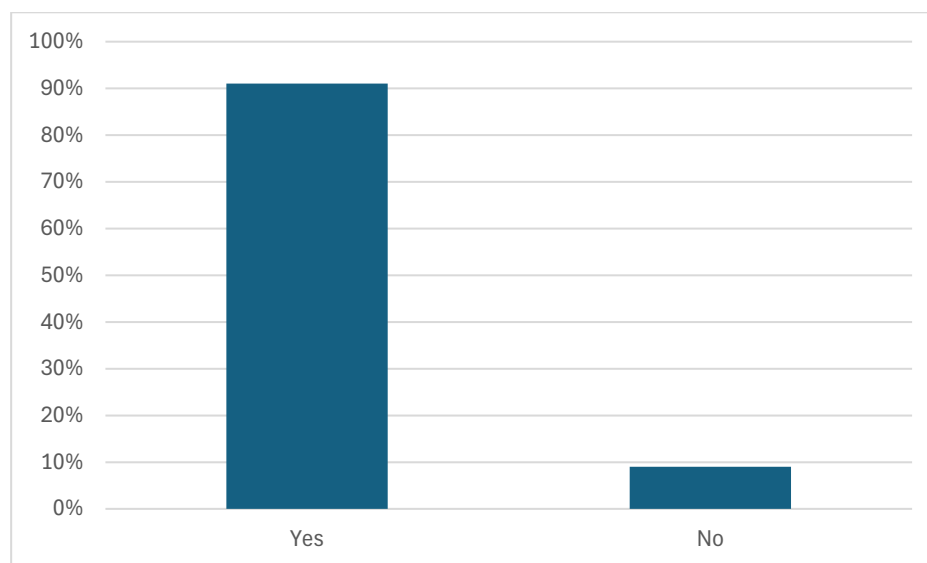


Figure 15. Percentage of Teachers Who identify French as an Obstacle to Understanding Geology

Figure 15 clearly shows that the majority of teachers surveyed (91%) believe that the French language constitutes a significant obstacle to learning this discipline, causing difficulties for learners in understanding technical terms and geological concepts. This linguistic barrier hampers their ability to assimilate concepts and follow lessons effectively, directly affecting their motivation to continue with geology lessons, as indicated in previous responses. Furthermore, this can impact their future academic orientation in higher education.

4.2.14. Proposed Solutions to Overcome Challenges in Teaching and Learning Geology in Secondary School

Table 3 highlights the solutions proposed by the surveyed teachers to overcome these difficulties, including:

Table 4. Proposed Solutions to Overcome Challenges in Secondary School Geology Teaching and Learning

Improving administrative and educational conditions to facilitate field trips.
Providing necessary equipment for laboratories to conduct practical work.
Planning continuous professional development in geology for teachers.
Allocating more time to the teaching of geology to enhance learners' understanding of geological phenomena.

- Providing digital resources and adapted digital materials to facilitate the comprehension and acquisition of abstract geological concepts.
- Simplifying certain units of geology, such as external geology.
- Modifying the geology curriculum in terms of its content and allocated time.
- Reducing the number of learners in classrooms.
- Returning to the mother tongue or offering learners the option to choose the language of instruction.
- Implementing modelling to bring learners closer to abstract geological phenomena.
- Providing pedagogical materials.
- Integrating modern technologies, notably virtual reality and interactive applications, to make concepts more understandable.
- Adopting active pedagogical approaches, such as project-based learning, to foster learner engagement.
- Ensuring that geology is taught by geologists and biology is taught by biologists.
- Teaching geology as a distinct discipline.

4.3. Analysis of Chi-Square Test Results

To better understand the relationship between the variables collected from the questionnaire, we used SPSS to perform statistical analyses. Pearson's chi-square test was applied to analyze the relationships between variables. The results of this analysis are presented below.

4.3.1. Relationship Between the Difficulties Encountered in Teaching Geology and the Perception of Lesson

Table 5. Relationship Between Difficulties Encountered in Teaching and Learning Geology and Teachers' Perceptions of Geology Courses

Chi-square Tests			
	Value	DF	Asymptotic Significance (2-sided)
Pearson Chi-Square	9,154a	2	,010
Likelihood Ratio	8,991	2	,011
Linear-by-Linear Association	5,231	1	,022
N of Valid Cases	142		

The Pearson chi-square test ($\chi^2 = 9.154$, $df = 2$, $p = 0.010$) indicates a statistically significant relationship between the tested variables. Since the p-value is less than 0.05, we reject the hypothesis of independence. This means that there is a relationship between the studied variables.

These results indicate a dependence between the analyzed variables, suggesting that teachers perceive geology courses as boring due to the numerous difficulties encountered in teaching and learning this discipline.

4.3.2. Relationship Between Learners' Perception of Geology Class and Their Academic Performance.

Table 6. Relationship Between Difficulties Encountered in Teaching and Learning Geology and Teachers' Perceptions of Geology Courses

	Value	Asymptotic Significance (2-sided)	
Pearson Chi-Square	37,116a	1	,000
Continuity Correction	31,065	1	,000
Likelihood Ratio	22,059	1	,000
Fisher's Exact Test			
Linear-by-Linear Association	36,854	1	,000

The results in this table clearly show the presence of difficulties in learning geology for learners, which is reflected in their low grades and lack of motivation. It therefore seems essential to consider the solutions proposed by teachers to overcome these difficulties, namely the integration of ICT, the provision of equipment for practical workrooms, the organization of geological field trips, and the reconsideration of the teaching program.

4.3.3. Relationship Between the Evaluation of the Geology Program and the Perception of Geology Lessons

Table 7. Relationship Between the Perception of Geology Courses and the Geology Program

Tests du Khi-carré			
	Value	DF	Asymptotic significance (2-tailed)
Pearson Chi-square	6,159a	2	,046
Likelihood ratio	6,108	2	,047
Linear-by-Linear Association	4,303	1	,038
N of valid observations	142		

The results of the chi-square test confirm that the negative perception of geology lessons is closely linked to dissatisfaction with the geology program. This dependence highlights the urgent need to revise the program to better meet the expectations of both teachers and learners, to introduce more practical activities, and to adapt pedagogical methods with more interactive and diversified approaches in order to make learning more dynamic and effective.

5. Discussion

The analysis of the results allowed us to identify several obstacles teachers encountered in their teaching practices of Earth Sciences.

Indeed, 80.3% of the teachers surveyed reported facing difficulties in teaching geology. These difficulties are mainly related to geological concepts based on the notions of time and space. Geology, being a diachronic discipline, requires a deep understanding of these notions to explain the majority of geological processes. As a result, learners find it difficult to imagine these processes. The work conducted by Chamanti-Houari (2019) found similar results and emphasized that Moroccan high school students struggle to assimilate and apply the notions of time and space to explain the phenomenon of fossilization and to imagine its development on a geological timescale.

Regarding the geological program taught in secondary school, it represents a significant challenge for teachers. Indeed, 75% of them believe that this program is unsatisfactory and that geology courses are considered boring, leading them to prefer teaching biology (56.3%). This preference can be attributed to the lack of continuous professional development. In fact, only 7% of the teachers surveyed have undergone continuous training in geology, while the others have relied on initial training or self-learning. As a result, some teachers risk transmitting erroneous conceptions to learners (Chalak & El Hage, 2011). Similarly, a study by Maziane (2024) clearly shows that the lack of mastery of content and gaps in knowledge are among the causes of student failure (Maziane et al., 2024).

The teaching of a discipline is largely dependent on the prerequisites acquired by learners, which refer to the fundamental knowledge and skills they must master before engaging with new concepts. In this regard, 78.9% of teachers report that their students' prerequisites are insufficient, resulting in difficulties in understanding new concepts and assimilating more complex notions. This situation, as reported by 88.7% of the teachers surveyed, contributes to a lack of motivation towards geology. Furthermore, 93% of teachers indicate that their students achieve better grades in biology than in geology. Beyond the insufficient level of prerequisites, other factors, such as the abstract nature of the discipline and the limited capacity for abstraction among learners, also affect students' motivation.

and practical work are indispensable tools for teaching and understanding geology, as they link theory to practice and enhance the understanding of geological phenomena. However, these activities are not always feasible. In fact, 87.3% of teachers state that they do not organize geological field trips due to several factors:

- Administrative constraints (lack of logistical resources, liability in case of accidents, lack of institutional encouragement to organize field trips);
- Pedagogical and didactic difficulties (lack of training on the organization of geological field trips);
- Personal obstacles (high numbers of students in class, fear of accidents, heavy responsibility on the teacher).

These findings corroborate the work of Eddif (2020). Similarly, 51.4% of teachers do not carry out practical work in geology. According to them, the lack of equipment in laboratories, the high number of students per class, insufficient time, and constraints related to an overloaded curriculum are the main causes of this situation. Our results are consistent with those of Najoui and Alami (2017). In addition, Salamé emphasizes that the absence and inadequacy of equipment in laboratories hinder the implementation of practical work, which pushes teachers to favor purely theoretical teaching (Salamé, 1991). This approach, although contrary to official recommendations and pedagogical guidelines, remains dominant in the teaching of Earth Sciences in secondary education.

The lack of time is another major difficulty reported by teachers. Indeed, 90% of teachers state that the time allocated to the teaching of geology is insufficient to complete the program while integrating practical work and geological field trips. This finding aligns with the conclusions of the

study conducted by Chamani et al., which highlighted the impact of the limited time allocation on the suppression of certain practical sessions and field trips, which are essential for learning geology (Chamanti-Houari, 2019).

Digital tools play an important role in supplementing geological field trips and practical work. According to our survey, the majority of teachers use these tools in their pedagogical practices. Among the most commonly used resources are flash animations, digital resources, modelling, and images. Indeed, ICT has a positive impact on improving academic results and can promote the success of learners in geology at the lower secondary cycle (Smouni et al., 2024). Some studies also emphasize that ICT can improve students' concentration and motivation, especially in overcrowded classes (Karim et al., 2023).

Finally, another difficulty raised by the teachers surveyed concerns the language barrier. Language plays a fundamental role in the comprehension and acquisition of knowledge (Laajan et al., 2024). However, 90.8% of teachers state that the French language constitutes a major obstacle in learning geological concepts. This barrier prevents students from following lessons effectively, leading to a loss of concentration and motivation and thus contributing to academic failure. These results are consistent with those of Hamdani et al (2019). In the same vein, Haidar (2012) indicated that the low level of French is a major obstacle to academic success and socio-professional integration (Haidar, 2012).

6. Conclusion and suggestions

The results of this study clearly reveal the numerous obstacles hindering the teaching and learning of geology in Moroccan secondary education. These difficulties are mainly related to:

- The lack of continuous professional development for teachers.
- The insufficiency of didactic materials.
- The limited time allocated to geology.
- The absence of geological field trips and the non-implementation of practical work.
- The abstract and complex nature of geological concepts.
- The low level of mastery of the language of instruction.

To improve the teaching of geology, the teachers surveyed propose several solutions:

- Reviewing and adapting the curriculum according to the time allocated to each lesson.
- Reducing the number of learners per class.
- Facilitating the organization of geological field trips.
- Equipping institutions with digital resources and didactic tools.
- Strengthening learners' level of French.
- Implementing continuous professional development in geology.

It would be pertinent to encourage further research in this area, as it represents a challenge for both teachers and students. The integration of new pedagogical strategies, particularly the use of immersive technologies such as augmented reality and the Merge Cube, could also enhance the understanding and assimilation of geological concepts (El Mokhtari et al., 2024).

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