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The Field Skills' Development through Teaching Environmental Interactions in High School: Draa-Tafilalet Region, Morocco

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Abstract: The study apprehends the educational impacts of fieldwork in earth sciences teaching at high school. We assess its role in students' skills improvement, based on a trip to Ait Idir (Ait Sedrate) in southeastern Morocco. The adopted approach consists of comparing skills acquired by a group of 26 high school students before and after the fieldwork. The area was chosen based on its scientific relevance, mainly in terms of morphologic diversity and accessibility. The students were engaged in the fieldwork on 4 December 2021 after doing a classroom course on introductive geology, granulometry, and sands' morphoscopy. In the field, students were asked to observe and discuss chosen landforms and deposits that may facilitate their skills development. Several technic tools were used such as maps, satellite images, and other geotechnical and mechanical tools. The results show the important positive impact of the fieldwork in teaching earth sciences at high school. It offered observable elements that students enjoy describing and discussing. The students engage their critical thinking to assess and discuss the landscape structure, the geomorphic forms, and their genetic processes and perceive the importance of the scale concepts for example. The post-test confirms that 53% of the students gave the right answers to asked general questions on topography, deposits, landforms, contextualization, and human–nature interactions for example. A total of 75% of asked questions were correctly answered by students concerning the site location, its physical framework, and its sedimentologic impacts. The research results are important in terms of soft skills development, and regarding their scientific, didactic, and cognitive impacts.

Keywords: skills; fieldwork; life and earth sciences; high school; Draa-Tafilalet; Morocco

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1. Introduction

Achievement in skills development is emerging among priorities for training, coaching, and education reform in several countries [1–4]. Major mutations occur from traditional education, which is generally teacher centered, often passive, and theoretical, to modern education, which is more learner centered, interactive, and oriented to skills development. Various skills are targeted such as educational, technical, professional, communicational, interpersonal, civic, or even global skills in operational education systems [5–7]. They are central in competency building and students' creativity launching. They may be developed along training, short formation cycles, and intense innovation in pedagogy. The success of the new approaches in teaching is tributary to going back and forth from utopia to reality [8]. Several factors may impact the results as they depend on the student's age, the adopted learning system, and its objectives for example [9]. Developing fieldwork skills is considered among the fundamental objectives of education in several disciplines, mainly in the life and earth sciences.

Working outdoors for at least a short time is pedagogically instructive in education [10]. Its results are optimal and gradually increase when fieldwork is planned in successive stages [11]. Examples of acquiring practical competencies while performing fieldwork in geology were cited by Nicholas [12]. However, barriers to fieldwork may be prominent due to institutional, academic, or organizational factors [13].

These obstacles must be dealt with beforehand for the better scientific and pedagogical performance of the fieldwork. The pedagogy of "ground truths" and data collected from the field are useful in teaching and knowledge transfer.

In Morocco, despite official directives, teaching is considered mostly theoretical and deficient in practical approaches either in the laboratory or in the field. The Moroccan National Assessment Authority (INE) and the Superior Council for Education, Training and Scientific Research (CSEFRS) [14] are leading a National Learning Assessment Program (PNEA) since 2016. This program focuses on measuring the student's achievement and the internal efficiency of the educative system. The analytical results of the survey among students in recent years of primary and college secondary levels confirm that soft skills acquisition is still weak. A total of 47% of students assimilated less than 38% of the life and earth sciences program prescribed by the Ministry of National Education for the third year of college secondary school. Only 24% of interviewed students had acquired more than 55% of the program. The goals in terms of knowledge skills achievement are not attained. The soft skills achievement under the present-day education system is generally weak, as confirmed by previous studies [15,16]. El Hammoumi et al. [17] suggested pedagogical innovation using interactive graphic animations to reduce the gap and develop the soft skills of baccalaureate students in life and earth sciences. They conclude with the fact that animations in the classroom are useful in earth sciences' didactic tools. However, the realities of observation in the field may be also instructive as they offer better opportunities to describe, debate, explain, and develop students' skills. In this point of view, practical skills either in the laboratory or in the fieldwork may be framed by a large vision that integrates the links between factors and processes in a continuous interaction between nature and humans. Unfortunately, fewer studies focus on this approach. The fieldwork in teaching earth sciences is marginal in most educative systems.

The goals of this article are to:

- apprehend evidence of the practical skills developed from fieldwork teaching;
- test the students' degrees of acquisition of knowledge skills related to how it allows students to understand the sediments' dynamics in their local and regional contexts;
- test the students' degrees of acquisition of technological skills and communication in the fieldwork practice;
- discuss the virtues and lessons students learned as useful skills and tools for the future.

The main objective of the article is to assess the results students achieved after completing the fieldwork. The change in students' competencies before and after the fieldwork is assessed by observation and written questionaries and reports they were asked to prepare before and after the fieldwork. The main skills targeted are the students' scientific knowledge improvement referred to in [3,4]; their social competencies which are tested by observing the individual integration in the working groups and their development of social relations and ethics during the fieldwork [16]; the technical skills illustrated by students' use of observation techniques and analytic tools [9]; communication skills, which are defined in official reports [14–16] and are shown in this study by each student's capacity to dialog and express his opinions by oral and written texts. Targeted skills were measured using two tests (pre-test and post-test), comparing their situation before and after the fieldwork.

Several questions were addressed about what students learned from the fieldwork when they engage their background knowledge to develop capabilities and understand the interactive factors of landscape dynamics based on observed indicators in the fieldwork.

These indicators may be instructive as ground truths that may be discussed and interpreted by students.

Each component of the observed ecosystem in the field is significant in terms of knowing the past evolution and how it may influence landscapes' equilibrium.

When these goals are attained, we presage students' acquisition of practical skills due to their own experiences, enhancing their confidence and ability to understand the environmental context and its components' dynamics.

2. Theoretical Background, Context, and Methodology

2.1. Theoretical Background

Developing soft skills tend to be central in the education goals all over the world [1]. As discussed in the following paragraphs, they include knowledge and scientific assimilation, social skills and group integration, and technologic competencies and communication abilities, for example. The official syllabus defined for the life and earth sciences course in the Moroccan high school education system targets the achievement of these skills. They served as a theoretical framework for our data gathering and analysis in this study.

In several scientific areas, fieldwork offers pertinent opportunities to develop students' skills [18]. Acquiring skills is a process that comes with experience [19]. In his epistemology of teaching science improvement, Kang [20] underlined the necessary critical reflection on field experience to support the emerging teaching development and practices. Stoica et al. [21] argue about the benefits of students' research projects in education, as they enhanced their creativity most of all. In earth sciences teaching, the fieldwork enhances several students' capabilities as observation, comparison, explanation, testing, and processing of materials in their local and regional contexts. The different geologic, morphometric, hydrologic, and sedimentary characteristics observed and discussed in the fieldwork are factors of students' understanding and their critical thinking development.

The catchment's morphometric characteristics, when described and explained to students, are macro data that allow critical thinking where calculated and/or described parameters offer opportunities to perceive the contrasts, the similarities, and the complex cases. The fieldwork offers opportunities to link causes to results in the dynamics of different environments. Elements to explain erosion, transport, and sedimentation processes are generally observed, discussed, and explained. Doyle [22] focuses on teaching environmental hydrometallurgy using a foundational knowledge base including fieldwork to help students to think creatively with an open vision of other scientific fields. Ruiz-Gallardo Ruiz-et al. [23] noted the positive results in practical training approaches by the adoption of problem-based learning, cooperative learning, and student workload, including in fieldwork. Çaliskan [24] reported that fieldwork is widely regarded as an essential part of the undergraduate education in earth and environmental sciences. It motivates students and teachers as learning is often based on observed and effective things. It provides opportunities to experiment with the acting processes and influencing factors in nature dynamics. The problem-based field competition towards active learning in soil science was conformed very instructively [25]. The fieldwork is therefore basic in developing technic, cognitive, and scientific students' skills. Due to the increased costs of fieldwork in teaching, simulation techniques, computer teaching, and virtual reality approaches were suggested as alternatives to actual fieldwork and trips [26,27]. From an international perspective, Hirsch and Lloyd [28] highlight the importance of active and experimental fieldwork for students in earth sciences, mainly geomorphology teachers. They focus on the rationale of doing fieldwork and how to prepare it and realize its actions to attain planned objectives. In forest disciplines, Thornbush et al. [11] adopted an interactive pedagogy in training students on practical issues of forest exploitation using campus experiments and fieldwork. They argue that interactive teaching methods improve the student's level of knowledge and their skills and abilities. Biermann et al. [29] investigated the field experiences of student teachers for secondary schools and their self-rated teaching skills and confirm their impact in terms of cognitive ability and educational experiences prior to academic teacher education.

In Morocco, Bouabdelli [30] showed the main developments of Earth Science Education in the twentieth century focusing on the need to reform the Moroccan education system to meet the challenges of employment for geology graduates. He studied the barriers to environment teaching in the Moroccan high school and reported its barriers as related to didactic and educational matters, the insufficient training, the lack of involvement, motivation, and interest of students, the technical problems, and the lack of practical activities and field trips, for example. Touli et al. [31] focus on the benefits of experimental science in skills development and underline obstacles to effective learning as constraints of laboratory tools and products and the security norms in work for example. More recently, the Moroccan commission for the new model of development report is officially adopted in 2021 [32]. It focuses on human capital and the need for reforming the education system, its approaches, syllabus, and targeted skills. Developing students' soft skills, virtues, and students' experimental learning are recommended for the future.

2.2. Methodology

The methodological approach adopted in this study is presented at two different but complementary levels:

- The general framework which integrates the fieldwork as a part of a more general research model. It includes its three stages before (the diagnostic stage), during (the realization), and after the fieldwork (the evaluation of achievements).
- The procedural phase of the fieldwork.

The first level was oriented to the diagnostic investigation and preparation planned before the field work. It aimed to define a reference that may be useful for the comparative analysis between the initial situation of students' knowledge and appreciate students' precedent acquisitions in other skills (personal, social, technical, communication). After the fieldwork, we investigated the achievements and compared them to the initial results for change appreciation. A pre-test (Appendix A)and a post-test (Appendix B)were used before and after the fieldwork. They consist of questionaries distributed in the classroom before and after the fieldwork. The questions are carefully chosen to test students' assimilation of the concepts and techniques officially defined by the course syllabus.

- The second level consists of the procedural dimensions of the fieldwork. They were precisely described to inform on the fieldwork itself and how its different actions may contribute to achieve the study's goals.

2.2.1. The Study Area, Participants, and Research Design

Fieldwork was completed in the proximity of Aït Idir High School, located in the middle of Dades Valley at Ait Idir village, 10 km from the Dades Gorges in Tinghir Province (Figure 1).

Three distinctive stages were defined in this study to apprehend the teaching impacts in terms of skills before and after the fieldwork: several actions were realized during preparatory, executive, and evaluation stages. In the preparatory stage, the scientific, administrative, and logistic actions were assessed. A diagnostic analysis was systematically carried out before going to the field. It was based on a pre-test asking questions centered on the students' knowledge (in sedimentary deposits, landforms, and the geomorphic processes for example). Other diagnostic questions focused on testing technological and communication skills. The teaching fieldwork was planned for the first week of September 2021. The concerned 26 students of Ait Idir secondary school were informed and sensitized to related preliminary readings they have to complete and the terrain security needs. The executive stage includes fieldwork completed on 4 December 2021 under the supervision of the teacher of earth and life sciences, accompanied by the professor of sport. Sub-groups of three to four students (male and female) were organized in the field and were asked to work together, observe, discuss, suggest, and note their observations. The last stage includes laboratory analyses of samples' materials. Students were asked to operate sand sedimentology, grains microscopy, and other preliminary laboratory actions during the following two weeks. They were finally asked to elaborate their own expressive ideas and discuss observed indicators in a synthetic individual report and illustrative videos that show their acquisitions and developed skills. A questionnaire, including precedent activities and variables, was given to students to briefly describe what they learned from the fieldtrip (the post-test). We, therefore, collected information that allowed us to apprehend the acquired skills, compared to the results obtained in the pre-test, for the planning of the course stage.

Figure 1. The students operating fieldwork tools in sub-groups at Ait Idir Village.

2.2.2. Variables and Data Analysis

A group of twenty-six (26) students of scientific baccalaureate at the secondary school of Ait Idir (Ait Sedrate) were engaged in the fieldwork study to assess the improvement of their skills. The planned activities used selected qualitative variables that facilitate the apprehension of the skills acquisition (Table 1). A total of 468 variables were observed, and students' understanding and perceptions were apprehended. The four topics shown in Table 1 are inspired by the official course syllabus and pedagogical orientations, but guiding elements and questions corresponding to "research activities" are formulated by the teacher to ensure the goals' achievements for each topic.

Table 1. Guiding questions in context and students' activities.

Focus Topics	Guiding Elements and Questions (Professor)	18 Planned Activities Forstudents
Apprehension of the regional and local context. Structure, lithology, and petrography	Help students observe and identify the regional contexts (chains and orography) and the local elements of the environment (terraces, sediment beds, sequence, etc.). A reminder of rock types and cycles (igneous, sedimentary, and metamorphic rocks). Focus on time and scale indicators in geomorphic forms and sedimentation and discuss their significance. Show the lithologic and petrographic aspects students have to observe	- Discussion and use of fieldwork tools (maps, satellite images, optic and mechanical tools, etc.). - Discussion of the observed orographic, geologic, and tectonic events. - Identifying and listing observed layers. - Description of the components of each layer and its micro-components. - Observation of crystals, minerals, physical properties, composition, microforms, hardness, and organization. - Discussion of the possible explanations of identified aspects using the acquired scientific background.

Table 1. *Cont.*

Focus Topics	Guiding Elements and Questions (Professor)	18 Planned Activities Forstudents
Soil erosion and factors	Discuss the erosion–sedimentation factors in the context. Uplift erosion and landscape evolution. Explain the major types of erosion and their indicators. Change, chronology, and landscape evolution.	- Observing and description of erosion indicators. - Observing and description of sedimentation indicators. - Location of modern and ancient geomorphic forms using morphometric indicators. - Location of modern and ancient sedimentologic indicators. - Explaining observed elements. - Discussion of spatial links between upstream and downstream deposits.
The carbonate rocks dissolution.	Rocks' composition, dissolution factors, and dynamics.	- Observation of the dissolution microforms. - Observation location of carbonate residues (initial and moved). - Discussion of specificities in forms, colors, and sediment origins.
Human nature interactions in the landscape.	Explain the differences between natural and man-made factors of erosion and sedimentation.	- Detection of the nature and human interactions in the landscape. - Discussion of their mutual impacts. - Apprehension of the risk notions.

2.2.3. Tools to Enhance Skills Development

Several fieldwork tools were used to introduce the field and stimulate students' debate and questioning. Among these tools are topographic and geologic maps, satellite images, and geotechnical and mechanical tools. The geological conditions are locally contrasting, sometimes in the micro-scale catchment, and allow discussions of the geomorphic drivers and processes. The geologic map analysis is therefore instructive as a pre-basis for the field's main work. The geologic map used in our case is Carte Geologique du Maroc, 1993, Tineghir 1 100,000, catchments. It is compared with the geologic maps Carte Géologique du Maroc, Jbel Saghro-Dades 1 200,000 or Carte Geologique du Maroc Ouaouizarhte—Dades 1 200,000 scale, to offer opportunities for multiple scales data discussion and develop pertinent skills of reality observation and apprehension with maps of different scales (Figure 2).

To discuss spatial links, we choose cases that illustrate the interactions between the field and its uplands and ask what lessons students learned while reading landscapes, characterizing materials, and recognizing landforms. Such discussions were basic to apprehend the processes' dynamics and experimental procedures of sampling.

The skills development is targeted. The guiding questions in the field aim to enhance students' curiosity and their critical, synthetic thinking. It was recommended to each subgroup to internally exchange ideas and elaborate a collective answer to specific questions the teacher or other students addressed on what they observed in the field or documents.

The fieldwork approach faces specific challenges either in its preparation stages or in related operational acts because it needs instruments, transportation, and safety precautions, for example. Several techniques and tools were used during the fieldwork. The geologic hammer, a small bottle of 10% hydrochloric acid to test for the presence of calcium carbonate, the compass to define directions, and the geologic and topographic maps are elementary tools provided in the fieldwork (Figure 3).

Several Vernier calipers were given to students to measure rocks and gravel dimensions. The GPS and smart compasses or even imaging using Google Earth for example in smartphones were also useful techniques in the field.

The sampling stage is crucial as selected sites, the criteria, and the relevance of sampling were debated (Figure 4).

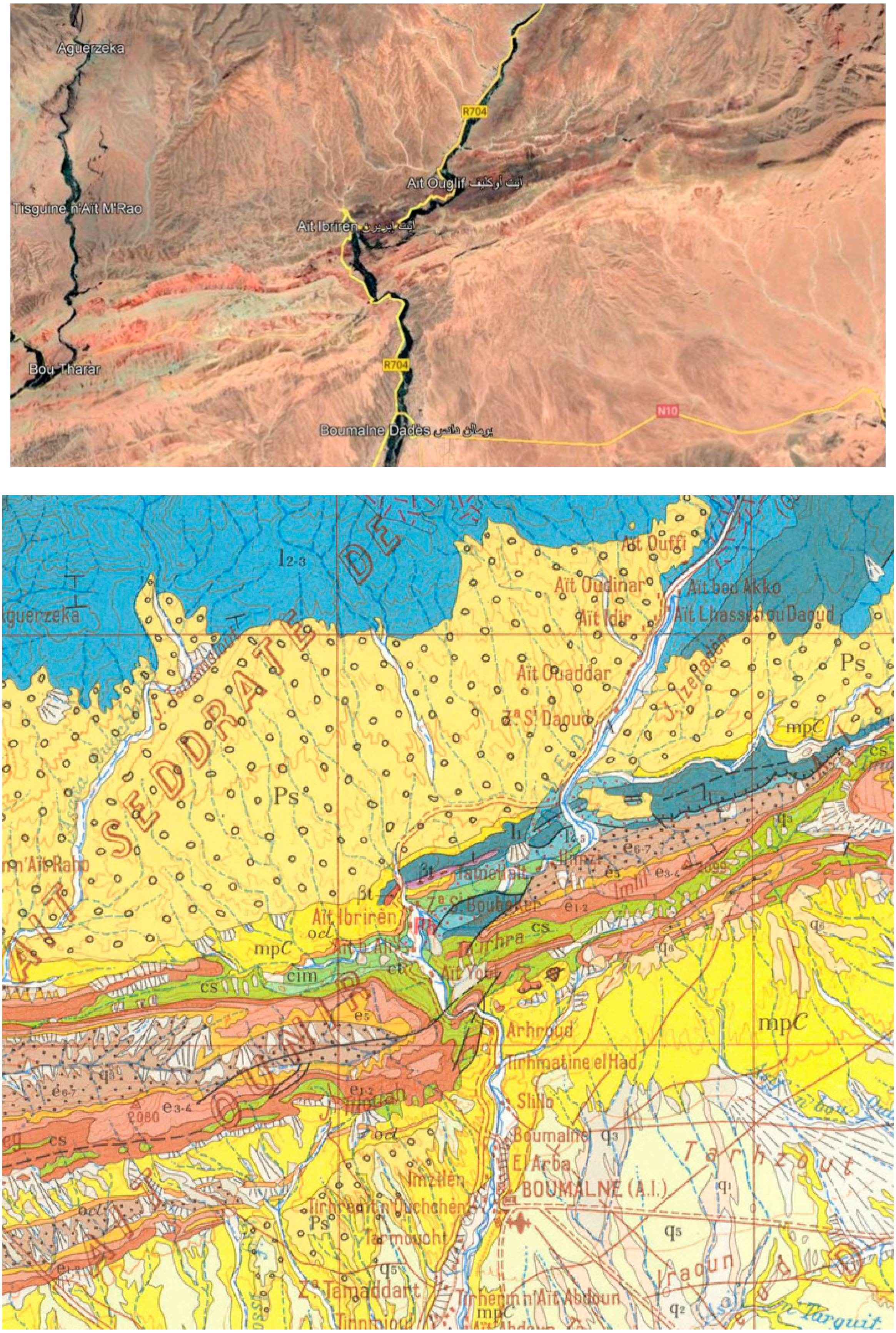

Figure 2. Maps and satellite images used as fieldwork tools (examples).

Figure 3. Elementary fieldwork tools used by students.

Figure 4. Students engaged in the sampling stage. (**left**) Refresh of the section to be sampled; (**right**) Discussion on the criteria to choose the sampling site.

3. Results

3.1. Fieldwork, a Space of Dialog, and Skills Development

Students have a growing interest and curiosity in the fieldwork. Since its beginning, they were seriously engaged in field activities while respecting norms (organization, dialog, mutual respect, exchange of documents, and tools). An intense ideas exchange occurred while answering the multiple questions underlined from observed facts. Since the first stage of the fieldwork, the students seized the opportunity to discuss the topographical, geological, and geomorphological elements observed in the local context. These elements were placed in a larger and extended framework. The Atlas Mountains, eroded valleys, and fluvial terraces were observed commonly on maps, satellite images, and fields. A total of 75% of asked questions were correctly answered by students concerning the site location and its physical framework. They used maps and observed components of local and regional environments to locate the fieldwork site using the coordinates and the geographic characteristics. Using the maps, the coordinates, and the altimeter, the students were able to assess and discuss the scale concept. A total of 65% of asked students declared that the dialog reinforces the positive, creative and thinking atmosphere within the sub-groups.

The choice of the sampling site helped students to ask the right questions about the user criteria and parameters. It offered the opportunity for a critical thinking exercise on the influencing factors of erosion and material sedimentation. These questions converge on how the sample can be representative and informative of the geomorphic processes and conditions. Before sampling, 55% of students underline the necessary precaution to avoid any misleading interpretation while operating the sampling action.

While refreshing each profile to sample, students observed vertical and lateral differences in sediments (the changing colors of materials, debris forms, and dimensions, sediments' bedforms, compacted materials and diagenesis, eroded blocks, etc.). The students were encouraged to recognize the particular versus the common aspects of the studied terraces and deposits. The physical and chemical explanations were developed while engaging the group in debates. The collective exchange of questions, arguments, and demonstrations shows the beneficial didactic values of the fieldwork in terms of boosting learning by encouraging students to ask their questions and provide arguments and demonstrations.

The hydrology, water flows, sediments' origins, and other indicators of erosion and sedimentation dynamics were observed, discussed, and environmentally interpreted by students at the local and regional scales.

3.2. Fieldwork Facilitates Contextualization in Teaching

The links of the local site to the far context within the whole chain of the Atlas Mountain showed evidence of the hierarchic approach that we need to adopt when dealing within the teaching environment.

The location of the site in its global context was done by simulating the main observed landscape components and discussing with students to understand their real meaning and see how we were represented on the topographic map, the satellite image of Google Earth, and the geologic map. The use of the compass, geographic coordinates, altimeter, and contour lines on the map, allowed students to better locate the site and make direct links between the maps and the observed realities. As a result, the fieldwork facilitates contextualization in teaching. We corroborate results obtained by Leit et al. [33] as students assessed the multiple dimensions of the context at different scales from their study, and how we can deal with contexts in a teaching environment.

3.3. Evidence of the Interdependence and Interactivity from Fieldwork

Students were sensitized to the concept of "the landscape as geosystem" that needs multiple scientific approaches and contributions to be specifically apprehended. However, at the high school level, presenting the general organization of the landscape in teaching earth sciences may contribute to recognizing the main structure of the landscape and its components: the landforms, geology and substrates, water flow and impacts, soils, and other ecological parameters, the human and anthropic aspects, etc.

Students were invited to discuss the factors affecting soil erosion and sediment budgets based on soil and sediments' thickness, geology (lithology, tectonics, and structure), vegetation, topography, water flow, and other factors.

The multiple suggested explanations to local earth surface dynamics legitimate precautious reasoning. Students discuss different viewpoints and tend to converge on the most convincing ideas.

The field-based data and observed truths help students in furthering their analysis, explanation, and interpretation of materials, landforms, and earth surface processes. The fieldwork offers opportunities for a multidimensional discussion with students to clarify the human–nature interactions based on the human impact evidence on nature (terraces, roads, etc.) and examples of natural factors of dynamics and risks. Indicators of interactions between the ecosystem's components and substrates (geology), hydrosphere, biosphere, or atmosphere were collectively detected, discussed, and interpreted to apprehend the system's equilibrium and its factors' relationships. As a result, we note that the student's discourse tends to reflect the multiple factors that evolved in deposits and landforms' genesis. The changing interactions between human factors and nature were also mentioned (building terraces, walls, managed infrastructures, etc.).

3.4. Applied Techniques and Development of Technical Skills

Students enjoy active learning from the field realities and individual observation, testing, and measuring using applied tools. A total of 75% of them said they were very satisfied to practice technical tools in the field during the trip. Most of them used digital technology provided by their smartphones to support the fieldwork (GPS, smart compasses, or even imaging using Google Earth, for example). Using these techniques is a preliminary but fundamentally sensitive action for the future possibilities of artificial intelligence techniques in earth sciences.

The introductive discussion of each technologic tool caught the attention of students who questioned its usefulness, the precision of the data it may produce, or the relevance of these data for environmental, temporal, or spatial interpretations.

All students had the opportunity to operate at least a measure using a chosen tool. They are aware of the technology use, its monitoring and control, and sensitivity to safety precautions. These skills were improved in the laboratory as sampled sand is treated by students using granulometric and microscopic techniques.

3.5. Apprehension of Latent and Evident Factors of Landscape Dynamics: The Karstic and Tectonic Effects

Students are encouraged to observe the geomorphic aspects of carbonate dissolution and deposition (karstification). Indicators of their impacts on landform genesis and evolution are discussed on a large and micro scale. The limestone and dolomitic layers are abundant, and the material dissolution and sedimentation traces are observed either on layers or on individual rocks. They are initially resistant but are progressively weakened by tectonics and karstification. The teaching environment in high school should consider this complexity [34]. In several cases, they are exposed to vertical fluvial incision, forming narrow and deeply incised canyons, including the Dades gorges, the stratification joints of these layers and their inclination are facilitating water infiltration and surficial water erosion (Figure 5).

Figure 5. Tectonic and karstic factors of hydro-geomorphology and sediment budgets.

The fieldwork offers several opportunities to observe the structural, tectonic, and geomorphic aspects mentioned in the classroom course. The tectonic events and the karstification are potential factors affecting landform dynamics. Traces of erosion and sediment types are discussed in the field as elements of a complex and dynamic landscape and offer pertinent ideas to explain observed realities. Their distinctive effects are considered and discussed with students to facilitate their assimilation of catchments' geomorphic dynamics and detail a more precise model of erosion and sediments transport in the area. After the fieldwork, more than 53% of asked students gave convincing scientific evidence of the landforms' genesis. The links between theory and field observations were therefore established by most students.

3.6. Environmental Risk from Sediments and Arable Soils Damaging

The multiple ravines sculpted on valley flanks offer pertinent elements to discuss the interactive processes integrating the lithologic and stratigraphic roles in weakening the cohesion of substrates and structures. The layers' inclination due to tectonic pressure in the past when exposed to episodic rain showers explains aggressive water flows and engenders active erosion on the summits and a rapid fans' formation by aggradation downstream. Students were asked to observe the dynamic evolution of the geomorphic landscape and how the extension of these fans is currently frightening the traditional oasis and farming downward. In the Dades valley, their deposits are progressively covering the vital agricultural area in the oasis (Figure 6).

Figure 6. The fan's extension in the oasis (the arrows show risky farming facing the fan).

The fieldwork offers opportunities for students to observe the continuum processes of alluvial fans forming including erosion, transport, and sedimentary processes. The dynamic factors of materials' mobility in alluvial fans resumed by Harvey et al. [35] were suggested for discussion. It facilitates students' assimilation of the changing context depending on the physiographic characteristics of catchments, the slope inclination gradient, the base level stability, and water flow transport. The continuum concept of erosion–sedimentation was therefore clarified. Students suggest that the total sediment budgets moved from the catchments may be evaluated more precisely downstream, at the exit of the catchment. The fans' negative impacts on the environment, economy, and human activities were observed downstream, where serious damages are caused by the extending fans to farms in the Dades valley (Figure 6).

The perceived overview of students' soft skills achievements during the fieldwork is prominent (Table 2).

Table 2. Achievement of targeted skills in fieldwork activities (pre- and post-tests).

Targeted Skills	Activities, Operational Training	Used Tools	Achievements (in %)
Knowledge skills	- Identifying and characterizing rocks (ICR). - Comparing geologic structures (GS), Site location (SL). - Topographic Maps reading (TMR). - Geologic maps reading GMR). - Present and past hydrologic and climatic indicators (HCI). - Environmental dynamics indicators (EDI). - Ecosystems equilibrium (EE). - Landforms evolution and processes (LEP). - Chronologic events and paleoenvironments (CEP). - Risks, hazards, and sustainability (RHS).	Observed components of local and regional environments. Maps, Satellite images. Using maps and coordinates, discussing the scale concept.	65
Technical skills	- Contours significance on maps. - Maps oriented (north, south, east, west). - The scale measure. - Geologic recognition (colors, symbols). - Sediments dimensions and types. - Sediment components. These skills are also developed in the laboratory as sampled sand and gravels are also assessed.	Field landforms and ecosystems, Maps (topographic and geologic), altimeter, compass, HCL, Oxygen water. Laboratory sedimentary and geochemistry techniques.	75
Personal development skills and social integration	- Interest in intrinsic motivation. - Innovative skills and creativity. - Interactivity and clever dialog in a group. - Initiatives taking. - Conceive interrelationships in ecosystems. - Data synthesizing. - Critical thinking development.	The group working pedagogy favors individual skills development and student-to-student interactions. Social integration and inclusion.	55
Communication skills	- Information seeking and transmitting. - Note taking in abbreviated writing.	Expressive photo taking, landscapes description, graphs conception, draft writing, reports.	52

4. Discussion

This study, devoted to the analysis of the fieldwork pedagogy and its impacts on developing students' skills leads to very significant results. The conceptualization and practice of field skills development in teaching life and earth sciences are relevant to answering several research questions. As underlined in the literature review, it is confirmed that a huge gap appears between planned objectives in the official documents and educational practices, concerning skills development in the Moroccan high school. The implementation of the reforms would be futile if the pedagogical and didactic approaches do not make it possible to achieve the set objectives. For the life and earth sciences, the course given in class can in no case be sufficient to achieve these objectives and must be supported by fieldwork and practical work in the laboratory. The study gives evidence of their positive impacts as discussed below.

4.1. Specialized Knowledge Skills Acquirement

Students were asked to observe and explain the sedimentary processes, their factors, and the risky expanding deposits on the agriculture farms. Downstream, they observe the dominant accumulation process. The gravel and sediments are sometimes suddenly cumulated after the flood. The profile is significant concerning the material's lithology, erosion, transport by water, and sedimentation environments.

The fieldwork allows student discussion of several hydroclimatic elements that explain the systems' complexity as observed and discussed based on real examples. Causality, spatial links, and evolution are often underlined by students when they observe phenomena such as the fans' morphometry, the sedimentary sequences, the buried soils exhibited under fan's deposits, the fans' relation to the valley's base level, fans as factors of risk, and fans paleohydrology and paleoclimate, for example [36].

The commonly accepted fact is that the role of the intensive heavy storms, even rare in arid zones, is important in erosion in these vulnerable areas where unpredictable rainfall events on bare, dry, and erodible surfaces could be efficient. The incision, erosion, and sediment transport that may occur as a threshold of soil resistance to flow shear stress is exceeded. However, different threshold values are expected where geology, soils, climate, and vegetation are different.

Such elements facilitate the introduction of primary concepts and simplified models of causation inference in Earth System Sciences [37].

While observing the earth and its materials, students observed specific structural landforms that must be explained by faulting tectonics, karstification, or other geological events. The carbonate rocks are dominant in the southern flanks of the High Atlas Mountain, where the tectonic effects and karstification were confirmed. The fieldwork gives opportunities to explain such aspects to students based on observed indicators.

The human–nature interactions were discussed while observing the fans' extension on behalf of farming lands. Aspects of severe damage to the agricultural land were observed. Peasants invest big efforts into removing the deposits to exhibit their buried arable soil.

Given the complexity of the processes responsible for these phenomena, the clarifications often provided take into account the level of the students and are sometimes reduced to the awareness stage. As a result, we underline the common benefic effects of the fieldwork as students have a better understanding of the local environment.

4.2. Technical Skills Development

Several techniques were applied during the fieldwork. Most students use these techniques to measure landform features and materials' characteristics. The topographic units represented on the maps, their length and affiliation in a larger context (the Moroccan mountain chains), the rocks' mass and robustness, and the sediments' thickness in horizontal layers are examples of these instructive operations. The technical skills of students are also developed from crossing maps and relief observation in selected segments of land to cease the topographic significance of flanks, abrupt scarps, cliffs, and other geomorphic landforms. The satellite images from Google Earth were helpful to elucidate these orographic features and their geodesic data (location, elevation, surface variation, etc.). They facilitate the apprehension of scale questions and map representations. Students learned the recognition of geographical orientations by using map coordinates and compass directions. The debate on sampling conditions was instructive and its adapted technics and tools were used and justified. Students are aware of the potential imprecision that can amplify the poor representativeness of the samples.

These active techniques allow students to acquire scientific concepts and better understand the local context and environment. Other technical skills are developed in the laboratory experiences when analyzing the sampled material. As confirmed by Peltier et al. [38], the success in obtaining targeted objectives and skills in earth science teaching and learning is therefore conditioned by bridging the coursework, the fieldwork, and the laboratory experiences.

4.3. Personal Skills Development and Social Integration

Fieldwork gives opportunities for students to observe, use field tools (maps, technical), understand physical and human-made landforms and deposits, analyze them, discuss their possible interpretations, compare local materials, express and argue ideas, and learn to listen to different opinions.

These skills are among the competencies that develop the student's self-efficiency and autonomy. In total, 75% of asked students after the fieldwork declared that the trip enhanced their desire for exploration and allowed them to presage multiple arguments to explain the observed phenomena. This assumption converges with results already published by Çaliskan [24], confirming that fieldwork contributes to reinforcing students' motivations, creativity, and social integration in groups.

The group discussed the converging arguments and operated mutual learning from others. Babu et al. [3] considered such learning as "Collaborative Learning" and in the field, it is "Learning by Doing". Both are useful for students' upskilling.

In high school, given the age and the still preliminary achievements of the students, it is neither reasonable nor logical to want to raise the level of skills of the students to the level of expertise, but it is feasible to work toward changing their competencies from novice level to advanced beginner. The fieldwork is a constructive approach to attain such objectives in terms of students' personal skills development.

Concerning the social integration, working in groups is generally instructive and inclusive as it provides opportunities to develop inclusive social and individual skills. A well-mastered group offers social conditions and mechanisms for learning and debate. The raising of interactivity between students at fieldwork reinforces the social reconciliation and individuals' integration into the group. As recognized by Burton [39], student's work products in the teaching and learning environment are very important. These products are outcomes from observed subjects that facilitate courses' implementation by teachers to meet students' needs and enhance field-based pedagogy.

Teaching life and earth sciences in the field is on the other side, a pertinent activity that focuses on observing lateral links between human and physical factors to build sustainable systems. Several sites where erosion and hydrologic risks are frightening roads, gardens, and even homes were observed and analyzed by students. Discussing the society's acute challenges in the fieldwork enhances students' social and ecological apprehension. Hazards explained by complex dynamics in case studies are inducing humans' roles. This is crucial for students' critical thinking on social and environmental links. It contributes to enlightening the concept of "social earth sciences" that makes sustainability and social impacts central to the scientific field [40]. The sustainability skills development is conditioned by broadening earth sciences teaching and research to human–environment interactions. The fieldworks offer practical topics that support the new pedagogic and didactic approaches favoring experimental and "teaching by doing" approaches, considered very useful in terms of skills development.

The fieldwork where "the learner is directly in touch with the realities being studied" is supporting the experiential theory of teaching [41,42] and evolutionary learning [43] that focuses on learning improvements by practice. The student's actions in systematic observation and analysis are progressively contributing to building their capabilities, critical understanding, and social integration. However, respect for quality norms in teaching and learning remains essential to obtaining credible results [44].

4.4. Communication Skills

The fieldwork offered multiple opportunities for intense communication processes among the students and between them and the teacher. The common types of communication were engaged as the professor shared the scientific information with students on the field and encouraged them to engage their oral and written description abilities. They are sensitive to hearing and understanding, and they express their opinions concerning different observed landforms, processes, and materials' characteristics and significance. The communication skills focus on verbal expression at field, graphs interpretation, and map analysis while observing realities. These skills were also developed when reporting. They were upgraded by creating situations for critical debate and action, when students were asked to share their understanding, argue, and try to convince others and create positive synergies. The introductive ingredients given by the teacher were inputs transformed during this communication process to facts.

These facts lead to students' appropriation of knowledge, understanding, and precise expression of learned concepts and paradigms. These skills reinforce their potential skills of engagement and will support their acting abilities in the future. The reporting process launched a week after the fieldwork was useful as grouped students were asked to produce detailed reports and videos illustrating discussed aspects. The results of the evaluative post-test were also sound.

5. Conclusions

Experiencing fieldwork in life and earth sciences teaching is very instructive for high school students. It improves their enduring knowledge and multiplies opportunities to learn new scientific paradigms and develop their soft skills. It offers opportunities for intellectual and physical endeavors of students, for open debate, self-reflection, self-learning, and active assessments.

To face the challenging didactic trends which focus on teaching life and earth sciences in the classroom (the traditional pedagogical approach) or using alternative virtual and modern approaches, the fieldwork remains fundamental due to its positive impacts. It should be integrated into the program within a hybrid approach where theory and field practices are strictly complementary and tied.

The results of this study show that 52 to 75% of the targeted skills in knowledge, individual skills, communication, or social integration, for example, were presumably achieved by students after their fieldwork exercise.

The fieldwork contributes to connecting students to their environment and enlightens questions about its past evolution, its present dynamic processes, genetic factors, their degrees of equilibrium, and their potential future perspectives.

Several lessons were learned from this study because the fieldwork offers multiple opportunities for students' improvement using observed realities and complementary data, mostly uneven in classroom. The teacher and student interactivity in the field is scientifically productive.

The students' improvements were confirmed multiple times in the post-test; for example, they showed greater scientific knowledge and understanding of their physical context. Several personal skills in observation, discussion, critical interpretation, social integration and communication were developed.

These outcomes are partly illustrated in the students' final reports and other prepared documents, where we appreciate the students' significant ability to use techniques and practice multiple communication modes (photos, videos, graphs, and writing reports).

Among the practical implications of the fieldwork, the study underlines its contribution to reinforce the students' ability to work together, the observation and debate skills, and the ability to interpret and understand the physical context as it is. Working in groups at field encourages the interactive collaborations, proximity, and social integration of students.

However, the fieldwork is complex, mainly in the planning phase, where a serious requirement for coordination with multiple actors (administration, logistic operators, students, partners) is evident. It is necessary to provide facilities and fulfil the trip's needs, plan and simulate work activities, and ensure conditions of their success.

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Appendix A. (Pre-Test)

This questionnaire targeted students of the first level in the Moroccan Experimental Science Baccalaureate, French Option. They were asked to answer questions on the Unit 1 (External geodynamics) specifically in the course "granulometry and morphoscopy of sands"

The questions presented in this test are intended to verify the level of acquisition of the skills programmed according to the didactic mode adopted (conventional mode, in class).

According to the official directives, the targeted skills of the granulometric and morphoscopic study of sediments in SVT, at level 1 of the baccalaureate) are:

Observation and knowledge (scientific and methodological skills).
Organization: classification and assembly (methodological competence).
Construction of concepts through abstraction and generalization (methodological competence).
Acquisition of a geological and environmental culture (cultural competence).
Oral and written expression (communication skills).
Good command of the use of laboratory and field tools (technological competence).
Analytical and interpretative skills.

After the class and following the conventional didactic approach, this test is distributed to students to assess the knowledge and skills acquired. Its duration is one hour. It gives an inventory of the skills and knowledge acquired. Its results will be considered as references to compare them with those which will be obtained after the adoption of the hybrid method, also integrating the laboratory and the field. This same questionnaire will then be distributed in perspective and completed by the same group of students after the field trip, the laboratory work and the hybrid course. to measure progress and results achieved.

Part 1: Test the level of acquisition of the lesson and the student's observation and knowledge skills (scientific and methodological skills) and also test the level of acquisition of a geological and environmental culture (cultural competence) (05 points)

Q1: Please rate your level of general understanding of the granulometry part of the course (tick the appropriate box):

a. weak
b. medium
c. well
d. very well.

Q2: Put in order the following steps of the sand sifting technique? (02pts) by numbering them according to the logical order of the realization from 1 to 6

☐ - All the sieves are shaken for 15 min, then the fractions retained in the different sieves are weighed

☐ - We weigh 100 g of the sand sample and put it on the upper sieve of a series of superimposed sieves, the mesh of which will decrease from top to bottom as follows: 2, 1, 0.5, 0.25, 0.125, 0.63 mm
☐ - The sand sample is left to air dry.
☐ - The material retained in each sieve is weighed.
☐ - The sand sample is treated with HCL acid and then with hydrogen peroxide.
☐ - The sand sample is washed to remove clays and silts

Q3: What is the purpose of treating the sample with HCL before starting the particle size study?

a. To remove limescale.
b. To remove organic matter.
c. To remove clays.

Q4: What is the purpose of treating the sample with hydrogen peroxide before starting the particle size study?

a. To remove clays.
b. To remove organic matter.
c. To remove limescale.

Part 2: Test the skills of producing analysis graphs (Technical and communication skills), (05pts).

A study of the grains of a sand sample gave the results shown in Table 1.

Q5: Based on Table 1, plot the cumulative curve of this sand, then graphically determine the quartiles (Q1, Q3).

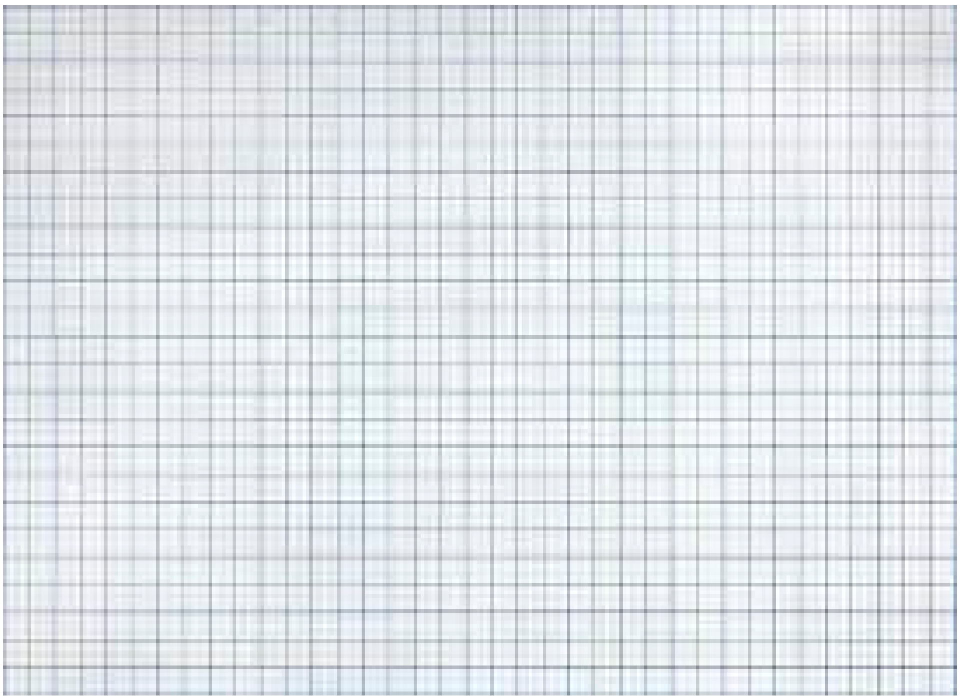

Figure A1. Graph paper for sand classification.

Q6: Calculate the Trasque S_0 index and deduce its ranking.

$$So = \sqrt{(Q3/Q1)}$$

Q7: Using these results and document 1 (Cumulative reference curves), determine the origin of this sand sample, its transport conditions and its sedimentation environment

a. beach sand
b. fluvial sand
c. Eolien sand

Table A1. Sand B.

Accumulated Sand B (%)	Diameter (mm)
1	2
10	1.6
30	1.25
48	1
65	0.8
88	0.63
98	0.5
100	0.4

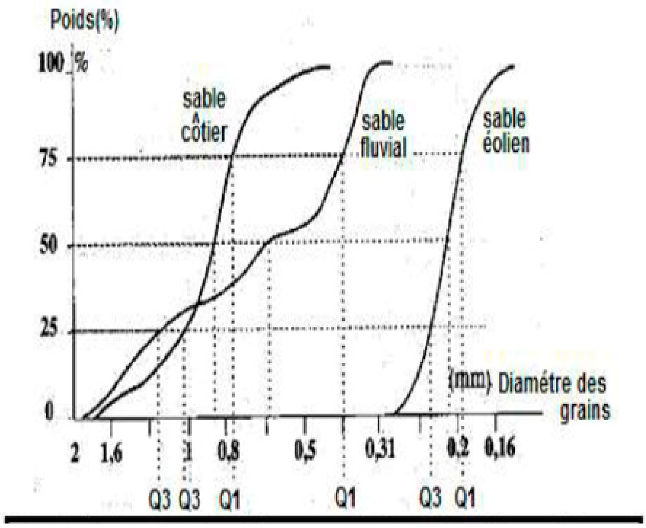

Figure A2. Cumulative grain size curve of some sediments.

Part 3: Test the skills of observation, analysis and interpretation of results based on images taken under the microscope (05pts). (Technical and analytical skills).

Q08: Analyze the document below

Figure A3. Quartz grains seen with a binocular magnifying glass.

Q09: Determine the category of quartz that is found in abundance in the sand of the document above

a. Glossy Dull (EL)?
b. Not worn (NU)?
c. Matte round (RM)?

Q10: What is the nature of the deposit environment for Unworn type quartz grains? (N.U).

a. The mouths, the coastal beaches
b. Coastal or desert dunes
c. Glacial deposits of origin proximal to the bedrock

Q11: What is the nature of the deposition context of the shiny Blunt type quartz grains? (E.L)

a. Glacial deposits of origin proximal to the bedrock
b. Coastal or desert dunes
c. The mouths, the coastal beaches

Q12: What is the nature of the deposition context of matt round type quartz grains? (R.M)

a. Coastal or desert dunes
b. The mouths, the coastal beaches
c. Glacial deposits of origin proximal to the bedrock

Part 4. Analysis, interpretation and environmental reconstructions (05pts)

The morphoscopic analysis of the sand grains of two samples made it possible to obtain the results following (Table A2):

Table A2. The morphoscopic analysis of the sand grains of two samples.

	Unused Grains	**Shiny Blunt Grains**	**Matt Round Grains**
Sample 1	22	8	70
Sample 2	10	70	20

Q13: Using the data in this table, specify the probable origin of sand sample 1.

a. short transport by water. The grains of this sand have undergone a short transport by water.
b. deposit at the mouths or in a beach.
c. long transport by water. The grains of this sand have undergone a long transport by water

Q14: Using the data in the table, specify the probable origin of the sand sample 2.

a. Short transport by water. The grains of this sand have undergone a short transport by water. Deposit at the mouths or in a beach
b. Long transport by the wind, deposit at the level of coastal or Saharan dunes.
c. Long transport by water. The grains of this sand have undergone a long transport by water. Deposit at the mouths or in a beach

Please answer using questions for sample 1

Q15: Give concrete illustrations of the types of streams and deposits generated in your area. Precisely locate the sites where these deposits can be observed (localization skills, knowledge of the context and establishment of spatial interactions between upstream and downstream).

Appendix B. Evaluation Questionnaire of the Post Test

(This questionnaire targeted students of the first level in the Moroccan Experimental Science Baccalaureate, French Option. They were asked to answer questions on the Unit 1 (External geodynamics) specifically in the course "granulometry and morphoscopy of sands".

The questions presented in this test are intended to verify the level of acquisition of the students and the skills programmed according to the didactic mode adopted (conventional mode, in class and hybrid mode integrating the course in class, the laboratory and the field work).

Reminder: According to the official directives of the Ministry of National Education, the targeted skills of the granulometric and morphoscopic study of sediments in Life and Earth Sciences, at level 1 of the baccalaureate (High School) are:

- Observation and knowledge (scientific and methodological skills).
- Organization: classification and data assembly (methodological competence).
- Concepts development through abstraction and generalization (methodological competence).
- Acquisition of a geological and environmental culture (cultural competence).
- Oral and written expression (communication skills).
- Use of laboratory and field tools (technological competences).
- Analytical and interpretive skills.

Part 1: Test the level of knowledge acquisition in the lesson (scientific and methodological skills) and also test the level of acquisition of a geological and environmental culture (cultural competences and skills).

Q1: Please rate your level of general understanding of the grain size part of the course after the geological field trip (tick the appropriate box):

☐ Weak
☐ Medium
☐ Satisfied
☐ Perfect

Q2: What are the different types of rocks you know? Whenever possible, give examples observed in the field.

Q3: What are the major orographic and morpho-structural units framing the situation of the sampling area in your field trip?

Q4: What are the major steps of the particle size analysis in the field and those you carried out in the laboratory after your return from the fieldwork?

Q5: what is the technical tool used during your field trip to observe the geological aspects

Part 2: Test the skills of drawing graphs (communication) and analysis

During the fieldwork, the students sampled two types of sand. the first group were taken from the bottom of the local ravine draining the nearby hills; the second type of samples of sand were taken from the lower terrace of the great valley of the Dades Wadi. This river brings back sediments coming from upstream over several tens of kilometers). The students were asked to study their grain size characteristics (. In the laboratory, the students weighed 100 g of very dry sand from each sample. Then, they sieved them in a column of sieves for 10 min. Finally, they recovered the sieve residues (the word residue designates the part of the grains retained in a sieve), they weighed the different fractions. The results obtained are shown in Tables A1 and A2. Please show the degree of classification of the sands according to the Trask S_0 index. and draw for both types of samples, a histogram and a frequency curve, then answer the following questions.

Q6: Analyze the frequency polygons then conclude the degree of homogeneity of each sample

Table A3. Classification degrees of sands.

Classification of Sand	S_0 $\sqrt{Q3/Q1}$
$S_0 \leq 0.5$	Ultra classified
$0.5 \leq S_0 < 1.23$	Very well classified
$1.23 \leq S_0 < 1.41$	Well classified
$1.41 \leq S_0 < 1.74$	Medium classement
$1.74 \leq S_0 < 2$	badly classified
$S_0 \geq 2$	Non classified

S_0 means the Trask 0 index; Q1 (corresponding to 75% of sands' diameter) and Q3 (corresponding to 25% of sands' diameter) are quartiles.

Q7: Plot the cumulative curves for the two samples on the same graph, then graphically determine the grain size characteristics: the quartiles.

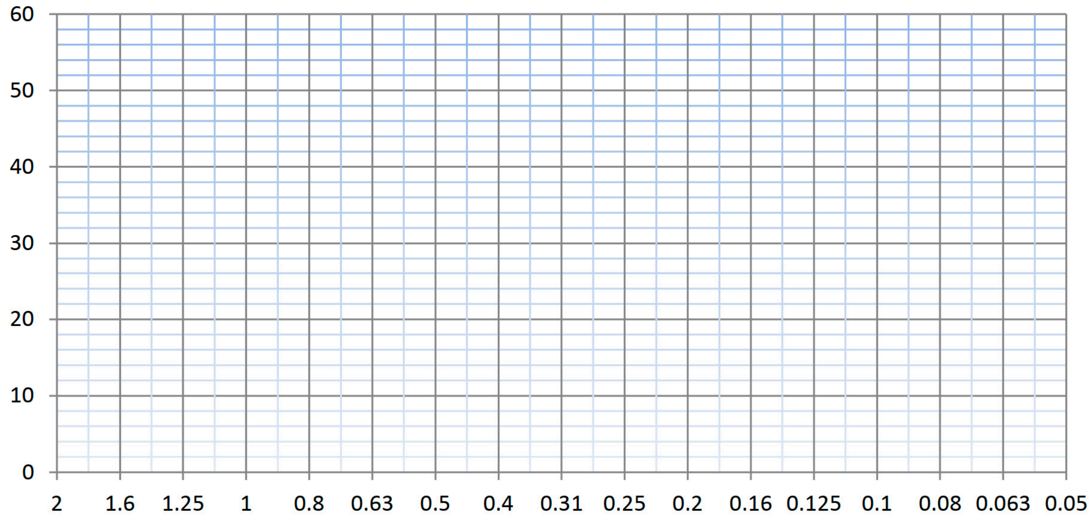

Figure A4. Graph paper for sand classification.

The abscissa axis is in %; the horizontal axis shows diameter of sieves holes in millimeters.

Q8: Calculate the trask index S_0 of each sand sample, deduce the classification of the two sand samples.

Q9: By justifying your answer, determine the probable origin of the two sand samples.

Table A4. Results of granulometric measures.

	Sample 1		Sample 2	
Diameter in mm	**Weight in %**	**Cumulative Weight in %**	**Weight in %**	**Cumulative Weight in %**
2	0	0	0	0
1.6	4	4	0	0
1.25	8.3	12.3	0	0
1	11.9	24.2	0	0
0.8	5	…	0	0
0.63	4.5	…	0	0
0.5	8	…	0	0
0.4	9.3	…	0.1	0.1
0.31	11.5	…	5.1	5.2
0.25	14	…	26.1	…
0.2	10	…	57.5	…
0.16	7	…	9.1	…
0.125	4,5	…	1.6	…
0.1	1.5	…	0.5	…
0.08	0.5	…	0	…
0.63	0	…	0	…

Part 3: Test the skills of observation, analysis and interpretation of results based on images taken under the microscope.

The morphoscopic observation of quartz grains shows the existence of forms A, B and C (Figure A5).

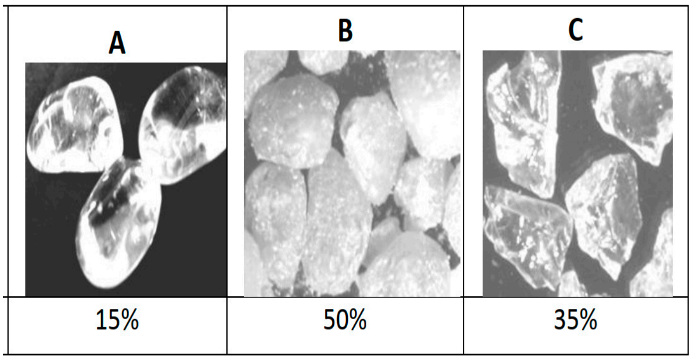

Figure A5. Different quartz grains to observe.

Q10: Based on your knowledge, explain the formation of grains A (Doc 2)

- Short transport by water. The grains of this sand have undergone a short transport by water. Deposit at the mouths or in a beach.
- Long transport by the wind, deposit at the level of coastal or Saharan dunes.
- Long transport by water. The grains of this sand have undergone a long transport by water. Deposit at the mouths or in a beach.

Q11: Based on the data in document 2, specify the transport dynamism experienced by the sand studied.

- a. long transport by the wind,
- b. long transport by water,
- c. short water transport.

Q12: Based on the analysis of the data acquired so far, the documents processed as well as your knowledge of the field, give a brief description of the evolution of the regional context (orography, geology, tectonics, erosion and sedimentation of deposits by example) throughout history and its characteristic paleoenvironments. Give clear arguments for each interpretation.

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