Adv. Geosci., 66, 1–9, 2025
https://doi.org/10.5194/adgeo-66-1-2025

Advances in Geosciences
Open Access
EGU

Teaching geology at the secondary college in Morocco: difficulties and remedies

Abdellatif Chakib[1,2] **and Mohammed Talbi**[1]

[1]Interdisciplinary Research Laboratory: Learning, Didactic, Evaluation, and Information Technology for Education "EIRADE-TIE", Fac. Sciences Ben M'Sik, Hassan II University of Casablanca (UH2C), Bd Idriss El Harti, P.O. Box 7955, Sidi Othmane, Casablanca, Morocco
[2]Life and Earth Science Dpt, Regional Center for Educational and Training Professions (RCETP Ben Mellel-khenifra), near the equestrian club, Beni Mellal, Morocco

Correspondence: Abdellatif Chakib (chakib_abd@hotmail.fr)

Received: 23 September 2023 – Revised: 29 November 2024 – Accepted: 11 December 2024 – Published: 24 February 2025

Abstract. This research aims, on the one hand, to carefully examine the teaching and learning activities of Earth Sciences in secondary schools, analyzing the adopted approach and the reorganization of program units, which serve as both the structural foundation and a guiding framework for this educational cycle. On the other hand, it is conducted within the scope of improving educational resources and incorporating Information and Communication Technologies (ICT). The objective is to propose solutions and recommendations for restructuring curricula, selecting relevant topics in existing programs, enhancing learning methods, increasing learner motivation, developing didactic materials, and fostering connections with the socio-professional environment.

We identified, at the end of this study, this teaching raises the question of its current place into curriculum and schoolbooks in terms of educational resources. A question concerning the relevance of this teaching's attractiveness, focusing on the objectives of each step in the teaching-learning process, the assets to be capitalized on, and the dysfunctions to overcome, while proposing alternatives and possible measures to enhance the effectiveness of learning. As a result, it may affect the motivation and interest of students in this discipline as recommended by the 2015–2030-Strategic Vision (CSEFRS, 2015).

1 Introduction

The teaching and learning of Life and Earth Sciences equip students with essential scientific knowledge to understand their physical environment. This process enhances their intellectual capacities, observational and analytical skills, imagination, creativity, synthesis, and critical thinking. It also raises awareness about contemporary issues concerning life, health, and the environment, encouraging a sense of responsibility and citizenship. As outlined in the Reference framework of Sciences of Life and Earth college cycle (MENFPESRS, 2009), Earth sciences represent a functionalist, technical, and experimental discipline. They involve observing phenomena at various organizational scales, conducting experiments, engaging in manipulations, and employing modeling to explore questions, test explanatory hypotheses, and develop critical thinking. This approach enables students to identify key concepts that explain the functioning of our planet.

The concern to improve this teaching is a priority objective for any country because science education occupies a prominent position as a lever for development (Hulin, 1992), which is why it holds a principal place among the scientific disciplines programmed in college, secondary education, and taught through the competency-based approach introduced with the Commission Spéciale Éducation Formation (1999) and the White Book (Livre Blanc, Fascicule no. 1 et Fascicules de 1 à 8, 2002). It should be stressed that in this system of science education, the teacher plays a vital role as they are the only ones capable of transforming teaching projects into effective and meaningful educational actions.

This process requires a review of the pedagogical quality of textbooks, focusing on the quantity and relevance of documents and texts, as well as the linear, massive, and hierarchical presentation of knowledge. Additionally, it involves providing teachers with operational guides to help them implement the various directives related to their pedagogical practice, in order to ensure that Geology instruction should enable students to deepen their methodological training, particularly by fostering their mastery of the experimental approach.

The contents of the Life and Earth Sciences (SVT) programs at the college level serve as the foundation for developing the skills targeted by the teaching of the subject. This content is divided into six units corresponding to six semesters, with an overall hourly allocation of 204 h, or 68 h per year. Each of the six units is accompanied by evaluation and support sessions, with an overall 34 h time allocation (Arrêté ministerial, No. 132, 2011). In this context, the teaching of Geology was the focus of our study, which targeted teaching-learning activities at the college level to assess the actual quantity and quality at different stages of the program. The study also aimed to analyze the adopted approach and the organization of the program units, which constitute the core axes of the discipline.

The analysis of this research will help to identify the problems faced by teaching Geology in college. The research method adopted focuses on the overall details: curricula, textbooks, content areas, learners' learning levels, and teaching and evaluation methods.

In this context, geology occupies a more or less marginalized place in the Life and Earth Sciences programs. It is taught at two levels of the cycle: external geological phenomena, allocated 34 h in the 1st year of college (semester 2), and internal geological phenomena, allocated 34 h in the 2nd year of college (semester 1). Geology is taught alongside biology as part of the Life and Earth Sciences (SVT) curriculum (MENFPESRS, 2009), comprising 33.33 % of the total subject matter.

2 Objectives, methodology, and research framework

The objectives of this work are to identify the teaching-learning difficulties facing high school students and teachers and to propose remediation solutions to improve the quality of this cycle. This cycle must meet the expectations of learners and ensure the adequacy of the education and training system with its socio-economic environment, following the reference framework of Life and Earth Sciences (MENFPESRS, 2007), the Ministerial Decree (Arrêté ministerial, No. 132, 2011), and the objectives outlined in the White Book (Livre Blanc, Fascicule no. 1 et Fascicules de 1 à 8, 2002).

Our methodology is centered on a comprehensive examination of the curriculum content within Earth Sciences education. This approach underscores the implementation of tangible and pragmatic laboratory activities aimed at cultivating vital skills in students, including acute observation, intellectual curiosity, critical thinking, enthusiasm for scientific and technological advancements, adherence to safety protocols, interpersonal respect, and environmental responsibility. To operationalize this approach, we have developed a tailored methodology for each of the three levels within the college cycle. This methodology takes into account predefined objectives, the sequential arrangement of program components, and the systematic development of competencies and attitudes throughout the college education process. This comprehensive strategy considers pedagogical nuances, material constraints, and the specificities inherent to this educational phase.

Given the importance of this study in the learning of Life and Earth Sciences in general and Earth Sciences in particular, and the impact it can have on teaching and learning in Moroccan colleges to improve their educational processes, we will present the work contexts from a complementary perspective.

2.1 Background and teacher training system

The importance of initial training at the Regional Centre for Education and Training Professions (RCETP) and continuing education is undeniable, as they enable teachers to develop the skills necessary to continually adapt to the demands of their profession and the discipline they teach. Similarly, this program offers future teachers a solid initial training focused on their professionalization and qualification, enabling them to embrace and explore recent educational innovations, adapt this training to the local context, and evolve by integrating the requirements of scientific disciplines, such as Earth Sciences and its objectives (MENFPESRS, 2007).

In this context, the architecture of the new training system at the RCETP (Ministère de l'Éducation nationale, 2012), where future SVT teachers are trained for secondary schools, is based on three fundamental principles: the competency approach with a modular architecture; alternation based on activities and professional situations that reinforce professionalization; and the reflexive and dynamic paradigm of practical/theory/practical logic. Consequently, the framework of pedagogical guidelines sets out four core skills to develop: learning planning, learning management, learning evaluation, research methodology, and project management. These skills are cultivated through three types of modules: main modules, comprising resources in educational sciences and didactic disciplines; support modules, aimed at strengthening the mastery of professional skills.

Because the teaching of Life and Earth Sciences mainly targets pedagogical methods centered on the learner by helping them to organize their learning, appropriate their knowledge, become familiar with diverse situations, and explore various sources of information, training in this field is cru-

cial. This training should involve designing initial training programs that go beyond the accumulation of knowledge, focusing instead on analyzing the internal coherence of the subject, its epistemology, and its didactics to develop the professional competencies of future teachers.

2.2 Technology and digital context

Teaching and learning geology at the secondary school level is a scientific process that begins with experimentation, enabling students to acquire theoretical and practical knowledge in various fields. This foundation, which is rooted in primary education, extends into the upper secondary cycle, where the effective use of information and communication technology (ICT) by teachers enhances the teaching and learning of geology. Over the past two decades, the Ministry of National Education has promoted an active, environmentally conscious, and digitally oriented approach to education (CNEF National Charter of Education and Training, Articles 9, 10, 119, and 121), encouraging teachers to integrate technological tools into their daily practices.

In this context, the Ministry of National Education actively contributes to the ICT sector, citing significant references such as the presentation of the first document "E-Morocco Strategy: Proposals for Operational Implementation", the Rabat Declaration (Tour Mondial de la Société de l'Information TMSI, de Genève à Tunis, 2003; Stratégie e-Maroc, 2010; UNESCO, 2010; Mullis et al., 2020) from the French-language ministerial conference on the information society, the Spring European Council (Commission of the European Communities, 2005) highlighting knowledge and innovation as engines of sustainable growth, and the Francophonie Summit (Bucharest, 2006) emphasizing the importance of ICT development in the face of globalization. This strategic vision recognizes ICT as a vital catalyst for educational innovation and a vast reservoir of resources for the optimal development of education systems, addressing the challenges of the third millennium (Moroccan News Agency (MAP, 2006)).

Besides, Morocco adopted a new telecommunications law in 2004 (55-01) amending and supplementing Law 24-96. In the following year (2005), a program called "GENIE (2006–2016)" (Ministère de l'Éducation nationale, de l'Enseignement Supérieur,de 60 la Recherche scientifique et de la Formation des Cadres, 2006) to generalize these technologies with a view to their integration into the education and training system, and the development and launch of the 2010 e-Morocco National Cyber-Strategy, this national strategy is based on two primary strategic objectives strongly linked to the reduction of Morocco's digital divide and international positioning in the field of ICT.

In the same vein, the program "Morocco Numeric 2013" was launched in 2009 to foster the development of digital technology (Ministère de l'Industrie, du Commerce et des Nouvelles Technologies, 2009). For instance, during the presentation of this strategy, an agreement was signed to implement Injaz, an initiative that enabled 85 % of higher education students to acquire subsidized mobile phones and Internet access. Subsequently, the emergency program launched in 2009 (Programme d'urgence 2009–2012, 2009) sought to integrate ICT into education. Similarly, several official projects focused on teacher training and fostering a digital culture in schools, such as the e-taaloum Project (E-taaloum, 2013), the Collab platform (Collab, 2016), the Massar project (Massar, 2014), the IT Academy and Microsoft Office Specialist Certification (MOS, 2013), the ITQANE e-learning training program (2014), and the GENIE program (2006–2016) (Ministère de l'Éducation nationale, de l'Enseignement Supérieur,de 60 la Recherche scientifique et de la Formation des Cadres, 2006). Additionally, the Strategic Vision for Education (2015–2030; CSEFRS, 2015) emphasized the importance of developing an action plan to promote awareness of ICT's role in school reform and integrating these technologies to enhance learning quality.

Various researchers in education have highlighted the critical role of ICT in teaching practice, including Kemmis et al. (1977), Taylor (1980), and O'Shea and Self (1986). Furthermore, several studies have explored the factors influencing ICT integration in classrooms, emphasizing the need for effective teacher training to optimize the use of ICT in improving teaching quality and student learning outcomes. These include the works of Karsenti (2009), Grégoire et al. (1996), Cleary et al. (2008), Bibeau (2007), and Biaz et al. (2009).

Indeed, by referring to an authoritative ICT competency framework in the field, such as the UNESCO ICT Skills Repository for Teachers (Arrêté ministerial, No. 132, 2011), this repository is structured around three successive stages of teacher training, also referred to as approaches to teaching: Technological Literacy, Knowledge Deepening, and Knowledge Creation. Each country adopts a different approach depending on the level of ICT integration in its society, economy, and education system. With this in mind, the RCETP training program incorporated the ICT module, designed to help trainee teachers acquire and develop essential skills in the field of information and communication technologies. This 34 h ICT module focuses on fostering the informed and practical use of ICT in professional practice. It aims to equip secondary school teachers to provide quality education and to address, among other challenges, the specific difficulties associated with teaching Earth sciences at the secondary school level.

2.3 Moroccan educational context of pedagogical reforms

Many of its reforms have been made to an evolution of the science teaching (without specification of disciplines: physics, chemistry, biology, or geology), in the Moroccan education system. In a sense, Life and Earth Sciences are taught

by a professor specializing in biology and geology (Science Framework of Life and Earth college cycle, 2009), at a rate of 2 h per week, on 26 h for the 1st college and 28 h for the 2nd college and 30 h for the 3rd éme college class.

Indeed, it should be remembered, first of all, that the charter of education and training is aimed at the entire Moroccan education system from the fundamental to higher education. All sectors are also considered, namely: scientific, technical, and professional, etc. This reform project (CAPSUR, 2001) was prepared by the Special Education Training Commission (COSEF, 1999). Thus, it appeared that teachers and educators participated in the work of COSEF, but they were not the only ones, The Ulemas, representative of political parties, trade unionists also "worked", each according to his convictions, his beliefs, his political line. In line with these new principles and guidelines. To this end, the charter aims to train a virtuous citizen, a model of rectitude, moderation, and tolerance; open to science and knowledge, and endowed with the spirit of initiative, creativity, and enterprise and encourage science culture, and creation, particularly in the fields; having a strategic scope. Concerning the college cycle, the charter will have as objectives the initiation of the learners to the basic concepts and laws of the natural sciences, the physical sciences and the environment and learning basic technical, professional, artistic and sporting skills, linked to socio-economic activities adapted to the local and regional environment of the school.

In 2008, the Kingdom of Morocco set up an emergency program aimed at accelerating educational reform over four years, organized around the intervention spaces identified as a priority, the emergency program constitutes their operational version in 4 spaces and 27 projects. It proposes an action program aimed at meeting four objectives: to effectively-implement the obligation to attend school until the age of 15, stamping initiative and excellence in high school and university, to address the system's cross-cutting problems and to give themselves the means to succeed.

Aware of the importance of science and technology education in a country's socio-economic development, given its roles in training the citizens of tomorrow, to achieve the goals of human and sustainable development and to guarantee the right to education for all, the Higher Council for Training Education and Scientific Research (CSEFRS) has taken the initiative to develop a new strategic vision (2015–2030) for the reform of the education system. The essential foundations of this strategy are to build a new school whose main objectives are the engagement in the society of knowledge, science, creation, and innovation in the fields of science, technology, and knowledge with a particular interest in those relating to education, teaching, scientific and technical research.

This strategic Vision concerns the journey of a cohort from the first year of primary school to the end of secondary school, in the context of the evolution of Moroccan society from a knowledge-consumption society to a knowledge-consuming society through the progress of scientific and technical research and innovation, in the fields of basic and applied sciences, modern technologies, humanities, and social sciences, humanities, and the arts.

2.4 An international look at the Moroccan education system

The World Bank's report on education in Africa (Banque mondiale, 2017) almost sounded the failure of Morocco's education system. Four measurement indices (access, equity, quality, and effectiveness) have been considered by the World Bank in assessing education in countries in the Middle East region of North Africa (MENA). This report shows that Morocco ranks 8th, ahead of Algeria (9th place), Tunisia (10th place), the United Arab Emirates in first place in the region, and 17 in the world, followed by Qatar, Saudi Arabia, Bahrain, Kuwait, Oman, and Jordan.

Also, Morocco ranks 123 out of 188 countries studied in terms of human development. It thus maintains its position in the category of average countries, as indicated in the report of the United Nations Development Program (UNDP, 2016), on human development 2016: human development for all, this document shows that Morocco has advanced only three places compared to the year 2015.

The report by the High Commission for Planning (HCP, 2017), entitled: Poverty in Morocco: Challenges and Opportunities, stressed that poverty and vulnerability and social and territorial inequalities in Morocco remain strong, especially in rural areas, the share of young people neither in employment, education nor in training represents student rates.

By analyzing global academic performance, drawn in particular from the 2019 "Trends in International Mathematics and Science Study" (TIMSS) survey led by Mullis et al. (2020), it appears that the results are worrying for Moroccan students. Their scores are below the global average of 500 points, while the highest ranked countries exceed 600 points.

In this international view of our education system and it is more than worrying diagnosis on the quality of the latter has led Morocco to put in place a framework law 51-17 (Loi-cadre, No. 51-17, 2018) related to the development of public policies in the education system.

3 Teaching and learning geology in college high school

Through an analysis of the disparity in hourly volume between biology and geology teaching at the college level as described in the official document on the pedagogical directions of life and earth sciences (July 2007), it is noted that there are fewer sessions in geology than those in biology (Table 1). Thus, the first year of the college consists of a single unit of geology: the external geology phenomena of an hourly volume of 34 h, scheduled towards the end of the school year. In the 2nd year of college, geology is also rep-

resented by a single unit of geology under the name: the internal geology phenomena, scheduled at the beginning of the first semester with an hourly volume of 34 h.

While for the 3rd year of college, the units have two units (64 h) devoted to biology and no unit related to Earth sciences.

At the end of his studies at the college, the student must design a first global and coherent representation of the world in which he lives. It also allows itself to be introduced to the methods used by the geologist. Thus, analogy reasoning applies to the use of current phenomena to offer explanations to those of the past. This method of reconstruction, included in a scientific approach, appears new to students and calls for their ability to reason. In addition to the capabilities of scientific and technological culture, those of social and civic excellences can also be the object of learning: reasoning logically and rigorously is necessary in the context of such reconstructions, for example, to search for useful information, to analyze it, to sort it, to organize it and to synthesize it.

In this context, it is time to reissue the official instructions at each school level specifying the general guidelines relating to the content, the teaching methods, the evaluation procedures to be undertaken. Thanks to this simplified reading in terms of hourly volume, it is clear that the Moroccan secondary school curriculum in SVT promotes biology and marginalizes geology relatively by minimizing its hourly volume, which could be among the reasons that accentuate the difficulties of acquiring geological concepts.

4 Difficulties and obstacles of teaching geology

Despite the place and importance of geology as diachronic science, that is, related to phenomena that take place over time (Termier and Termier, 1979). It aims to define both the current functioning of the planet and its history. According to Gohau (1987) and Orange (2003), geology is both a historical science and a functionalist. Functionalist geology studies current geological, external phenomena (erosion, sedimentation, etc.), or internal (volcanoes, earthquakes), while historical geology reconstructs the Earth's past. This past is interpreted from the recordings of geological phenomena in the Earth's layers. Work and studies that have focused on teaching geology in college are in the minority compared to those involving teaching other experimental disciplines.

On the other hand, several studies have revealed challenges hindering the teaching of geology. For instance, research by Chakib et al. (2014), Jardioui et al. (2015), Benbrahim et al. (2016), Amiri et al. (2022), El Qryefy et al. (2023) and Saayoun et al. (2023) highlight students' difficulties in articulating empirical references and theoretical statements during fieldwork. En-Nhili et al. (2023) emphasized the challenge of understanding the time scales involved. Moreover, studies indicate that students struggle with comprehending long times and the speed of geological phenomena, as observed by Sayad et al. (2014).

Furthermore, learners encounter obstacles in assimilating geological concepts, primarily related to the discipline's temporal aspects. These difficulties include grasping time scales, developing diachronic reasoning, understanding the role of contingency in geological history (Gould, 1990), and comprehending dynamic phenomena with speeds making them inaccessible to direct observation. Additionally, students face challenges in spatial orientation, transitioning from two-dimensional to three-dimensional representations, altering the reference frame of observation (Yahia et al., 2020), and requires mastery of concepts from various scientific subjects to acquire their fundamental principles (Bassou et al., 2023).

Also, in college education, our study shows a kind of difficulty harming the act of learning, both for students and for teachers, among others: Means of training in geology that are made available to future geology teachers; insufficient geological content; hourly volume and complexity; lows prior knowledge of geology students; inadequacy or absence of field trips.

Thus, this research helps to highlight the obstacles faced by teachers and learners to reduce them and propose solutions to overcome them and to be able to implement teaching projects into practical and practical educational actions in this cycle.

5 Discussion and general synthesis

At the end of this study, we can affirm that the conducted study successfully achieves the initially outlined objectives, addressing challenges faced by learners and enhancing their educational experience within the college setting. The research provides comprehensive insights and numerous enhancements pertaining to the structure and implementation of teaching and learning in the context of college education. It effectively navigates various obstacles of epistemological, didactic, ideological, economic, curricular, and professional nature that may underlie resistance encountered in teaching this discipline. These include:

- To place the student at the center of science teaching/learning activities through the introduction of modeling activities and the consideration of the students' initial representations and representations following the strategic vision guidelines (2015–2030; CSEFRS, 2015).

- Establishing a continuing teacher training program for new strategies for teaching/learning geology in college, due to the change in the teacher training system, and changes in curricula.

- Units' description of college high school geology programs that constitute the structural and structuring axis

Table 1. Geology units taught in College high school (Arrêté ministerial, No. 132, 2011).

Semester	1st year of college	2nd-year of college	3rd-year of college
1st semester	The relationships between organisms and their interaction with the environment (34 h)	The internal geology phenomena (34 h)	The functional unit of the body (34 h)
2nd semester	The External geology phenomena (34 h)	The reproduction of organisms and the transmission of genetic characters of humans (34 h)	Educational health (34 h)

of this cycle, in terms of educational resources (ICT, audiovisual means, geological models, manipulations, and scientific modeling and experiments).

- To accompany the different learning's of various evaluation tools and objectives during the development of the programs, adapted themes, with a sufficient hourly volume.
- Choice of appropriate topics in the current programs in the sense of openness to the professional and civil environment.
- The text books must be accompanied by TP guides, equipped with well-developed technical sheets, with the learning objectives to be achieved, the necessary materials, the description of the TP, the time of completion, etc. and equip the designers with the necessary training in the design, editing, and evaluation of textbooks.
- The organization and integration of the geological field exits mentioned in the program.
- Reducing the number of students in classes, especially in scientific subjects (less than 30 students).
- Insert the ICT in the content taught and propose digital resources common to the teaching of Earth Sciences with the availability of scientific and educational databases to explore recent educational innovations and adapt this training to the local context.
- Equips libraries into documents needed to support programs and transform them into cultural and training spaces that allow the learner to fill in the gaps.

Moreover, a crucial aspect to consider involves adopting and developing a geology-specific manual for college high school classes. This entails selecting programs, themes, and geological units suitable for this cycle, tapping into the geological richness of the country, and allocating sufficient instructional time.

To achieve excellence in teaching and understanding geology in Moroccan college classes within the education system, urgent structural reforms are necessary to address challenges related to the quality of geology education and education in general. These challenges are emphasized by the strategic Vision (2015–2030) and the framework law (Loi-cadre, No. 51-17, 2018) related to the reform of the education, training, and scientific research system. Additionally, providing teachers with a computer center and a multimedia library in each school, tailored to the program taught, is imperative. The proposed article contributes to a thorough evaluation of current college secondary programs in the SVT discipline, specifically focusing on geological subjects, aiming to inform a comprehensive debate on the conditions of teaching and learning geology in Morocco and engage all educational stakeholders in the qualification process of geology teaching.

6 Conclusion

This investigation unveiled numerous constraints primarily associated with the curriculum, program structure, textbooks, laboratory equipment, pedagogical evaluation methods, the significance of initial and ongoing teacher training, the impact of the school environment, and discipline-specific challenges in teaching and learning Geology (such as space-time, scale barriers, complexity, and abstraction of geological concepts). Additionally, challenges related to overcrowded curricula in Science of Life and Earth (SVT) programs were identified, characterized by insufficient practice sessions in geology, the absence of a practical work guide with appropriate technical sheets, and a dearth of field trips.

Furthermore, this study, delving into the dynamics of teaching and learning Geology in colleges, exposed both strengths and weaknesses in the instructional process. Despite various merits, the identified weaknesses often pose substantial impediments to effective teaching and learning of the discipline.

To overcome these difficulties, and to mitigate their negative impact on the pedagogical activities, our study shows that specific measures and approaches should be taken. It requires a real rearrangement of the units of the Geology program in college, with a revision of the time allocated for the units, the adoption of the subject-specific manual, the improvement of methods of learning among learners and provide teachers with an operational guide that can help them to

implement the different instructions related to their pedagogical practice.

Concerning school equipment and space, an accurate diagnosis of the state of the laboratories should be made to equip them with necessary and adequate equipment and to resolve the problem of overcrowded classrooms promptly to ensure minimum conditions for improving the quality of learning. Particular attention must, therefore, be paid to the internal environment of the institution and the conditions for learning and evaluation.

Similarly, our research has shown that teachers and learners are aware of the importance of ICT as teaching aids in teaching/learning geology following innovations introduced by the new program, and that, finally, field walking is undoubtedly necessary to alleviate the obstacles associated with space-timescales among others.

Code and data availability. The datasets used and analyzed during this study are available in the repository of the Moroccan Ministry of National Education, titled "DC" (Moroccan Ministry of National Education, 2023), at https://www.men.gov.ma/Fr/Pages/DC.aspx (last access: 12 April 2023).

Author contributions. AC designed the study, analyzed the challenges of teaching geology in Moroccan secondary schools, and proposed solutions to improve curriculum structure, educational resources, and teacher training. He wrote the manuscript, including the discussion and conclusion sections, with input from all co-authors.

MT contributed to the recommendations on integrating ICT in geology education, analyzed teaching materials, reviewed curricula, and developed practical solutions, particularly for improving textbooks and field trips. He also provided critical revisions, especially in the methodology section.

Competing interests. The contact author has declared that neither of the authors has any competing interests.

Disclaimer. Publisher's note: Copernicus Publications remains neutral with regard to jurisdictional claims made in the text, published maps, institutional affiliations, or any other geographical representation in this paper. While Copernicus Publications makes every effort to include appropriate place names, the final responsibility lies with the authors.

Special issue statement. This article is part of the special issue "Criminal investigation and scientific methods applied to geological evidence: the contribution of forensic geology, botany, and entomology to the judicial system (EGU 2023 ITS4.2/BG1.12 session)". It is a result of the EGU General Assembly 2023, Vienna, Austria, 23–28 April 2023.

Acknowledgements. We would like to express our sincere gratitude to our colleagues from the Department of Life and Earth Sciences at the Regional Center for Educational and Training Professions for their invaluable assistance throughout this study. We also acknowledge the constructive feedback provided by the anonymous reviewers, which significantly improved the quality of this manuscript.

Review statement. This paper was edited by Jason H. Byrd and reviewed by Rouhi Abdelali and two anonymous referees.

References

Amiri, E. M., Zerhane, R., Aidoun, A., Janati Idrissi, R., and Madrane, M.: The adoption of the interdisciplinary approach in the teaching of life and earth sciences at university: a reality or a wish? Vol. 13.3, DigiBug Repository, https://digibug.ugr.es/handle/10481/79581 (last access: 13 May 2023), 2022.

Arrêté ministerial, No. 132: Liée au programme des Sciences de la Vie et la Terre secondaire collégial et qualifiant, Edition du Ministère de l'Éducation Nationale et Formation des Cadres et de Recherche Scientifique, Rabat, Royaume du Maroc, 2011.

Banque mondiale: Sur l'enseignement en Afrique Réduction de la pauvreté et Gestion économique. Washington, DC: World Bank, https://www.banquemondiale.org (last access: 21 June 2023), 2017.

Bassou, H. A., Essedaoui, A., and Selmaoui, S.: Teaching practice and learning difficulties in life and earth sciences in secondary schools in morocco, Journal of Southwest Jiaotong University, 58, 8–9, 2023.

Benbrahim, M., Khiri, F., Rassou, K. K., and Benchtoui, Z.: The reality of implementation of competencies approach in teaching Sciences of Life and Earth in Moroccan public school, International Journal of Innovation and Applied Studies, 16, 764–771, 2016.

Biaz, A., Bennamara, A., Khyati, A., and Talbi, M.: Integration of Information and Communication Technologies in Teaching Work: Current State and Perspectives, EpiNet: Electronic Journal of the EPI, 120, https://edutice.hal.science/edutice-00558936/file/a0912d.htm (last access: 15 January 2023), 2009.

Bibeau, R.: Les technologies de l'information et de la communication peuvent contribuer à améliorer les résultats scolaires des élèves, Revue de l'EPI, vol. 94, https://edutice.hal.science/file/index/docid/277825/filename/a0704b.htm (last access: 26 January 2023), 2007.

Chakib, A., Zahour, G., Ghalloudi, J., Touri, B., Radid, M., and Talbi, M.: Lexigloss" tutorial to address linguistic obstacles to learning geology major, Procedia-Social and Behavioral Sciences, 116, 1497–1500, 2014.

Cleary, C., Akkari, A., and Corti, D.: L'intégration des TIC dans l'enseignement secondaire, Formation et pratiques d'enseignement en questions, 7, 29–49, 2008.

Collab: Plateforme de formation à distance, Edition du Ministère de l'Éducation Nationale et Formation des Cadres et de Recherche Scientifique, http://collab.men.gov.ma/ (last access: 15 March 2023), 2016.

Commission of the European Communities: https://eurlex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2005:0229:FIN:FR:PDF (last access: 15 May 2023), 2005.

Commission Spéciale Éducation Formation (COSEF): Charte nationale d'éducation et de formation [National Charter for Education and Training], http://www.coimbragroup.eu/tempus/Docs/charte_fr.pdf (last access: 12 March 2023), 1999.

Conseil Supérieur pour l'Education, la Formation et la Recherche Scientifique (CSEFRS): Vision Stratégique de la Réforme 2015–2030: pour une école de l'équité, de la qualité et de la promotion, http://www.csefrs.ma/publications/vision-strategique-de-la-reforme/?lang=fr (last access: 12 June 2023), 2015.

El Qryefy, M., Agorram, B., Boubih, S., Selmaoui, S., and Bouali, R.: Assessment of Knowledge and Learning Difficulties in Metamorphism Among Future Teachers, Eur. J. Theor. Appl. Sci., 1, 230–235, 2023.

En-Nhili, L., Boubih, S., Amiri, M., and El Alaoui, M.: Diagnosis of learning difficulties of plate tectonics concepts among secondary school students using: Focus group, nominal group, and questionnaire, E3S Web of Conferences, EDP Sciences, p. 01061, 2023.

E-taaloum: Dispositif d'apprentissage en ligne, Edition du Ministère de l'Éducation Nationale et Formation des Cadres et de Recherche Scientifique, http://e-taaloum.men.gov.ma/ (last access: 17 February 2023), 2013.

Gohau, G. A.: A History of Geology. Rutgers University Press, ISBN 978-0813516660, 276 pp., https://www.rutgersuniversitypress.org/a-history-of-geology/9780813516660/ (last access: 13 May 2023), 1987.

Gould, S. J.: Aux racines du temps. Librairie générale française, ISBN 978-2253942474, 2253942472, 318 pp., https://www.google.co.ma/books/edition/Aux_racines_du_temps/mgcCGwAACAAJ?hl=fr (last access: 28 August 2023), 1990.

Grégoire, R., Bracewet, R., and Laferriere, T.: L'apport des nouvelles technologies de l'information et de la communication (NTIC) à l'apprentissage des élèves du primaire et du secondaire, Revue documentaire, RESCOL, http://www.erudit.org/culture/qf1076656/qf1098199/44210ac.pdf (last access: 14 March 2023), 1996.

HCP: La pauvreté au Maroc: défis et opportunités, Rapport National du Haut-Commissariat au Plan, https://www.hcp.ma/ (last access: 18 April 2023), 2017.

Hulin, N.: Une question lancinante : comment former à l'enseignement des sciences, in: Sciences à l'école: les raisons du malaise, sciences et vie, no. 180, 1992.

Jardioui, Y., Chihab, N., and Saadi, A.: Analysis of Students' Conceptions About the Phenomenon of Plate Tectonics, Procedia, 191, 270–274, 2015.

Karsenti, T.: Intégration pédagogique des TIC en Afrique: stratégies d'action et pistes de réflexion/Pedagogical use of ICT in Africa: teaching and reflecting strategies, https://idl-bnc-idrc.dspacedirect.org/server/api/core/bitstreams/8f290c29-3489-41a3-9b2e-c95f8bee8280/content (last access: 12 February 2023), 2009.

Kemmis, S., Atkins, R., and Wright, E.:How do Students Learn? Working Papers on ComputerAssisted Learning, Occasional Paper 5, Centre for Applied Research in Education, University of East Anglia, Norwich, 1977.

Livre Blanc, Fascicule no. 1 et Fascicules de 1 à 8: Commissions de révision des curricula marocains du primaire, secondaire préparatoire et qualificatoire, imprimerie du Ministère, Royaume du Maroc, Rabat, 2002 (in Arabic).

Loi-cadre, No. 51-17: Pour la réforme du système d'éducation, de formation et de recherche scientifique, Edition du Ministère de l'Éducation Nationale et Formation des Cadres et de Recherche Scientifique, Royaume du Maroc, Rabat, http://www.chambredesrepresentants.ma/sites/default/files/loi/projet_loi_51.17_0_0.pdf (last access: 11 October 2023), 2018.

MAP: Extrait du Texte intégral du message de SM le Roi Mohammed VI au XIe sommet de la francophonie, Bucarest, 28 septembre 2006, Roumanie, MAP, https://www.maroc.ma/en/royal-speeches (last access: 16 May 2023), 2006.

Massar: Système de gestion scolaire, Edition du Ministère de l'Éducation Nationale et Formation des Cadres et de Recherche Scientifique, http://massar-sgs.blogspot.com/2014/02/massar-sgs.html (last access: 19 August 2023), 2014.

Ministère de l'Industrie, du Commerce et des Nouvelles Technologies: Maroc Numeric 2013: Stratégie Nationale pour la Société de l'Information et de l'Économie Numérique, Royaume du Maroc, https://fr.diplomatie.ma/maroc-numeric-2013 (last access: 23 September 2023), 2009.

Ministère de l'Enseignement Supérieur, de la Formation des Cadres et de la Recherche Scientifique, Comité d'animation, de pilotage et de suivi de la reforme (CAPSUR): Contribution à l'élaboration de la reforme pédagogique de l'enseignement supérieur, document 1: organisation générale. Rabat, Royaume du Maroc, 2001.

Ministère de l'Éducation nationale: Curriculums de qualification des professeurs des trois cycles et guide des modules transversaux dans les CRMEF. Module des Technologies de l'Information et de la Communication (TIC), Unité Centrale de la Formation des Cadres, pp. 133-167. Rabat, Kingdom of Morocco, https://fr.scribd.com/document/729819974/Module-des-Technologies-de-l-Information-et-de-la-Communication-en-Education-MathMaroc-com (last access: 22 April 2023), 2012.

Ministère de l'Éducation nationale, de l'Enseignement Supérieur,de la Recherche scientifique et de la Formation des Cadres: Programme GENIE, http://www.men.gov.ma (last access: 10 July 2023), Rabat, Maroc, 2006.

Ministère de l'Education Nationale, de la Formation Professionnelle, de l'Enseignement Supérieur et de la Recherche Scientifique (MENFPESRS): Programmes et orientations pédagogiques générales relatives au cycle de l'enseignement secondaire qualifiant/Direction des Curricula, pp. 16-23-27-33- 39, Rabat, Maroc, July 2007.

Ministère de l'Éducation nationale, de l'Enseignement supérieur, de la Formation des cadres et de la Recherche scientifique (MENFPESRS): Programmes et orientations pédagogiques relatifs aux Sciences de la Vie et de la Terre (SVT) du secondaire collégial, Rabat, Direction des curriculums et de la vie scolaire, Maroc, 2009.

Ministère de l'Education Nationale, de la Formation Professionnelle, de l'Enseignement Supérieur et de la Recherche Scientifique (MENFPESRS): Programmes et orientations péda-

gogiques générales relatives au cycle de l'enseignement secondaire qualifiant, Direction des Curricula, 16-23-27-33- 39, Rabat, Maroc, July 2007.

Moroccan Ministry of National Education: Direction des curricula, Moroccan Ministry of National Education [data set], https://www.men.gov.ma/Fr/Pages/DC.aspx, last access: 12 April 2023.

MOS: Microsoft Office Specialist Certification, Edition du Ministère de l'Éducation Nationale et Formation des Cadres et de Recherche Scientifique, Rabat, Royaume du Maroc, http://www.portailtice.ma/fr/node/297 (last access: 22 November 2023), 2013.

Mullis, I. V. S., Martin, M. O., Foy, P., Kelly, D. L., and Fishbein, B.: TIMSS 2019 international results in mathematics and science, https://timssandpirls.bc.edu/timss2019/international-results (last access: 25 May 2023), 2020.

Orange, R. D.: Utilisations du temps et explications en sciences de la terre par les élèves de lycée: étude dans quelques problèmes géologiques, Diss. Nantes, 2003.

O'Shea, T. and Self, J.: Learning and teaching with computers: The artificial intelligence revolution. Prentice Hall Professional Technical Reference, ISBN 0135277620, https://dl.acm.org/doi/abs/10.5555/576781 (last access: 15 July 2023), 1986.

Programme d'urgence 2009–2012: Pour un nouveau souffle de la réforme de l'Éducation- Formation. Ministère de l'Éducation Nationale, de l'enseignement Supérieur, de la Formation des Cadres et de la Recherche Scientifique, Direction de l'Évaluation et de la Prospective, Royaume du Maroc, https://www.csefrs.ma/wp-content/uploads/2017/10/Point-de-vue-CSEPlandurgence.pdf (last access: 17 January 2023), 2009.

Saayoun, S., El Fathi, T., Abidi, O., Lamri, D., Al Ibrahmi, E. M., and Khyati, A.: Investigating moroccan teachers'perspectives on the alignment between life and earth science textbooks and curriculum, Journal of Southwest Jiaotong University, 58, 6–8, 2023.

Sayad, A., Boutkhil, L., Bouali, A., and El Meskin, F.: Obstacles d'enseignement des sciences de la terre au secondaire collégial et qualifiant au Maroc, Arabian Journal of Earth Sciences, 1, 1–15, 2014.

Stratégie e-Maroc: Réalisations, Orientations & Plans d'action, Réussir notre Société de l'Information et du Savoir: Livre de Référence, http://www.albacharia.ma/xmlui/bitstream/handle/123456789/30507/0248Strat%C3%A9gie%20e-Maroc%202010.pdf?sequence=1 (last access: 11 July 2022), 2010.

Taylor, R.: The Computer in School: Tutor, Tool, Tutee, New York: Teachers College Press, https://citejournal.org/volume-3/issue-2-03/seminal-articles/the-computer-in-school-tutor-tool-tutee (last access: 11 June 2023), 1980.

Termier, H. and Termier, G.: Histoire de la Terre, Revue géographique des Pyrénées et du Sud-Ouest, 50, 607–609, https://www.persee.fr/doc/rgpso_0035-3221_1979_num_50_4_3900_t1_0607_0000_1 (last access: 13 March 1979) 1979.

Tour Mondial de la Société de l'Information TMSI, de Genève à Tunis: Rappel des priorités et orientations définies par les instances de la Francophonie à Rabat (Maroc, 4–5 septembre 2003), 2003.

United Nations Development Programme (UNDP): Human Development Report 2016: Human Development for Everyone. New York: United Nations. Pages: 214, https://doi.org/10.22004/ag.econ.267637, https://econpapers.repec.org/paper/agsundpar/267637.htm (last access: 27 May 2023), 2016.

UNESCO: TIC UNESCO: Un référentiel de compétences pour les enseignants, http://unesdoc.unesco.org/images/0021/002169/216910f.pdf (last access: 19 May 2023), 2011.

Yahia, F. E. A., Alami, A., Selmaoui, S., Agorram, B., and Zaki, M.: The Place and Pedagogical Function of the Scientific Image in Morocca Life and Earth Sciences Textbooks, Brit. J. Educ., 8, 31–43, 2020.