IJEIR
International Journal of Educational Innovation and Research ISSN: 2810-0808
Volume 3, Number 1, 2024, pp. 50-61
DOI: https://doi.org/10.31949/ijeir.v3i1.7110

The Fossilization: What Initial Representations of Future Instructors?

Imane Chmanti-Houari[1]*, Mohammed Oudrhiri Hassani[2]
[1]Department of Educational Sciences, University Mohammed V, École Normal Supérieure (ENS), Laboratoire de Recherche en Sciences de l'Education, Sciences Humaines et Langues (SESHUL), Rabat, Morocco.
[2]Chemistry Department, University Sidi Mohammed Ben Abdllah, Faculté des sciences Dhar Al Mahraz., Laboratoire de Didactique et d'Innovation Pédagogique et Curriculaire (LADIPEC), Fès, Morocco.
*Corresponding Author: imane.chmanti-houari@ens.um5.ac.ma

ABSTRACT
Previous research has shown the influence of teachers' initial representations on their assimilation and transmission of scientific concepts to students. In this regard, the aim of the present study is to identify the difficulties faced by future Life and Earth Sciences (LES) teachers in assimilating the concept of fossilization, particularly those related to the mobilization of time and space. Using a mixed-methods approach, we designed a questionnaire that was administered to 30 trainee teachers at the RCJET in Fez, selected by simple random sampling. The data was processed using statistical data processing software (answers to closed questions) and the content analysis method (answers to open and semi-open questions). Various types of obstacles to the mobilization of time and space were detected. The inability to apply the principle of actualism. The conception of the evolution of fossilization processes outside the space-time framework. The inability to conceive fossilization as a contingent and exceptional phenomenon, requiring a long time, difficult to observe with the naked eye, difficult to experiment due to their taking place in different palaeogeographic sites. They also raised the need for special training in geology. As a result, we are proposing an increase in the number of hours spent on practical work, the scheduling of geological field trips, the development of new methods and approaches, and the integration of Information and Communication Technologies (ICT). In order to generalise and validate its results, although they were significant, our research will be extended to a larger sample, and in other countries.

ARTICLE HISTORY
Received 2023-10-20
Accepted 2024-01-05

KEYWORDS
Fossilization
Geological time
Geological space
Obstacles
Training
Future instructors

INTRODUCTION

Taking into account the initial representations of future teachers has become a trend in the field of education. The research conducted in this area (Crépin-Obert, 2023 ; Lhoste, Y., Schneeberger, 2018 ; Clément & Hovart, 2000) has shown that highlighting and processing the initial representations of future teachers will certainly help them to improve their teaching practices in the classroom. It will also facilitate the didactic transposition of the concepts taught and the choice of appropriate strategies and methods for transmitting these concepts. In this context, many researchers in science didactics have been interested in the question of the initial representations of future teachers of scientific subjects, in particular biology-geology (Crépin-Obert 2023 ; Cordeiro & de Castro Morini ,2023 ; Lhoste and Schneeberger, 2018).

Researchers have confirmed that future teachers may have the same initial representations as students (Gouanelle & Schneeberger, 1995 ; Schneeberger, 1997 ; Haidar, 1999 ; Crépin-Obert, 2023 ; Lhoste, 2023). Identifying and overcoming these obstacles has become a specific pedagogical objective that teachers need to be aware of and take into account during their training. This makes it possible to determine the objectives and can also better guide the planning of training programmes. They can also contribute to improving the effectiveness of their teaching practices, more specifically didactic transposition.

A number of studies have attempted to decipher the link between teachers' representations and difficulties, and the effectiveness of didactic transposition : the transition from academic knowledge to knowledge to be taught in classroom settings (Chevallard & Johsua (1985). Crépin-Obert's (2023) qualitative study, disccussing a text by Darwin on the historical controversy around the age of the Earth.Teachers-in-training reported difficulties in transmitting the scientific concepts implied in this text, and adapting them to the levels and abilities of pupils, due to their complexities. As a result, they are unable to develop effective teaching strategies to deal with students' representations of the temporal evolution of geological phenomena. They, themselves, need ongoing training to overcome their difficulties in assimilating some of these concepts. Participants in Lhoste's study (2023) highlighted difficulties in simplifying the concepts of evolutionary theory and the classification of living organisms, and also in planning and implementing their teaching. This study also showed that the prejudices and religious beliefs of students and ,sometimes, even teachers can clash and make teaching evolution difficult. Consequently, the author stresses the importance of integrating the teaching of evolution and the classification of living organisms into teacher training. Cordeiro, and de Castro Morini (2023) who looked at the analysis of teachers' conceptions of biological diversity. Although the participants had already had initial training in phylogeny, they presented errors and inaccuracies, both in definitions and in conceptual applications. They argue that more investment in training is needed.

Rassou et al (2017) highlighted a gap in the training of future LES teachers. Indeed, the latter are sometimes brought in to teach geology without any training in the discipline. A large proportion of these teachers (51.7%) are biology graduates, who do not enjoy teaching geology courses and have sometimes erroneous or incomplete representations of geological concepts. This is due to their lack of knowledge and the absence of continuous training in geology. These conceptions can be transmitted unconsciously to learners during the process of didactic transposition, and during classroom learning (Chalak & El Hage, 2011).

“Before starting classes and practicing the teaching profession, future instructors must receive training that enables them to acquire professional skills to deal with unexpected situations” (Schneeberger & Triquet, 2001). Since its creation in 2012, the training program of teachers at Moroccan RCJETs has been based on a framework of skills predefined by the Ministry of National Education, Professional Training, Higher Education and Scientific Research (MNEPTHESR). This framework is based on a certain number of pillar skills for the professionalization of the job of a teacher.

From what has been mentioned above,, it can be seen that teachers' initial representations can hinder the acquisition of the skills required for the didactic transposition of academic knowledge and its integration into the learning process. Bearing this in mind, this study seeks to ascertain whether difficulties in the use of time and space are obstacles to the acquisition of the concept of fossilization by RCJET trainee teachers at secondary school level.

LITERATURE REVIEW

The academic literature has highlighted the obstacles to the appropriation of geological concepts, particularly fossil and fossilization concepts.

Difficulties in assimilating the concepts of fossil and fossilization

The word fossil comes from the Latin fossilis and refers to anything extracted from the earth, including petrified rocks, minerals and animals. They are considered to be good markers of time and space (stratigraphic fossils and facies fossils), as well as evidence in favour of the theory of the evolution of species (Crépin-Obert, 2010).

Nowadays, it is accepted that the fossil is formed at the same time as its host rock due to the fact that the fossilizable parts of an organism had been buried in the sediment which progressively turned into rock. However, the students find it challenging to imagine this simultaneity between the two phenomena of fossilization and sedimentation. According to Sauvageot-Skibine (1995), this is linked to an obstacle of conceiving the preexistence of the rock in reference to the fossil. Laperrière-Tacussel (2002) pointed out that the concept of fossil constitutes a knot of converging obstacles: epistemological obstacle linked to the construction of the concepts of time, space and transformation of matter. Sauvageot-Skibine (1995) relates students' difficulties in imagining the simultaneity between the phenomena of fossilization and sedimentation to the conception obstacle of the preexistence of the rock in reference to the fossil.

In his doctoral thesis, Crépin-Obert (2010) detected three major types of polymorphic (multifaceted) obstacles learners have: "artificialism", "animism" and "analogism". In the same work, he pointed out the historical obstacles linked to the concept of fossil in relation to time. Regarding the evolution of species, Crépin-Obert (2002) highlighted various types of obstacles: the lack of mastery of the temporal variable, notions of ancestors and species, the polysemy of word "evolution", the confusion between the life cycle of a living being and evolution. Along the same line, Lecointre (2002) explained the students' fixist attitude (obstacle of the immutability of species) by the inability to perceive the relative slow pace of the phenomena involved in evolution or in the creation of new species by hybridization. Finally, Orange-Ravachol and Triquet (2007) emphasized the obstacle of accepting the factor of chance in the mechanisms and understanding the contingency of an irreversible history of the living.

The issue of mobilization of time and space in geology

Geology is a field science where the geologist relies on found clues, field observations, experimentation, laboratory analysis and modelling in order to reconstruct the history of the earth (Sanchez & Devallois, 2004). However, grasping geological concepts is not so easy for learners (Gohau, 1995). Didacticians have unveiled various types of epistemological obstacles (Bachelard, 1967), which are generally linked to problems of mobilizing the spatiotemporal scale. Through analyzing explanations given by high school students on some geological problems (the reconstruction of the past of an ocean, the evolution of the area of a ridge, ophiolites, the origin of life) Orange-Ravachol (2003) pointed out that these learners do not use time in the same way as scientists.

Monchamp and Sauvageot-Skibine (1995) identified the obstacle of fixism, where students imagine dynamic phenomena in a static manner, as well as the obstacle of catastrophism, where students give the earthquake the character of a catastrophe occurring in a short time (a few seconds) while negating its geological history and automatically the immensity of time required for it to happen. In the same vein, Boughanmi (2009) found that the catastrophist and fixist explanations from Tunisian learners about the geological phenomena involved in plate tectonics such as earthquakes, volcanism and orogeny, prevent them from conceiving the immensity of the time in play.

In addition, Savaton (1995) focused on the obstacles linked to the study of the geological map. He emphasizes that the notion of space remains vague in terms of the perception and distinction of different geological planes (surface, soil, subsoil). He explains that these failings are due to a psychological overvaluation of direct observation, "you have to see to know ... the space that is not seen is difficult to interpret".

METHODS

Research Goal

This study sets the objective of answering the following question: Do the difficulties in the use of time and space constitute obstacles for trainee teachers when it comes to the acquisition of the concepts of fossilization?

Sampling and Conditions of Administrating the Questionnaire

In our study, we adopted the questioning strategy known as "question X" developed by Worley (2015). In order to obtain more complete information on the research topic, we combined closed questions (quantitative method) and open questions (qualitative method) (Semyonov-Tal & Lewin-Epstein., 2021). Open-ended questions allow participants to express themselves freely, to give their ideas and personal points of view, which made it easier for us to analyse and interpret the answers to closed-ended questions (Karaman & Büyükkıdık, 2023).

This questionnaire was submitted to 30 trainee teachers from the Fez RCJET at the beginning of their training. The choice of this sample was made through simple random sampling. In fact, the population corresponds to a subpopulation of all the trainee teachers of LES from the Moroccan RCJET centers. Thus, it is valid because there is a relationship between the subpopulation and the entire population of Morocco, especially since all trainee teachers undergo the same training with the same didactic and pedagogical means and similar socio-cultural conditions.

All participants were informed of the objectives of the study in order to ensure their informed consent. Participation was voluntary, guaranteed respondents' anonymity and confidentiality.

The process of developing and ensuring the validity of the questionnaire had three stages: 1) drafting the first version of the questionnaire; 2) checking its validity; 3) developing the final version of the questionnaire.

The design of the first version of the questionnaire was carried out in two phases. First, identifying the topics covered and the types of questions proposed based on the research objectives as well as the various concepts explained in the theoretical framework of the study. After its development, this first version of the questionnaire was submitted to the various members of the research team (didacticians, geologists) who proceeded to check its validity by revising the order of items, the scientific content, and the wording and the nature of the questions. Then, a brief general interview was conducted with 30 trainee teachers (less than 5 min for each trainee teacher) focusing mainly on the type of diploma they have, and some acquired knowledge in geology, in particular related to the concept of the fossilization.

Finally, following the results of the oral interview and the comments from the research team, certain modifications were made to the questionnaire. These provided adequate guidance for the development of its final version.

Description of the Questionnaire

The questionnaire includes, closed-ended questions (Q1, Q2, Q4) and semi-closed questions (Q3). This diversity of question types was used to collect both qualitative and quantitative data. This investigation allowed the revelation of the epistemological obstacles blocking the adequate mobilization of space and time parameters when it comes to understanding the concepts of fossilization.

Data processing

The data collected was first analyzed using statistical data processing software (Excel). This type of software was used for descriptive statistics in order to arrive at elements of interpretation. As for the answers to the open ended and semi-open-ended questions, the content analysis method (categorical content analysis) was used.

RESULTS AND DISCUSSION

Findings

Question 1: What is the mode of fossilization?

The collected responses revealed that the majority of trainee teachers (70%) did not identify any mode of fossilization. Among respondents, the three modes of fossilization were reported by 36.40%, another 36.40% identified epigenization while 27.30% (three respondents) identified the molds (Table 1).

Table 1. Results of identification of the modes of fossilization (Question 1)

Propositions	Recorded numbers	Frequency
Epigenization	4	36,40%
The three modes of fossilization	4	36,40%
The molds (internal and external)	3	27,30%
Total	11	100%

We see that even trainee teachers face difficulties in identifying the different modes of fossilization:

Category 1: those of a spatiotemporal order. In fact, only 36.40% of respondents identified epigenization. This phenomenon results from physicochemical reactions taking place in scales of space that are difficult to access for the naked eye.

Category 2: those of spatial vision (27.30%); 18.30% of these respondents identified one of the molds without specifying the other (internal or external). The others (9%) mixed the internal mold and the external mold together.

Question 2: What are the processes of fossilization?

This question aims to assess the degree of knowledge the respondents have of the different modes of fossilization. We had a percentage of 70% of respondents.

The most cited fossilization processes were: "burial; sedimentation; diagenesis and compaction". The other processes "decomposition of organic matter; dissolution; transport and rework; morphological deformations" (Table 2) were all cited with more or less low percentages (at most 9%).

Table 2. Recorded numbers for each proposition of question 2

Propositions	Recorded Numbers	Frequency
Burial	19	24,30%
Sedimentation	16	20,50%
Diagenesis	13	16,60%
Compaction	11	14,10%
The decomposition of organic matter	7	9,00%
Dissolution	5	6,40%
Transport and rework	3	3,80%
Morphological deformations	3	3,80%
Genetic transformations	1	1,30%
Total	78	100%

Question 3: What are the characteristics of the best preserved (fossilized) organisms?
This question aims to clarify the representations future teachers have of spatial parameters included in the fossilization (Table 3).

Table 3. Recorded numbers for each proposition of question 3

Propositions	Recorded numbers	Number of justified answers	Frequency
Of small size	18	39,1 %	11
Marine organisms	13	28,3 %	08
Of large size	9	19,6 %	10
Aerial organisms	6	13%	04
Total	46	100%	33

The majority of respondents (39.1%) point out that organisms of a small size are more likely to fossilize, compared to large organisms (19.6%). While 28.3% think that the marine environment is the environment most conducive to fossilization compared to the aerial environment (13%).
Remark: 9 teachers out of 30 explained their answers, of which the total is 33; each respondent was given the chance to provide more than one explanation for the same answer.
Are these two spatial parameters (the fossilization environment and the size of the fossil organisms) dependent for trainee teachers?

Processing of trainee teachers' transcripts showed that only 9 of them justified their choices. This indicates the low degree of knowledge of the spatial parameters linked to fossilization (the conditions of fossilization and the parameters of the fossilization spaces). The analysis of the justifications was carried out using two content analysis grids (Table 4 and 5), each of which explains the justifications for choosing each spatial parameter (size and living environment). If the authors want to display a figure, use the following format:

Table 4. Analysis grid of the explanations for yes or no answers for question 3, related to the size of the organisms

	For "yes"				For "no"			
Explanations	Require less space (easily buried; quickly in sediment)	Difficult to degrade; retain their shape; leave their imprints	Examples of fossils	Total	Require more space (buried with difficulty)	Easily degradable; easily deformed	Possibility of transport	Total
Large size	00	01	01	02	02	06	00	08
Small size	02	05	01	08	00	02	01	03

Table 5. Analysis grid for the explanations of question 3, related to the fossilization environments

	For "yes"			For "no"		
Explanations	Favorable environment for fossilization (less oxidation; erosion, biological degradation)	greater sedimentary input	Total	Unfavorable environment for fossilization (direct exposure to de-structuring agents; erosion; hydrodynamics of water; transport)	Less sedimentary input	Total
Marine Environment	04	01	05	02	01	03
Aerial Environment	00	00	00	03	01	04

Question 4: Can the processes of fossilization be:

To bring together the models the respondents designed when reconstructing the evolution of fossilization in time and space. Only 33.30% of respondents did not answer (Table 6):

For temporal evolution: a significant number of respondents (27.80%) mentioned a temporal succession of the processes of fossilization (a causal linear reasoning), and 18.50% imagined that these processes are synchronous or carried out in on go. The repetition, over time, is chosen by 14.80%;

For spatial evolution: 22.20% of participants answered that the processes of fossilization take place under several levels of the sedimentary series, and 16.70% think that they take place under a single level of the sedimentary series.

Table 6. recorded numbers for each proposition of question 4

Propositions	Recorded Numbers	Frequency
Successive	15	27,80%
Carried out under several levels of the sedimentary series	12	22,20%
Carried out under a single level of the sedimentary series	9	16,70%
Repeated	8	14,80%
Synchronous (at the same time)	6	11,10%
Carried out in one go	4	7,40%
Total	54	100%

To better clarify these conceptions, we cross-checked the responses on the temporal modalities with the spatial ones of question 4. Table 7 below represents the obtained results.

Based on these results, X2cal is inferior to X2the and P-value is greater than 0.05. This dependency test (Chi2) clearly shows the independence of spatiotemporal parameters in the representations of our future teachers. In fact, they mentioned these two parameters separately.

Table 7. results of Chi2 dependency test, modalities representing time and space from question 4

Q4 / Q4	Synchronous	Successive	Repeated	Carried out in one go
Carried out under single level of the sedimentary series	5,97 (6)	10,31 (9)	8,14 (7)	7,59 (10
Carried out under a several level of the sedimentary series	5,03 (5)	8,69 (10)	6,86 (8)	6,41(4)

The values in the table are the number of quotes for each pair of modalities.

H0: "The time and space parameters are independent".

H1: "The time and space parameters are dependent".

Number within parenthesis: theoretical number

Number without parenthesis: actual number

X2the = 7.81, 95% confidence interval, df = 3, P-value = 0.49.

X2cal = 2.37

Discussion

A number of studies in the literature have dealt with the problem of obstacles to assimilation of the fossil concept, but they have only focused on learners' conceptions (at primary or secondary school level) of the nature of fossils, and the temporal reconstruction of their history (Crépin-Obert ,2010 ; Triquet et Orange,2007 ; Sauvageot-Skibine,1995 ; Laperrière-Tacussel, 2002). Our research focused on trainee teachers' conceptions of the evolution of the fossilization phenomenon in time and space. Our results have shown that these trainee teachers encounter different types of obstacles.

Based on the results of questions 1 and 2, we can see that future teachers are not sufficiently familiar with all fossilization processes and modes. Indeed, the answers to question 2 show that the majority of future teachers cannot identify any mode of fossilization; while the results of question 2 indicate an insufficient level of knowledge of all fossilization processes on the part of future teachers. The percentages attributed to each proposal (process) do not exceed 24.30% of all responses, despite the fact that these processes are part of the Bachelor's degree course in Earth and Universe Sciences (SEU). These future teachers therefore do not master all fossilization processes. Eddif (2017) and Rassou et al. (2017) have also identified the problem of a lack or inadequacy of knowledge of geological phenomena, by examining the initial representations of geological concepts held by future science and technology teachers. These authors show that this is a training gap that can hinder the understanding and subsequent transposition of geological concepts into the classroom.

For the fossilization process, various types of obstacles arise:

Obstacle of mobilising space : The obtained responses are frequently characterised by incomplete explanations with an underestimation of the space parameter compared to that of time (Q2). Difficulties concerning spatial vision arose among respondents (Q1) who identified one of the moulds without specifying the other (internal or external) and those who mixed the internal and the external moulds. These findings fit with the results of Savaton's (1995) research into learners' obstacles to using the geological map. This author explains that participants have a blurred perception of the notion of space, and find it difficult to conceive and interpret geological plans (spaces) that cannot be observed directly.

Obstacle of perceiving the time factor : The time factor is introduced into explanations in an indirect or imprecise way (Q3) either by indicating the temporal succession of some stages of fossilization without specifying the time scale ; or by completely ignoring these steps but mobilising the Human scale or the geological time scale and finally, by considering time as the only variable at the origin of the fossils. This corresponds to the findings of Crépin-Obert (2010 ;2002), who detected in these learners a failure to master the mobilization of time when reconstructing the fossil's history. Some explanations encompass the duration

of the whole phenomenon of fossilization within the duration of the burial stage; they thus neglect the time of all the other stages (the death of the organism; the degradation of its organic substance; the diagenetic transformations, the possibility of transport). Our respondents were not able to conceive the time intervals necessary for the progression of fossilization. As a result, they either converged totally towards intervals on the Human scale, or towards intervals on the geological time scale. However, the duration of the evolution of this phenomenon is indefinite and open to all possibilities, depending on the prevailing circumstances in the paleo-environment. This correlates with the findings of Boughanmi (2009), who confirmed that learners may have catastrophist or fixist conceptions, which block their estimation of the geological time required for the unfolding of geological phenomena. Sauvageot-Skibine (1995), points out that learners have difficulty imagining the history of a geological phenomenon. She explains that they imagine that the phenomenon takes place in one stage, over a short period of time.

Obstacle of actualism (conception of "time" and "space" simultaneously)

Even if they have practised microscopic observations during their university studies, future teachers are unable to conceive the process of epigenisation (Q1). The researches, affirm that they are unable to carry out feedback within time "temporal extrapolation" (Boughanmi, 2009; Orange-Ravachol, 2003), to imagine the substitution of the original mineral of the shell (old mineral), by another replacement mineral (more recent mineral).

By reconstructing the spatiotemporal progress of fossilization processes (Q4), the respondents retrace models which do not approximate the reference model of fossilization. They conceive the evolution over time (in cyclic or linear form) separately from the evolution in space (scale of the indurated strata). However, these two parameters are inseparable for all geological phenomena. The reference model reconstructs the evolution of fossilization and sedimentation processes simultaneously according to a two-dimensional evolution (in space and time) and under exceptional conditions that are rarely repetitive over time. Sauvageot-Skibine (1995), explains that the difficulties in imagining the simultaneity between fossilization and sedimentation are due to the obstacle of the conception that the host rock is older than the fossil. These subjects, therefore, do not manage to reach back the arrow of time, to imagine the progress of the fossilization processes during the sedimentation of the host rock and at the scale of the sedimentary basin (paleo-environment). It is the obstacle of abstraction of the principle of actualism.

Obstacle of contingency

When conceiving the fossilization of an organism (Q3), a good number of respondents overvalue the marine environment. However, they qualify the aerial environment as unfavourable for this phenomenon. They consider it as a destructive environment where erosion, oxidation and hydrodynamics are abundant and sediment input is generally insufficient. Others consider the size of the organism to be a determining factor in fossilization. Large-sized organisms are the least preserved, covered by sediment with difficulty ; therefore, they suffer the most destruction. On the other hand, those of small sizes are easily covered by sediment and they are the least destroyed. These conceptions are the proof of the ignorance of these teachers of the conditions of fossilization. In fact, they ignore that the production of this phenomenon does not depend on a specific environment or organism, but on the environmental factors prevailing at the time of fossilization. That is "the contingency ». In the same framework, the study by Orange-Ravachol and Triquet (2007) revisits this obstacle, to the controversy between common thought and scientific knowledge. This is because learners don't mobilise time like scientists, and don't accept the coincidence and irreversibility of the mechanisms involved in geological phenomena.

All these results clearly show that the difficulties encountered by future teachers vis-à-vis the assimilation of these geological concepts are manifested in different aspects of mobilization of time and

space factors. These factors will certainly present obstacles for the assimilation as well as for the construction of concepts related to the phenomenon of fossilization in their future classes with the students.

CONCLUSION

Our research takes part in contributing to the improvement of the teaching-learning act of Earth Sciences. It is interested in the obstacles of the conception of time and space in the case of the concepts of fossilization. The adopted methodology relied on a questionnaire administered to future teachers from the RCJET.

This work has enabled us to identify a number of obstacles in the mobilization of time and space. In fact, regarding the reconstruction of the spatiotemporal progression of the fossilization processes, we noted that the respondents ignored the contingency of the fossilization processes and retraced this phenomenon based on models which do not approximate the reference model and are out of their spatiotemporal frame. Also, the obstacle of lack of knowledge that was previously acquired arose, commonly in their answers and their explanations.

Yet, these future teachers are supposed to have an adequate level in biology and geology. In fact, it is graduates in the field that they will have to teach at the two levels of secondary education. Therefore, they must be able to transpose and model any geological phenomenon in its spatiotemporal framework, in particular the progression of fossilization. This theme is part of the teaching programs (concepts of fossil and its derivatives, reconstruction of the evolutionary history of phosphate and coal deposits in Morocco).

RECOMMENDATIONS AND LIMITS

Our interviewees' difficulties can be attributed to the methods and approaches of their training at RCJET centers. In fact, the majority of them (22 out of 30) are biology graduates, who emphasized a profound need for special training in geology, to overcome their difficulties in appropriating geological phenomena. In this respect, we recommend that more time be devoted to practical work and the scheduling of geological outings. In this context, we suggest the development of new methods and approaches for their training, such as the integration of Information and Communication Technologies (ICT), through the design and development of digital devices, allowing them in particular to model and help in the assimilation of the phenomenon of fossilization.

Despite the significant results obtained, this study was marked by constraints. On the one hand, the small size of the sample was due to difficulties in accessing a larger number of trainee teachers in the RCJET. Secondly, we focused on the difficulties faced by future instructors in Morocco. These constraints may affect the generalizability of the results. Of course, in order to generalize and validate its results, our research will be extended to a larger sample, in collaboration with research teams in Morocco and other countries.

REFERENCES

Bachelard, G. (1967). La formation de l'esprit scientifique, 5e édition, Librairie philosophique J. *VRIN, Paris*.

Bouganmi, Y. (2009). *Obstacles à la problématisation du temps dans une approche interdisciplinaire: l'explication de quelques phénomènes naturels par des élèves et de futurs enseignants tunisiens* (Doctoral dissertation, Université de Bourgogne; Université de Tunis).

Chalak, H., & Hage, F. E. (2011). L'enseignement des sciences de la Terre au Liban: enjeux, obstacles et orientations professionnelles. *RDST. Recherches en didactique des sciences et des technologies*, (3), 209-240. https://doi.org/10.4000/rdst.427

Chevallard, Y., & Johsua, M. A. (1985). *La transposition didactique : du savoir savant au savoir enseigné*. La Pensée Sauvage.

Clément, P., & Hovart, S. (2000). Environmental education: Analysis of the didactic transposition and of the conceptions of teachers. In H. Bayerhuber & J. Mayer (Eds.), *State of the art of empirical research on environmental education*, 77-90. Münster: Waxmann Verlag.

Cordeiro, R. S., & de Castro Morini, M. S. (2023). Concepções docentes acerca da biodiversidade na perspectiva da sistemática filogenética. *Investigações em Ensino de Ciências*, 28(2), 421-438.

Crépin-Obert, P. (2002). Des conceptions initiales aux systèmes explicatifs des élèves de l'école primaire sur l'origine des espèces. *Grand*, 70, 101-123.

Crépin-Obert, P. (2010). Idées et raisons sur les coquilles fossiles: étude épistémologique comparée entre une situation de débat à l'école primaire et une controverse historique. *RDST. Recherches en didactique des sciences et des technologies*, (1), 93-120. https://doi.org/10.4000/rdst.175

Crépin-Obert, P. (2023). Controverse historique sur les âges de la Terre : réception en formation des enseignants d'un texte de Darwin. *Recherches en didactique de l'évolution: Enseignement, apprentissage et formation*, 147.

Eddif, A., Selmaoui, S., & Ouazzani, H. (2017). Les volcans : quelles conceptions des futurs enseignants marocains des sciences de la vie et de la terre?. *Le Pédagogue*, 1(3/4), 63-77.

Gohau, G. (1995). Traquer les obstacles épistémologiques à travers les lapsus d'élèves et d'écrivains. *Aster: Recherches en didactique des sciences expérimentales*, *20*(1), 21-41. https://doi.org/10.4267/2042/8624

Gouanelle, C., & Schneeberger, P. (1995). Enseigner les fossiles à l'école primaire. *Aster*, (21), 81-107. https://doi.org/10.4267/2042/8637

Haidar, A. H. (1999). Emirates pre-service and in-service teachers' views about the nature of science. *International Journal of Science Education*, 21(8), 807-822. https://doi.org/10.1080/095006999290309

Karaman, P., & Büyükkıdık, S. (2023). Teachers' Use of Open-ended Questions: A Mixed-methods Study. *The Clearing house: a Journal of eduCaTional sTraTegies, issues and ideas*, *96*(2), 79-87.

Lhoste, Y., Schneeberger, P. (2018). Points of view of actors involved in the training of biology and geology teachers (middle school and high school) about the way to engage students in a professional development process. *Recherches en Didactiques des Sciences et des Technologies*, (17), pp. 21-48.

Lhoste, Y. (2023). Le concept d'espèce pour penser l'évolution et la classification du vivant. *Recherches en didactique de l'évolution : Enseignement, apprentissage et formation*, 231.

Laperrière-Tacussel, M. (2002). Essai de construction de situations pédagogiques sur le thème des fossiles. *Grand*, (69), 83-98.

Lecointre, G. (2002). *Comprendre et enseigner la classification du vivant*. Belin

Monchamp, A. & Sauvageot-Skibine, M. (1995). Du fixisme à la tectonique des plaques. Et pourtant elles bougent... *Aster: Recherches en didactique des sciences expérimentales*, *20*(1), 3-20. https://www.persee.fr/doc/aster_0297-9373_1995_num_20_1_1048

Orange-Ravachol, D. (2003). *Utilisation du temps et explications en sciences de la Terre par les élèves de lycée : étude dans quelques problèmes géologiques*. (Doctoral dissertation, Université de Nantes). Université de Nantes. Service commun de la documentation. BU Droit.

Orange-Ravachol, D., & Triquet, E. (2007). Sciences et récits, des rapports problématiques. *Aster: Recherches en didactique des sciences expérimentales*, (44), 7-22.

Rassou, K., Khiri, F., Benbrahim, M., Tamraoui, Y., Elberrani, H., & Anfour, M. (2017). Difficultés Relatives A L'enseignement-Apprentissage De La Géologie En Classes Secondaires Qualifiantes Cas De La Délégation d'Inzegane Ait Melloul. *European Scientific Journal, ESJ*, 13, (18), 294-313. https://doi.org/10.19044/esj.2017.v13n18p294

Sanchez E., P.M., Devallois D. (2004). *L'enseignement des sciences de la Terre en classe de seconde : Pratiques de classe, difficultés*, perspectives pour la formation, Institut National de Recherche Pédagogique, Accès. Saint Fons Cedex.

Sauvageot-Skibine, M. (1995). Enseigner les sciences de la terre en tenant compte des représentations. *Aster: Recherches en didactique des sciences expérimentales*, *21*(1), 3-8. https://www.persee.fr/doc/aster_0297-9373_1995_num_21_1_1058

Savaton, P. (1995). La carte géologique: représentations d'élèves de classe de Première scientifique. *Aster: Recherches en didactique des sciences expérimentales*, *20*(1), 139-164. https://www.persee.fr/doc/aster_0297-9373_1995_num_20_1_1054

Schneeberger, P. (1997). Place du concept de représentation dans la formation des enseignants : un exemple dans le domaine de la biologie. *Spirale-Revue de recherches en éducation*, 2(1), 263-282.

Schneeberger, P., & Triquet, É. (2001). Didactique et formation des enseignants. Des recherches en didactique des sciences à la formation des enseignants: quels liens, quelles interactions?. *Aster: Recherches en didactique des sciences expérimentales*, *32*(1), 3-13. https://www.persee.fr/doc/aster_0297-9373_2001_num_32_1_1187

Semyonov-Tal, K., & Lewin-Epstein, N. (2021). The importance of combining open-ended and closed-ended questions when conducting patient satisfaction surveys in hospitals. *Health Policy OPEN*, 2, 100033.

Worley, P. (2015). Open thinking, closed questioning: Two kinds of open and closed question. *Journal of Philosophy in Schools*, 2(2), 17-29.