

Diagnosis of learning difficulties of plate tectonics concepts among secondary school students using: focus group, nominal group, and questionnaire

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Abstract. The teaching of geology or earth sciences occupies an important place in the life and earth sciences programs of the secondary cycle in Morocco. The theory of plate tectonics is the conceptual model that allows an understanding of most of the dynamic processes of the Earth. Our work aims to diagnose the difficulties related to the learning of the concepts related to plate tectonics by following a hybrid methodology of three techniques, namely: focus group, nominal group, and questionnaire. The results obtained allowed us to identify difficulties in the educational act in its different facets, whether epistemological, pedagogical, didactic, curricular, and logistical. These difficulties should be taken into consideration by the different actors in the educational process, in order to guarantee the successful learning of this discipline.

Keywords. Learning difficulties, focus group, nominal group, plate tectonics, secondary school.

1. Introduction

The teaching of geology or earth sciences occupies an important place in the programs of life and earth sciences (LES) in Morocco. Thus, according to the pedagogical guidelines, geology represents 50% of the program in the first and second years of secondary school and in the first year of the baccalaureate in mathematical sciences; 25% of the program in the first year of the baccalaureate in experimental sciences and in the second year of the baccalaureate in physical sciences; and 16.66% of the program in the second year of the baccalaureate in life and earth sciences. Among the specific skills targeted by the geology program in secondary school, the acquisition of knowledge on internal and external geological phenomena and their relation to plate tectonics [1, 2].

The study of geology allows the student to know the materials of the earth's crust (mineralogy and petrology), to understand the phenomena that operate on the surface and inside the earth (volcanism, sedimentology, tectonics, and seismology) and to determine the succession of events that are the subject of historical geology (stratigraphy and paleogeography). Thus, geology has the particularity of being both a functionalist science that aims to explain the current functioning of the earth and a historical science that aims to reconstruct the history of our planet [3].

Plate tectonic theory is the conceptual model for understanding most of the Earth's dynamic processes [4]. It is primarily concerned with plate movements and their consequences [5]. Indeed, this theory constitutes a global framework for conceiving, understanding, and asking questions related to the global functioning of the earth. It allows for the explanation, organization, and structuring of a large number of geological facts and phenomena that often remain isolated in the learner's mind [6]. Plate tectonic theory unifies and integrates several fields of study in the earth sciences, such as petrography, volcanology, sedimentology, paleontology, stratigraphy, and tectonics. For this reason, it is considered a unifying and integrating model to explain a number of geological phenomena [7]. Therefore, a solid understanding of the basic principles of this theory is essential to educating future geologists and a scientifically literate public [8].

In many countries, geology is considered a difficult discipline and disliked by learners [9]. According to Gobert, plate tectonics represents a difficult science topic for American middle school students [10]. McDonald added that this theory is also conceptually complex, and students often struggle to develop an understanding of it [11]. In Lebanon, students have little interest in geology, and teaching this science seems problematic for them [12]. For Spanish students, geology is a boring and uninteresting subject [13]. Moroccan learners are not exempt from this situation; the geology curriculum is felt to be quite difficult for them [14, 15].

According to several research studies in science didactics, students have misconceptions about geological phenomena and encounter difficulties in assimilating and understanding concepts related to plate tectonics [16, 17, 18, 19, 20, 21, 22, 23, 24]. These misconceptions impede learning and are fundamental challenges to "constructivist" scientific teaching [25].

In Morocco, according to our literature review, the difficulties linked to the learning of geology in secondary schools have been very little addressed by research in science didactics, and no research has been interested in determining them in an exhaustive way. The identification of these difficulties is the starting point for any successful learning act.

During the teaching councils in our qualifying high school where I teach, the LES teachers have always agreed that the majority of learners attach little importance to learning geology and they find it difficult to conceive and understand the geological phenomena related to plate tectonics. In addition, most students get low marks in continuous testing of geology compared to biology.

Illuminated by this problematic and influenced by our practices as teachers of life and earth sciences in high school, it seems important to us to diagnose, in an exhaustive way, the difficulties encountered by learners during the learning of earth sciences. Thus, we asked ourselves the following question: What are the difficulties of learning geological concepts related to plate tectonics among secondary school students in Morocco?

2. Materials and methods

To diagnose the difficulties encountered in learning concepts related to plate tectonics, we used an original mixed approach, adopting three complementary methods: the nominal group technique, the discussion group, and the questionnaire. According to our literature review, this approach is the first time it has been used in this kind of situation in LES.

2.1 Nominal Group Technique

The Nominal Group Technique (NGT) was developed by two American researchers, André Delbecq and Andrew Van de Ven, in 1968. It was first used in the field of management but soon spread to various other fields including, education, health, and social sciences [26, 27].

In our research, the use of this technique was retained in the framework of identifying the problems related to the study of plate tectonics in secondary schools in Morocco. To do this, we gathered a group of 15 students (14 to 15 years old), and we asked them the following nominal question: what are the difficulties that hinder the learning of plate tectonics?

To answer this question, participants combine individual work and group discussion in a six-step process [28, 29]:

- Step 1: Each participant individually writes down as many ideas as he/she feels are solutions to the nominal question for ten minutes.
- Step 2: Collection of the answers produced by the participants. In turn, each participant writes one of his or her proposals on the board in front of the group. The collection of new ideas continues, without any discussion, until everyone has had the opportunity to express all their ideas.
- Step 3: Clarification of ideas one after the other. The facilitator ensures that all participants interpret each statement in a similar way. Ideas deemed redundant or irrelevant to the topic can be crossed out.
- Step 4: Presentation and discussion of the selected answers.
- Step 5: Participants are invited to vote individually on the selected proposals by prioritizing them and assigning a decreasing "pi" weighting. The highest score will be given to the first-ranked proposal, the next highest score to the next-ranked proposal, and so on.
- Step 6: The answers and their corresponding Σpi are ranked, in a table, in descending order of importance.

The completion of the NGT generated nine statements. After the vote, these statements were ranked according to their importance.

2.2 Focus Group

The focus group (FG) is a qualitative research technique [28, 30]. This method encourages the free and spontaneous expression of participants (5 to 10 people) on a given problem under the guidance of a facilitator. In fact, on the sidelines of a training session for SVT teachers, we invited seven teachers (experts) with professional experience ranging from 10 to 25 years. In the beginning, the facilitator explains to the teacher-experts that his or her role is to give all participants a fair chance to speak, ask for clarification, and summarize appropriately. The facilitator then clarifies that all responses are valid and that there are no right or wrong answers. He then guides the focus group to answer the following question:

What student problems and difficulties do you encounter when teaching plate tectonics?

In order to allow each participant to express himself and to listen to what he had to say, a roundtable discussion was held. The meeting lasted two hours, during which the experts proposed the maximum number of ideas related to the subject. The collected data are presented in a table.

2.3 Questionnaire

2.3.1 The study sample

The questionnaire was administered to 114 students in their third year of secondary school (14 to 15 years old), belonging to the Provincial Directorate of Ouazzane in northern Morocco. The sample was selected randomly one month after the geology course. 60.53% of the respondents were female (69 girls), and 39.47% were male (55 boys). 55.26% of the students (63) are studying scientific subjects in French at the public school "Imam Malik" (46 students) and the private school "l'Horizon" (17 students). However, the remaining 44.74% (51 students) pursue studies in the Arabic language at the school Imam Malik (18 students) and the college Imam Ghazali (33 students).

Table 1. Study sample.

School establishment		Imam Malik Middle School		Imam Rhazali Middle School		Horizon School Group		Total number of students
Gender of students		Female	Male	Female	Male	Female	Male	
Language of teaching	Arabic	14	4	17	16	0	0	114
	French	29	17	0	0	9	8	

2.3.2 Presentation of the Questionnaire

The questionnaire, in paper format, was developed based on the results of the TGN and the focus group. It is composed of nine different questions in the form of open-ended questions, multiple-choice questions, and a diagram to be constructed. This questionnaire allowed us to analyze the students' conceptions and verify the importance of the difficulties declared by the respondents having practiced the two techniques previously mentioned.

3. Results and discussions

3.1 Nominal Group Technique

The completion of the NGT generated nine statements. After voting, these statements are ranked according to their decreasing Σp_i . Table 1 shows the results found.

Table 2. The difficulties that hinder the learning of plate tectonics, ranked in descending Σp_i .

Student's answers	Σp_i	Order
Lack of practical studies (exit, real observation), explanatory models, tools, samples, and ICT.	110	1
Lots of terms, words and definitions to memorize.	100	2
Lack of motivation and competitiveness of students, uninterested colleagues and lack of interest in geology.	85	3
Difficulty in understanding geological history.	78	4
Difficulty in schematizing geological structures.	77	5
Geological phenomena are complex and difficult to conceive.	74	6
Non-participation of the students in the realization of the lessons.	67	7
Difficulties in answering control questions.	64	8
Course not well explained by the teacher.	20	9

Examination of Table 2 reveals that students attribute their difficulties in plate tectonics primarily to teaching methods, overloaded course content, a lack of motivation, and the complexity of geologic concepts and phenomena. Indeed, the answer that tops the list with the highest weight ($\Sigma p_i = 110$) refers to the lack of practical studies (output, real observation),

explanatory models, tools, samples, and ICT. In second order comes the difficulty associated with having multiple terms, words, and definitions to remember ($\Sigma\pi = 100$). These first two answers reflect that students are confronted with didactic and pedagogical difficulties related to classical methods used when teaching plate tectonics. In the same sense, in seventh place, the high scores highlight a negative judgment of the non-participation of students in the realization of lessons. In addition, in third place, there is a psychological difficulty that concerns motivation (lack of motivation and competitiveness of students, uninterested colleagues, and lack of interest in geology) with a weight of 85. Difficulty in understanding geologic history and difficulty in diagramming geologic structures ranked fourth and fifth, respectively. These responses formulated by the students show that they have difficulties grasping geological time and space. This result is corroborated by the difficulty of the sixth rank, where students feel that geological phenomena are complex and difficult to conceive. At the bottom of the ranking, with a weight of 20, is the way the teacher explains the course. Finally, and as a logical result of all the above difficulties, the students announced in eighth place the difficulty of answering the questions of the test.

3.2 Focus Group

The data collected by this technique are presented in the following table:

Table 3. Student problems and difficulties encountered by experts when teaching plate tectonics

The problems and difficulties
-1: Lack of imagination and abstraction;
-2: The teaching of LES in the French language;
-3: Students find it difficult to assimilate geological concepts and phenomena and to relate them to plate tectonics, such as subduction, oceanic expansion, speed of plate movement, and formation of mountain ranges... ;
-4: Difficulties to understand plate tectonics in its real dimensions and to locate oneself in time and space;
-5: Difficulties in understanding the origin and nature of the forces responsible for the movement of plates;
-6: Difficulties in differentiating between plate tectonics and continental drift;
-7: Absence of prerequisites;
-8: Lack of motivation;
-9: Students have misrepresentations about the structure of the earth.

In addition to certain problems and obstacles already evoked by the NGT method, namely difficulties in assimilating geological concepts and phenomena and in putting them into their real dimensions, difficulties in locating oneself in geological time and space, and the lack of motivation of the students, Other new problems were detected among the students by the focus group method, such as the lack of imagination and abstraction, the teaching of life and science in French, the absence of prerequisites, the erroneous representations of the structure of the earth, and the difficulties in differentiating between plate tectonics and continental drift.

3.3 Questionnaire

The data collected by the questionnaire are coded and processed using SPSS statistical software. The results are presented in tables and graphs. To present and analyze these results, we will adopt the following method: First, we will begin by citing the question we asked the students and its purpose. Then, we will present the results. Finally, we will analyze, interpret, and discuss these results.

Question 1: The results of this question, which concerns the profile of the respondents, are shown above in the paragraph "the study sample".

Question 2: *During the life and earth sciences sessions, you are better motivated when studying geology or biology.*

The objective of this question is twofold: on the one hand, to find out the percentage of students motivated to study geology compared to biology and, on the other hand, to detect the impact of the language of instruction on this choice. Figures 1 and 2 present the results obtained.

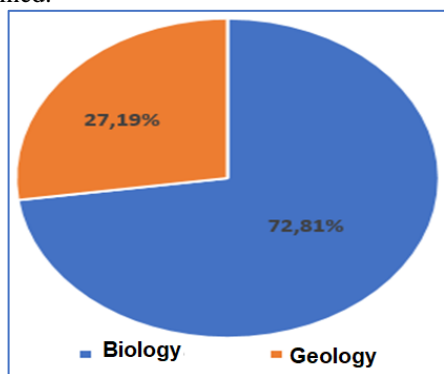


Figure 1. Student's choice between biology and geology.

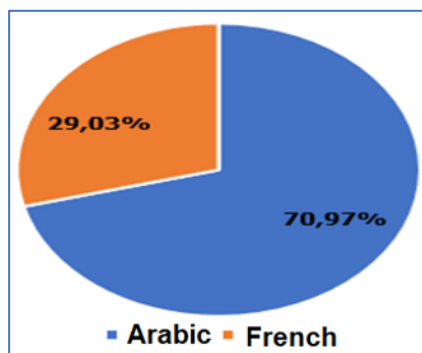


Figure 2. Impact of language of teaching on student's choice of geology.

The majority of the students surveyed (72.81%) are better motivated by biology compared to 27.19% for geology, which shows that geology is a subject less preferred by the learners. This situation is exacerbated if the teaching is in the French language. Indeed, among the students who like geology, 70.97% of them study in the Arabic language compared to 29.03% only in the French language. Thus, for many students, the teaching of geology in French is a problem and an obstacle to overcome.

Question 3: *What type of LES course do you prefer? (Choose only one answer.)*

- courses with paper documents; or
- courses with animations: video, flash, ...; or
- courses with explanatory models.

This question was correlated with the first difficulty identified by the NGT: "Lack of practical studies (field trips, real observation), explanatory models, tools, samples, and ICT". Thus, the respondents chose one of the three types of LES courses proposed. Figure 3 shows the results obtained.

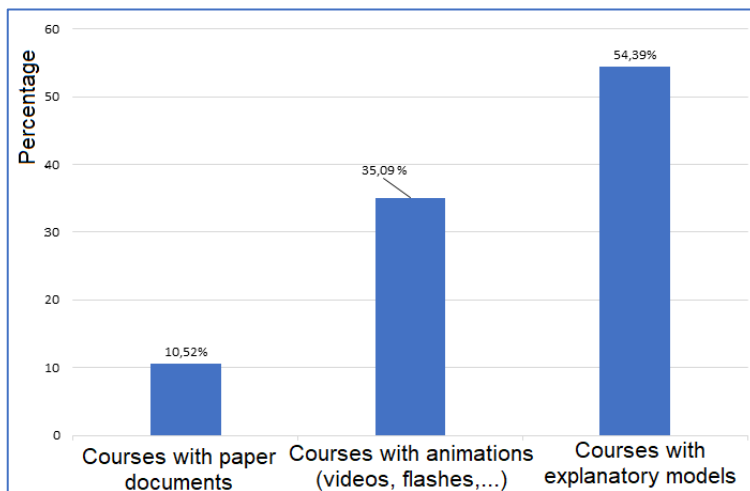


Figure 3. Types of LES courses preferred by students.

The majority of the respondents (54.39%) prefer courses with animations (videos, flashes, etc), and 35.09% of the students prefer courses with explanatory models. However, only 10.52% of the respondents liked traditional courses with paper documents. These results implicitly show that the absence of animations and explanatory models in the teaching of geological phenomena could cause learning difficulties. Indeed, several studies judge positively the integration of explanatory models and ICT in the teaching of LES, especially geology [3, 14, 15, 31]. These results confirm the findings already discussed above.

Question 4: During plate tectonics: (choose only one answer)

-the continents slide on the oceanic crust; or -fragments of the lithosphere move on the asthenosphere; or -the constituents of the earth are static; or -I don't know.

This question aims to find out the learner's conception of plate tectonics.

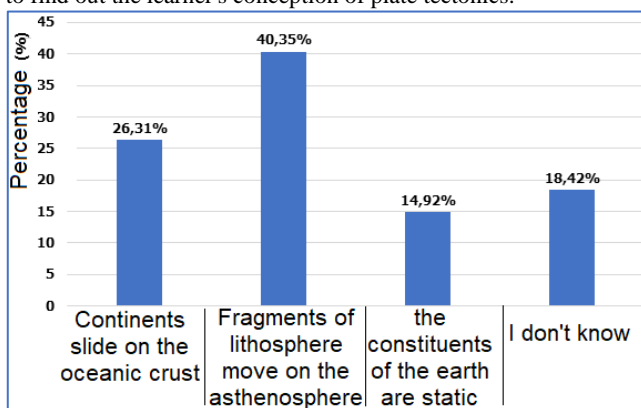


Figure 4. Learner's conception of plate tectonics.

Less than half of the respondents (40.35%) gave a correct answer. They consider that during plate tectonics, fragments of the lithosphere move on the asthenosphere. On the other hand, the rest of the respondents chose invalid propositions. Indeed, 26.31% of them have an outdated conception of continental drift. They considered that the continents slide on the oceanic crust. For 14.92% of the students, the constituents of the earth are static, and 18.42% answered "I don't know".

The previous results show that, for some learners, the static view of the earth (fixism) appears to be an epistemological barrier to learning. These learners, who believe that the earth is fixed, might provide a religious explanation for their view [12].

Question 5: The main limits of a tectonic plate are: (choose only one answer)

- seas and oceans; or - ribs; or - divergence zones; or - convergence zones and sliding zones; or - I don't know.

This question tests the extent to which learners have difficulty determining the different boundaries of a tectonic plate. The results found are presented in Figure 5.

Only 46.49% of the surveyed students chose the real possible boundaries of a tectonic plate, namely divergence zones, convergence zones, and sliding zones. While 42.10% consider seas, oceans, and coasts as boundaries of tectonic plates. This last result reveals that the respondents have difficulties determining the different limits of a tectonic plate and locating themselves in space. This finding is reinforced by the percentage of students (11.41%) who answered "I don't know".

Learners' difficulty in apprehending geological space has been mentioned in several research works [32, 33, 34]. These studies have shown that students have difficulties locating themselves in space and apprehending the dimensions of geological structures when moving from plane (2D) to volume (3D) and vice versa. However, spatial skills in geology are extremely important for understanding many geological structures and phenomena [35].

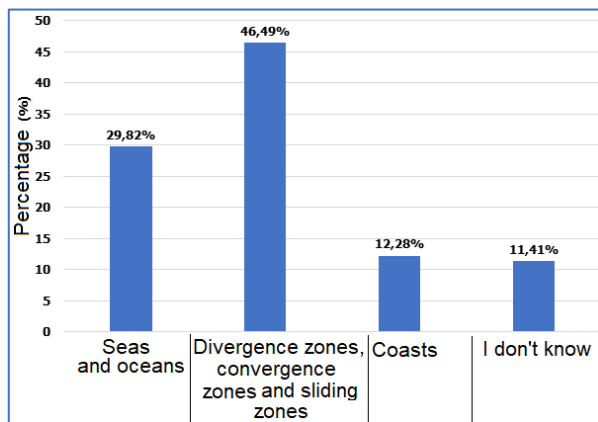


Figure 5. Possible boundaries of a tectonic plate

Question 6: The tectonic plates are: (choose only one answer)

- static; or - moving from a few millimeters to a few centimeters per year; or - moving a few meters per year; or - I don't know.

This question determines how learners estimate the dynamics of tectonic plates. Indeed, almost half (50.88%) of the students gave an answer that corroborated current scientific findings. They think that tectonic plates are moving a few millimeters to a few centimeters per year. However, the rest of the respondents believe that the tectonic plates are static (13.15%) or have a dynamism of the order of a few meters per year (26.32%). In addition, 9.65% of the students do not have an answer.

These results provide evidence that half of the surveyed sample shows difficulties in appreciating the speed of tectonic plate movement. Indeed, for some learners, it is difficult to grasp the dynamism of geological phenomena that occur at unobservable speeds [7].

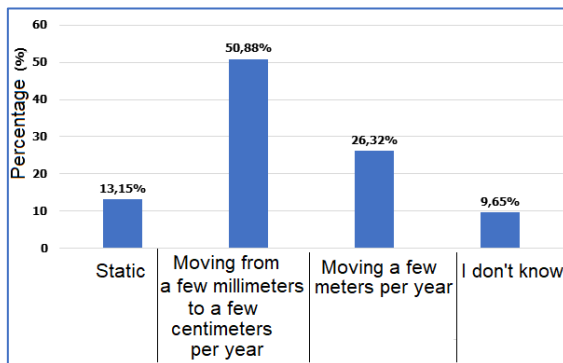


Figure 6. Dynamism of tectonic plates according to students.

Question 7: The formation of a mountain chain requires: (choose only one answer.)

- hundreds of years; or - thousands of years; or - millions of years; or - I don't know.

This question was asked to find out how learners estimate the time of geological phenomena, such as the formation of mountain ranges. The results obtained are presented in Figure 7.

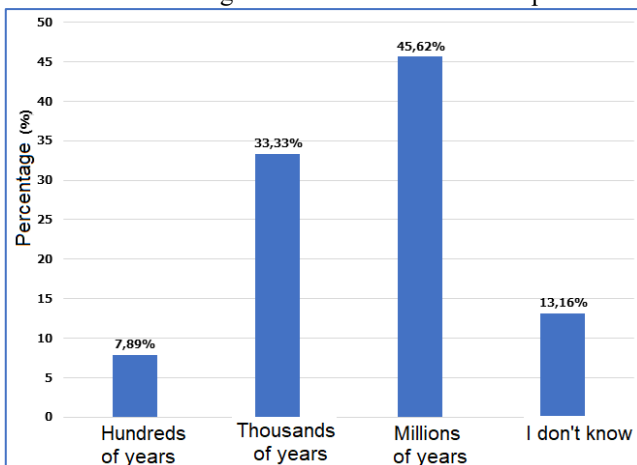


Figure 7. Geological time of formation of a mountain range

45.62% of the students chose the right answer. They think that the formation of a mountain range requires millions of years. The rest of the respondents show difficulties related to geological time. Indeed, 33.33% of them believe that a mountain chain is formed over thousands of years, and for 7.89%, this formation requires only hundreds of years. Moreover, 13.16 percent of the students do not give an answer.

Several research studies [12, 32, 34, 36] have discussed the difficulties learners face in addressing the long history of geological processes. Indeed, the slow pace of geological phenomena makes them almost imperceptible compared to the human scale. Thus, it is difficult to appreciate the duration of geological events that occur over a geological time span.

Question 8: Give a legend diagram of a volcano.

The objective of this question is to know the type of conception of volcanoes developed by the learners on the one hand and to estimate the extent of their difficulty in making an illustration of a geological phenomenon on the other. According to the typology developed by Orange, there are three types of conceptions of volcanoes: local, central, and global [37].

The categorization of the students' productions according to these conceptions gave the results presented in Figure 8.

The majority of learners (77.19%) have a local conception (Figure 9). For them, volcanoes are related to local phenomena. They manifest themselves in the form of fiery mountains that contain flammable materials within them [36]. According to this conception, the magma reservoir is placed inside the volcano, and the operation of volcanism is independent of that of the globe [12].

7.89% of respondents express the central conception (Figure 10). According to this conception, molten material inside the earth violently escapes to the surface of the globe [37]. According to Chalak and El Hage [12], both local and central conceptions are barriers to learners learning about volcanism.

Furthermore, no interviewee expressed a global conception. However, this conception links volcanism and plate tectonics. It postulates that magma is the product of a partial fusion that takes place in specific places under well-determined conditions. In addition, 14.92% of the students answered, "I don't know". These students, therefore, express their difficulty in drawing a volcano.

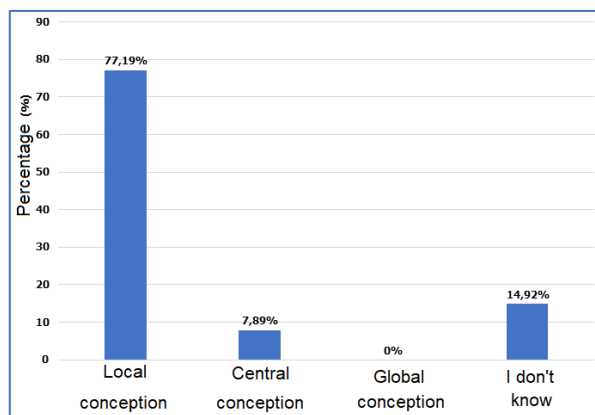


Figure 8. The type of conception of volcanoes among learners

The previous results clearly show the difficulty of the students surveyed in correlating volcanism and plate tectonics. It seems to us that these students only consider the surface part of the volcano without reference to tectonic plates and without the need to situate the volcano in a broad environment about the planet Earth, as suggested by the global view. These results are consistent with those in the literature review [37, 38].

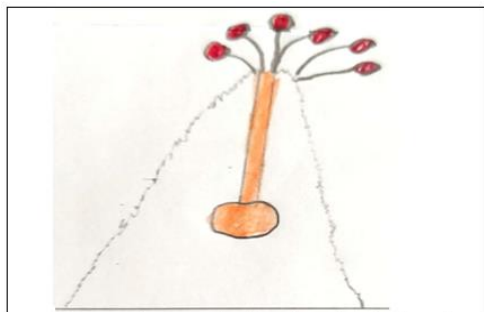


Figure 9. Student production showing the local design of the volcano.

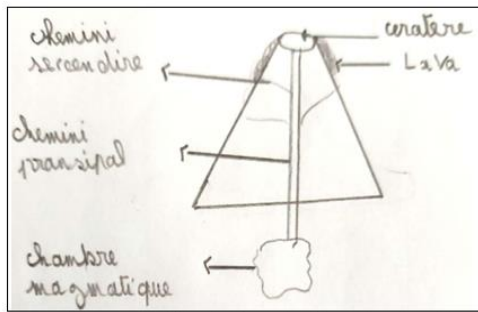


Figure 10. Student production showing the central design of the volcano.

Question 9: Defining a tectonic plate.

To highlight the difficulty of forgetting and memorizing for the learners, we ask them to formulate a definition for a tectonic plate. The results obtained are presented in Figure 11. 64.04% of the surveyed sample answered "I don't know", and no student managed to give a complete and correct answer. However, 18.42% of the definitions are wrong, and 17.54% are incomplete. These results affirm the problem of forgetting and memorization. They reveal that scientific knowledge passes on the surface to students, probably because it is transmitted in a propositional and dogmatic way, far from any scientific debate and problematization. Moreover, knowledge that does not pass well to learners is quickly forgotten [39].

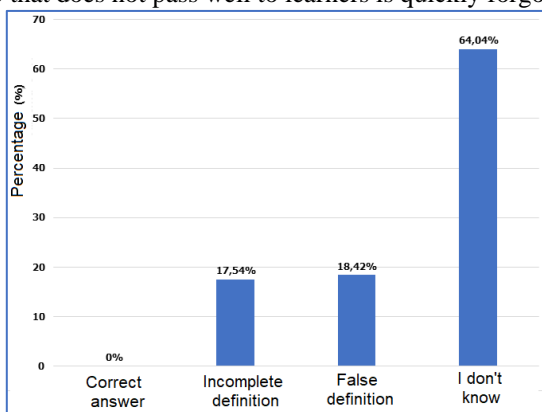


Figure 11. definition of a tectonic plate

4. Conclusion

This study aimed to diagnose the difficulties related to the learning of concepts related to plate tectonics by following a hybrid methodology of three techniques, namely the discussion group, the nominal group technique, and the questionnaire. The analysis and interpretation of the results that we carried out allowed us to detect all of the difficulties met by the Moroccan secondary school students during the learning related to the tectonics of the plates. These difficulties affect the educational act in its different facets, whether epistemological, pedagogical, didactic, curricular, or logistical.

Indeed, teachers and students agree on the same learning difficulties, namely:

- The difficulty in understanding the geological space-time scale and in situating geological events in the appropriate time and space;
- The difficulty of apprehending the dynamism of geological phenomena appearing static at the human scale and overcoming the obstacle of fixism;

- The difficulty in assimilating abstract concepts and conceiving complex geological phenomena, such as subduction, oceanic expansion, the formation of mountain ranges, and volcanism, ... ;

- Lack of scientific and technical teaching equipment and resources (explanatory models, tools, samples, and ICT);

- The absence of geological excursions and practical activities;

- Lack of motivation and participation among students.

Furthermore, teachers mention the lack of imagination and abstraction among students, the lack of necessary prerequisites, the difficulties in differentiating between plate tectonics and continental drift, and the presence of erroneous representations of geological structures and phenomena. In addition to these difficulties, there is the problem of teaching life and science in the French language.

In addition, the students, for their part, mention the difficulty of schematizing geological structures, the problem of inadequate teaching methods and techniques adapted in class by their teachers, and the difficulty of answering test questions.

The results of this study allow for a comprehensive view of the set of difficulties that hinder the learning of geological concepts related to plate tectonics. These difficulties should be taken into consideration, by the different actors in the educational act, to guarantee successful learning of this discipline.

To complete this work and reinforce its results, a study dealing with teaching difficulties seems necessary.

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