



**THE IMPACT OF NUMERICAL SIMULATION ON GEOLOGY LEARNING.
A CASE OF OCEAN EXPANSION IN MOHAMMED IV HIGH SCHOOL, MARTIL
CITY, MOROCCO**

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ABSTRACT

In the official texts of the teaching of geology in Moroccan high school observation, experimentation, modeling, and geological field trips occupy a prominent place. Since geological phenomena are complex, abstract, and inaccessible for direct apprehension. However, high school teachers encounter challenges due to the lack of geology training and the insufficient availability of necessary materials. This research aims to assess the impact of a numerical simulation on the learning of the ocean expansion. It is based on a semi-experimental study using a pre-test and a post-test with two groups of students each consisting of the same number (n=12) of the Mohamed IV high school in the city of Martil in Morocco. The results were analyzed and compared using the Student T-test, revealing that the incorporation of numerical simulations can facilitate the understanding of complex geological phenomena.

INTRODUCTION

The construction of knowledge by learners is a crucial skill, particularly when debates are initiated to argue its validity. (Lang, 2019). However, it has been observed that the traces of these debates tend to be erased, in traditional teaching, in favor of the desired solutions (Limat, 2021). In this perspective, skills related to the development of geology learning become a major issue. (Girault, 2019). According to Rassou, Khiri, Benbrahim, Tamraoui, Elberrani, & Anfour, (2017), the teaching and learning of geology encounter several challenges for both students and teachers. These are the continuing education of high school teachers in geology, the complexity of the geological content, the insufficient hourly volume dedicated to it, and the relationship that geology has with time and space. The lack of interest in the study of geology, as shown by the small number of students enrolled in earth and sciences at universities, highlights

the necessity for adopting new curricula incorporating innovative teaching approaches and tools.

To address these challenges alternatives and multiple didactic variants, justifiable according to the objectives of the moment (Astolfi, 1991). In the education system of Morocco, the National Charter of Education and Training has given importance to ICTs for the renovation of the education system (Lever 10, Articles 119 and 121).

In this context, numerical simulations constructed from collaborative efforts of researchers in didactics, have many advantages to apprehend complex scientific phenomena (Sigrist, 2019). These new technologies allow a mode of teaching that transcends time and space enabling the exchanges of knowledge between teachers and learners. Therefore, they constitute innovative means, not only for the transmission of knowledge, but also for the exploration of training strategies to promote the development of new skills (Ngouloure, 2015). In this perspective, new technologies play a pivotal role in promoting learning autonomy, self-assessment ability,

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and accelerating the process of interaction between learners and teachers by developing great potential to improve student learning. (Le Bouil, 2022). In high school experimental science teaching, these technologies can simulate real phenomena, create study models or virtual experiences, allowing learners to engage in observational debates that establishes connections between study variables leading to development of new knowledge (Marzin-Janvier and Kermen, 2015). Similarly, numerical simulations are considered as a didactic tool for solving complex problem situations and as an alternative to inaccessible experiments (Didier, & William).

Thus, the use of these simulations is highly solicited to simplify complex cognitive tasks (Désilets, & Tardif, 2015) by aligning dynamic reality with abstract scientific phenomena in the classroom (Bouchereau, 2020). Therefore, they can activate basic procedural skills among science students, such as observing, measuring, communicating, classifying, and predicting (Karsenti, 2019). Additionally, the contrite to the development of the methodological procedural skills, nurturing the scientific mind of learners, such as: formulating hypotheses, designing explanatory hypotheses, carrying out practical manipulations, analyzing and interpreting data, and formulating models. (Perron, 2018). According to Jebeile (2016), these numerical simulations enable students to acquire skills in scientific communication, data interpretation and variable control in simulated experiments. They can also be viewed as a strong link between empirical models and tangible material expressions of studied phenomena (Flichy, 2017). Beyond their roles in modeling phenomena inaccessible to direct observation, such as those of geology, they can also enhance learning when integrated into concrete experiments. (Rassou, Khiri, Benbrahim, Tamraoui, Elberrani, & Anfour, (2017). In light of these, the use of simulations emerges as the most effective alternative to reconstruct the local or regional pale environment and chronology of complex geological phenomena. However, and according to Neggez and Habis (2021), approaches, processes and techniques related to the use of digital tools must be integrated into the definition of ICT.

PROBLEMATIC

A literature review of the studies conducted worldwide has revealed various challenges associated with geology teaching:

-Institutional difficulties

The geology teaching curriculum prescribed in the official instructions of the Moroccan education system does not align with the curriculum realized in class. The official recommendations for geology teaching in high schools emphasize observation, experimentation, modeling, and geological output. However, high school teachers are confronted with the lack of geology training and the problems of lack or shortage of necessary materials.

-Pedagogical and didactic difficulties

While the official instruction for If the official instructions of geology teaching in high schools clearly define the disciplines objectives, there is a notable neglect in the processes of implementing sortable study approaches to comprehend geological concepts. Additionally, in textbooks, the curriculum of geology education focuses on teaching objects that do not refer to teaching practices. Moreover, these teaching objects deal only with general geology, which does not allow, the apprehension of local geology. This observation is further substantiated by interview results obtained from baccalaureate holders and fundamental licensees during the entrance examination to our institution to train in the didactics of the life and earth sciences. These candidates were unable to give us examples of rocks in their regions. -Furthermore, difficulties arise from the specific relationships geology has with time, space and other disciplines:

-Difficulties related to time:

- Grasping the immensity of time during which the geological phenomena too place (Coellier, 2019).
- Developing diachronic reasoning.
- Understanding the role of contingency in geological history.
- Grasping the dynamics of phenomena with observations hindered due to slow production (Sanchez, 2006).
- Overcoming difficulties related to fixism, which constitutes a major obstacle to the understanding of dynamic phenomena that seem static on a human scale (Rassou, Khiri, Benbrahim, Tamraoui, Elberrani, & Anfour, 2017).

In terms of difficulties related to the relationship between geology teaching and space, challenges include understanding different scales and orienting oneself in space while considering the three dimensions for a comprehensive grasp of the structure of the earth and its dynamism. (Moine, 2006).

For difficulties related to the interaction of geology with other sciences, such as biology, chemistry, mathematics and physics, the adoption of the interdisciplinary approach allows teachers to enable establish connections between these different disciplines to apprehend common objects of study.

Overall, geology education faces functionalist and chronological problems (Maurines and Orange Ravachol, 2016). To address these problems, in this research, we propose the integration of new technologies and modeling to comprehend complex geological concepts. Specifically, a digital simulation, incorporating a pedagogical scenario on ocean expansion, is introduced to facilitate understanding among students of the Mohamed IV high school in the city of Martil (Morocco).

Therefore, this study attempts to find answers to two keys questions:

-Does this numerical simulation have an add value to the quality of learning related to ocean expansion in high school?

-Is this potential added value related to the procedural pedagogical activities that make these numerical simulations a methodological tool that improves the learning conditions of the concept of ocean expansion?

METHODOLOGY

To assess the impact of a numerical simulation of ocean expansion on the improvement of learning conditions in secondary education, we conducted semi-experimental research using pre-test and post-test methodologies. The experiment tools place Mohamed IV high school in the city of Martil (Morocco), involving a sample of 24 students divided into two groups of the same number. The control group (n=12) and the experimental group (n=12). Both groups received a geology course dealing with ocean expansion under very similar teaching conditions in hollowing official instructions.

In the initial phase of consisting the study, and to ensure their equivalence of the groups, students were subjected to test consisting of 3 questions each evaluating or one of the first three learning objectives of Bloom's taxonomy with a low level of difficulty. Question 1,

category of knowledge, focused on the nature of rocks that make up the oceanic crust. Question 2, category understanding, deals with the difference that exists between the oceanic crust and the oceanic lithosphere. Question 3, category analysis, required students to utilize of mineralogical analyses of different rocks of the oceanic lithosphere to propose hypotheses to explain the processes of its formation. This pre-test was conducted in the class of the Mohammed IV high school with duration of using the half an hour, and the data collection was operated once students completed their work. The results of both groups of students were analyzed using descriptive statistical method, followed by a comparison using the student T-test to determine statistical significance.

In the second phase of the study, aimed at enhancing studies skills, both groups were confronted with two highly structured questions to explain the mechanism of ocean expansion. The control group of students answered these questions under traditional conditions, while the experimental had the chance to respond using a numerical simulation focused on ocean expansion, following an educational scenario (Document 1). The tutorial was run in pairs by computer in the school's multimedia room. Pedagogical support was given to these students throughout the entire duration of the relevant pedagogical activities.

Document 1: Pedagogical Scenario for the Pedagogical Exploitation of Digital Simulation on Ocean Expansion.

- Prerequisites of students include understanding the drift of continents and the hypothetical theory presented by Alfred Wegener in 1912.
- The exploration of solid arguments in the ocean floor is based on the explanatory theory of plate tectonics developed in 1960, incorporating:
 - Contributions from the study of oceanic topography and variations in thermal flux at the level of the ocean floor.
- The scenario involves utilizing Seabed Mapping Data to locate Oceanic Ridges and Abyssal Plains.

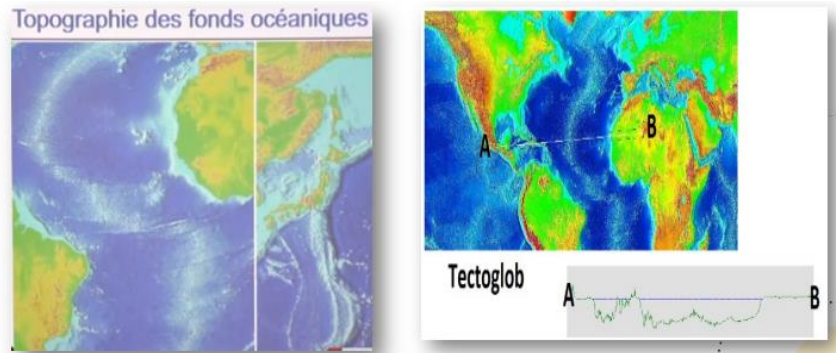


Fig1: Topography of the ocean floor.

- Thermal flux variation data reveal significant thermal flux at the ridges and notably at the abyssal plains.

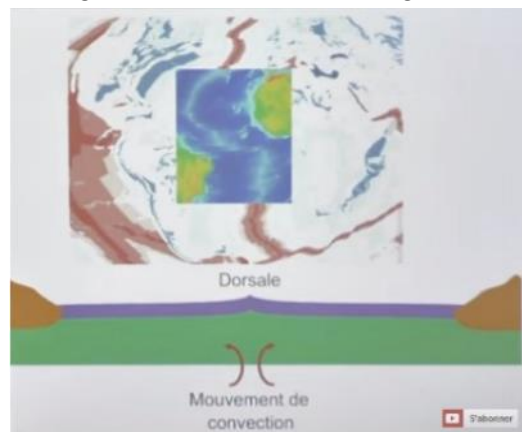


Fig2: Variation in thermal flux at the bottom of the oceans.

A possible hypothesis of ocean expansion the occurrence at ocean accretion:

- Through deep convection currents in the mantle. To confirm this hypothesis, verification experiments was designed; produced and interpreted using a Bain Marie set up involving water heating and a wooden plate.

Confirmation experience: Design, production, and interpretation: Bain Marie: water to heat, piece of wood plate.

In the search for concrete arguments for ocean expansion, the contributions of pale magnetism were explored to verify the previous hypothesis of ocean expansion:

- The magnetic field is not stable over geological time. It has undergone magnetic reversals.
- The formation of volcanic rocks during magma cooling, which records the surrounding magnetic field.

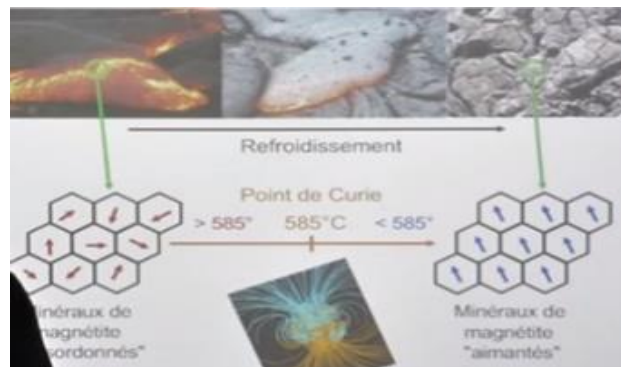


Fig3: Magnetism of basaltic rocks during their cooling.

- This paleomagnetism can be measured by magnetometers. In the 1960s, surveys conducted at the ocean floor level enabled us to measure the ambient paleomagnetism in basalts. Basalts with a white band recorded a normal polarity, while basalts with a Color band recorded reverse polarity.

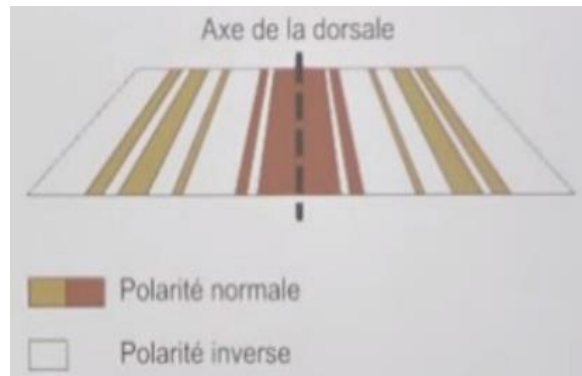


Fig4: The magnetic polarity of basalts on both sides of the dorsal.

A symmetrical and parallel distribution of normal and reverse polarity bands is observed on both sides of the dorsal. To conform the hypothesis of the ocean

expansion, an examination was conducted of the of basalt magnetic anomalies on both sides of the oceanic ridge:

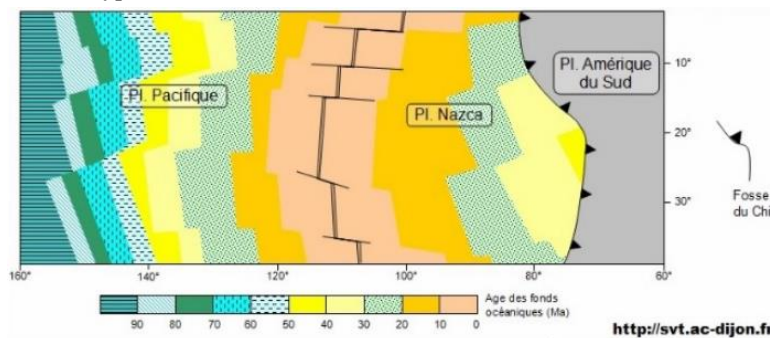


Fig5: The age of basalt anomalies on both sides of the dorsal.

- Basalts getting older as we move away from the oceanic ridge, ocean expansion and providing the opportunity to calculate the rate of ocean expansion.
- Ocean expansion confirmed with possibility to calculate ocean expansion rate.

Explanatory model of ocean expansion using a sophisticated numerical simulation, accessible in https://drive.google.com/drive/folders/1-pJAvJDv9BDK_Yy1okS3je7TKT0bewYH



Fig6: Screenshot of numerical simulation

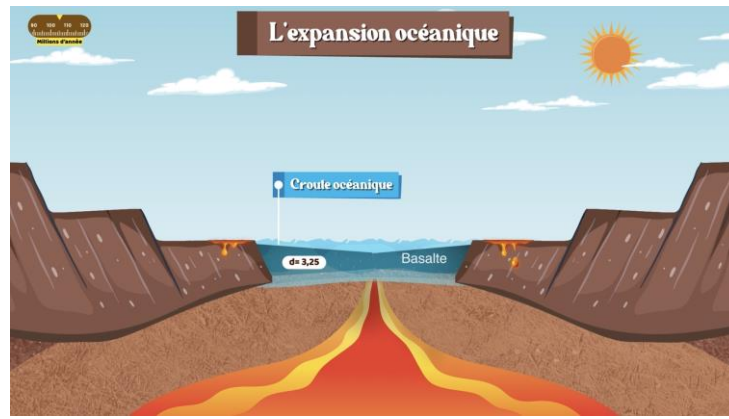


Fig7: Screenshot of numerical simulation

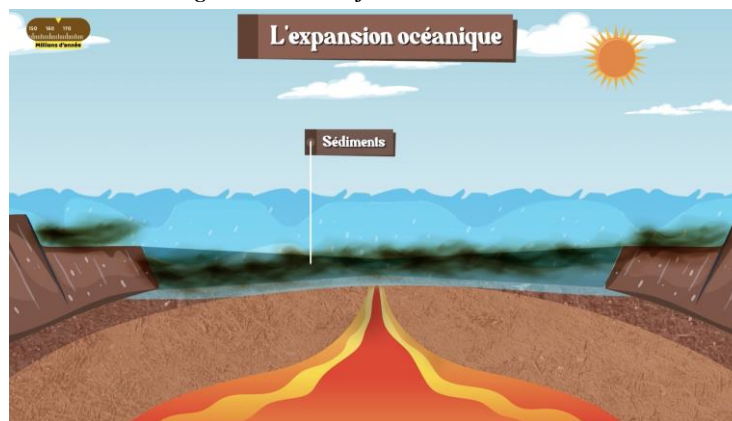


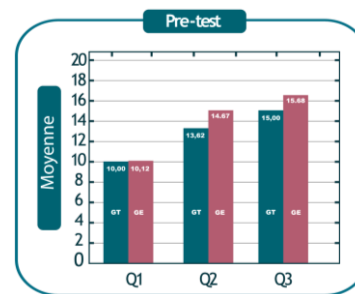
Fig8: Screenshot of numerical simulation

After completing the proposed pedagogical activity, both groups were invited the two groups to answer the post-test questions, designed in alignment with the program, language of instruction and cognitive learning objectives outlined in the official recommendations. These questions were chosen to assess the learning objectives in Bloom taxonomy of high difficulty level. Question 1, falling under application category required students to utilize the petrological and chemical characteristics of oceanic crust basalts. Question 2, categorize synthesis and evaluation consists in explaining, using both a diagram and text, the phenomenon of ocean expansion.

Data were collected in the classroom and analyzed using IBM SPSS: Statistical Analysis Software. The student test was used to compare groups representing two independent samples with an alpha level of 0.05 used in all analyses.

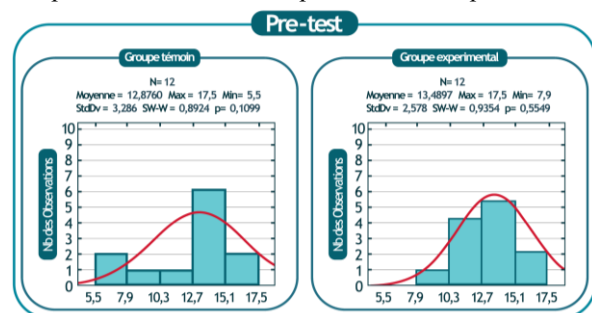
RESULTS AND DISCUSSION

Pre-test results are presented in graph 1, illustrating for both groups.



Graph 1: comparison of the means of the pupils' grades in the two groups to the three questions of the pre-test.

The means of the grades for both student groups exhibit slight variation in both questions 2 and are almost identical in question 1. To attribute statistical significance to these results, we suggest a study of a normality test for this pre-test. The results are presented in Graph 2.



Graph 2: Descriptive statistics and normality tests (pre-test).

The analysis of the results from this graph implicates that the average score of the students in the experimental group during the pre-test is $m=13.4897$ ($s=2.878$) while that of the students in the control group is $m=12.8760$ ($s=3.286$). The difference between the two averages is approximately 0.6137 . To ascertain whether this difference is significant to reject the null hypothesis that no significant difference existed between the two groups at the time of test. We used the student t-test to compare the means of two independent samples with a normal distribution as indicated by a non-significant p-value of Shapiro-Wilk in graph 2. The results of the comparison are presented in Table 1:

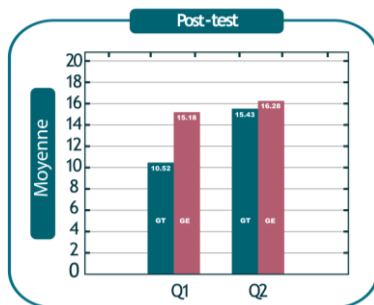
Table 1: Independent Sample T Test (Pre-Test)

Variables	Pré-test
Moyenne GE	13,4897
Moyenne GT	12,8760
t-value	0,6137
ddf	24
p	0,657
F-ratio variances	1,5256
P Variances	0,4057

From the obtained results, it can be concluded that the two variances are considered homogeneous since the F-ratio is not significant ($F=1.5256$). Given that the calculated p-value ($p=0.657$) is higher than the selected alpha level (0.05), the null hypothesis H_0 is retained. Therefore, it can be stated that there was no significant difference between the two tested groups. This outcome validates allows us to validate our experimental model which is based on a pre-test and post-test.

Post-test results:

Descriptive data for the post-test results of both the control and experimental groups are presented in Graph 3 below:



Graph 3: Comparison of the means of the grades of the students of the two groups to the two questions of the post-test.

For question 1 of the post-test, the average grades of students in the experimental group are higher than those of students in the control group. However, for the second question of this test, the average is almost equal in both groups of students. To attribute statistical significance to these results, we suggest conducting a normality test study for this pre-test. The results are presented in Graph4.

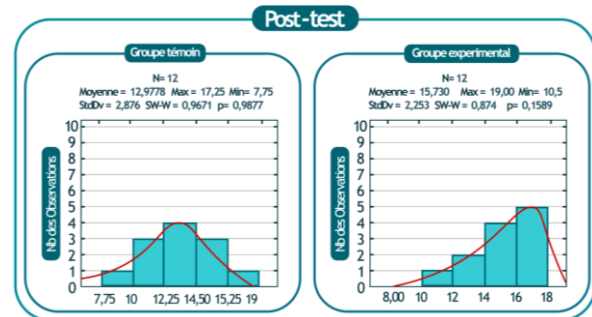


Figure 4: Descriptive statistics and normality test (post-test)

The results clearly indicate that the average score of students in the experimental group for the post-test is $m=15.730$ ($s=2.253$). Whereas that of students in the control group is $m=12.9778$ ($s=2.876$). The difference is approximately 2.7522 . To check if this difference is significant and to reject the null hypothesis that the educational system tested had no effect on students results, the student T-test was employed. The difference between the means of two independent samples with a normal distribution as indicated by a non-significant p-value at Shapiro-Wilk in figure 4. The results of the comparison are presented in Table 2:

Table 2. Independent Sample T-Test (Post-Test)

Variables	Post-test
Moyenne GE	15,730
Moyenne GT	12,9778
t-value	2,7522
ddf	24
p	0,007
F-ratio variances	1,5174
P Variances	0,4291

According to this table, the variances can be considered homogeneous ($F=1.5174$, ns) and the p-value is much lower than the selected alpha level ($p=0.007 < 0.05$). This allows us to reject the null hypothesis and admit that the integration of numerical simulation in a learning situation of ocean expansion has evenly had a positive effect on student performance.

CONCLUSION

The purpose of geology teaching is to explain how the Earth works and to establish a chronology of geological events. This is a challenging teaching that involves working at various spatial and temporal scales often difficult to comprehend as geological events are inaccessible. This study sheds light on the use of new technologies in secondary education to understand the phenomenon of ocean expansion. It is therefore part of the field of applied didactics to overcome the difficulties faced by both students and teachers. The integration of numerical simulations and its pedagogical scenario facilitated the concept apprehension among students the experimental group of Mohamed IV high school.

While acknowledging the limitation of our small study sample, we believe that the results obtained can be generalized to a large target audience provided these new technologies, especially numerical simulations, are integrated, into study approach aimed at developing of the scientific mind in students. The findings of our research overlap with those previous studies conducted in the Moroccan educational context highlighting the positive impact of the pedagogical exploitation of the multimedia tools on student learning. Based on our research, we identify several avenues that could lead to a facilitation of learning.

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