TÜRK FEN EĞİTİMİ DERGİSİ
Yıl 15, Sayı 1, Mart 2018

Journal of
TURKISH SCIENCE EDUCATION
Volume 15, Issue 1, March 2018

http://www.tused.org

# Impacts of the Use of a Digital Simulation in Learning Earth Sciences (the Case of Relative Dating in High School)

Youssef NAFIDI[1] , Anouar ALAMI[1] , Moncef ZAKI[1] , Bouchta EL BATRI[1] , Hanane AFKAR[2]

[1] Interdisciplinary Laboratory of Research in Didactics of Sciences and Technology, Faculty of Sciences Dhar Mahraz—Sidi Mohammed Ben Abdellah University. B.P. 1796 Fès-Atlas, 30003 Morocco
[2] Regional Centre of Training and Education (CRMEF), Fez-Meknes Region (Morocco)

**Received:** 06.03.2017 **Revised:** 26.10.2017 **Accepted:** 08.11.2017

The original language of article is English (v.15, n.1, March 2018, pp.89-108, doi: 10.12973/tused.10223a)

## ABSTRACT

In an attempt to evaluate the impact of the use of a simulation on the learning concepts of relative dating, a study was carried out with first year students at the Technical High School of the city of Taza (Morocco). The method of the study was semi-experimental research design with pre-test and post-test. The study used two groups including the experimental (n = 16) and control (n = 16) groups. The learning outcomes of both groups of students were compared and analysed for significance using the Student's t-test and the Mann-Whitney U test. The findings showed that the integration of a simulation of relative chronology can have a positive effect on students' learning if it is properly integrated at an appropriate time during the students' training.

**Keywords:** Earth Sciences, relative chronology, high school, learning, simulation.

## INTRODUCTION

Information and Communication Technologies (ICT) bring innovative means, not only for the transmission of knowledge, but also for the exploration of training strategies, which promote the development of competences (Lebrun, 1999 ; Perreault, 2003). Some interesting research has focused on the pedagogical utility of the use of educational software. (Bransford *et al.*, 2000; de Jong *et al.*, 1998). These technologies showed a great potential to improve students' learning if they are well integrated in an applicable educational context. These tools, among others, facilitate the use, the treatment and the production of information (Bransford *et al.*, 2000; Depover, *et al.*, 2007; Kutluca *et al.*, 2010).

Among the most promising means in the teaching of experimental sciences, we certainly find simulations intended for learning in face-to-face or in the context of distance education (Bibeau, 2005). These educational applications can simulate real phenomena while creating models or virtual experiments, allowing learners to control the variables, to formulate

Corresponding author e-mail: alamianouar@yahoo.fr © ISSN:1304-6020

some hypotheses, to interpret data and to facilitate the understanding of the complex phenomena (Roth et al., 1993; Rutten et al. 2012; Droui et al., 2013). The simulations are also considered like a tool for the resolution of the problems (Droui et al., 2015) and an alternative to the inaccessible experiments (De Jong, 1991; Strauss et al., 1994).

Several studies in teaching are interested in the use of computer simulations in the teaching of sciences to further promote learning. In this perspective, the use of simulations is very appropriate for carrying out simplified procedures and cognitive tasks (Grabe *et al.*, 1996) and reducing the gap between the dynamic and complex reality of the phenomena under study and their simplified and static teaching in class (Wilensky *et al.*, 2000). In addition, simulations can activate basic procedural skills in science students, such as observing, measuring, communicating, classifying and predicting (Roth *et al.*, 1993), as well as procedural skills integrated into the scientific approach, like controlling variables, formulating hypotheses, interpreting data, experimenting and formulating models (Padilla *et al.*, 1983). Lazarowitz and Huppert (1993) have reported that computer simulation used in biology can allow the students to use the skills of graphic communication, data interpretation and variable control in simulated experiments, besides helping them improve these skills. Simulation can also be considered as an intermediate level between theoretical models and the material manifestations of the phenomena studied (Richoux, Saveltat and Beaufils, 2002). The use of students' geometric optics simulation software for understanding lens imaging has shown that simulations can play the role of a ‘cognitive bridge’ between theory and experiment (Buty, 2003).

Moreover, simulation can be used as an additional tool in the laboratory. For example, the combination of simulations and laboratory experimentation can save time by reducing the duration of the laboratory session (McKinney, 1997; Kennepohl, 2001; Gibbons *et al.*, 2004), support laboratory familiarisation (Dalgarno at al., 2009) and ensure a better understanding of the basic techniques and concepts used in laboratory work (Martínez *et al.*, 2003). In addition, simulations are not only useful for modelling systems that are difficult for students to observe in real life, but they are also more powerful in influencing the learning process when combined with real experimentation (Martin, 1997; Nuhoðlu *et al.*, 2007).

The use of simulations is the most promising alternative for experiments that we cannot achieve in the classroom (Mintz, 1993). In this sense, Strauss and Kinzie (1994) point out that simulations replace dangerous or costly experiments. Simulation can play an important role in providing opportunities to do virtual experiments. Moreover, problem-based simulations allow students to carry out their own experiments by formulating hypotheses and confronting them with observations, as well as build new knowledge and make sense of what they are learning (Droui, 2014).

Simulation provides scientific investigation environments and cognitive tools needed to apply problem-solving skills. It allows students to explicitly develop metacognition, and it allows them to reflect on their learning (Droui, 2014), to improve motivation and interest in the classroom (Martínez *et al.*, 2003) and to present themselves as an effective prediction tool (Lavoie *et al.*, 1988). And since non-verbal representations stimulate brain activity (Clements and McMillen, 1996), simulation can multiply the forms of representation (images, animations, graphs, and numerical data). By allowing the learner to choose the representations he or she prefers, it allows the learner to individualise learning, increase motivation and follow in the footsteps of learners during their learning (Cholmsky, 2003).

Simulation occupies an important place in Earth sciences. According to Stengers (1993), a new perspective is opened up by the computer as a simulation tool to study certain phenomena that are not reproducible in the laboratory. It is possible to work on small or large samples. When one is confronted with difficulties in understanding the dynamics of complex geological phenomena, it makes it possible to apply an explanatory model to a geological event of the past, and thus reconstruct a geological history of a sedimentary region. It also enables forecasting and studying the future development of a phenomenon (Sanchez, 2007).

**Statement of the problem**

Didactical research concerning the teaching of Earth sciences is not abundant in comparison to those that concern the teaching of other experimental sciences. However, they convergingly reveal the learning difficulties and obstacles facing the students during the assimilation of the geological data (Ault, 1994; Sanchez, 2008), in terms of understanding several complex geological phenomena related to stratigraphy, paleogeography, etc. …, these difficulties are largely associated with the reports that the discipline maintains with time and space (Gould, 1990).

The difficulties associated with the relationship between the Earth sciences and time are as follows: difficulties understanding the immensity of the time during which geological events take place, difficulties developing a diachronic reasoning (Dodick and Orion, 2003; Sanchez, 2003), grasping the role of contingency in geological history (Gould, 1990), and understanding the dynamics of phenomena whose observation is inaccessible due to slow production (Raab *et al.*, 2002) and to fixism, which constitutes a major obstacle to the understanding of dynamic phenomena that seem static on a human scale (Monchamp *et al.*, 1995). Learning difficulties in geology are also linked to the relationship between discipline and space, i.e. the difficulties understanding the different scales involved (Trend, 2000), getting oriented in space, moving from two-dimensional representations to three-dimensional representations or changing the reference frame of observation (Sanchez *et al.*, 2006; Lamarti *et al.*, 2009).

Overall, many learners have difficulties grasping the concepts of geological time (Yoon *et al.*, 2015). Dodick and Orion (2003) assert that an essential objective of geology is the reconstruction of the geological structures and systems that have been developed over time. Therefore, learners need to understand the geological time to deepen their understanding of the Earth's structure and systems. In order to overcome the learning difficulties that make students dislike and undermine the Geology subject (Gohau, 2001; Dodick *et al.*, 2003), Earth sciences teachers are urged to integrate technological innovation into their teaching practices.

This paper is a study in which students use a computer simulation (Chronocoupe) to overcome some of the difficulties associated with the assimilation of the concept of relative chronology in the Earth sciences. Chronocoupe is a numerical simulation that allows the learning of the relative chronology of the Earth sciences. It was developed by Gilles Fuxa and Eric Sanchez. It is free for educational purposes. We have chosen this tool because of its advantages: ease of use, conformity of the content to the official school program, the scientific reliability of its content and the good educational and instructive quality. Moreover, this pertinent simulation has been proposed for several years as an educational aid for candidates applying for the aptitude certificate of Second Degree Professorship in France.

The integration of the ICT in teaching is accompanied by a constant questioning of the expected and potential effects of these tools on the learning process. Studies related to pedagogical use of simulations show that these digital resources are useful for students' learning (Rutten *al.*, 2012; Smetana *et al.*, 2012). Based on these studies, in this research, it is aimed to determine the effect of the use of a digital simulation in learning Earth sciences (the case of relative dating) and to compare students' success. Accordingly, this study is an attempt to answer the following questions:

- Would the enrichment of the course of reconstruction of the geological history of a region based on the principles of relative dating by a computer simulation have a positive effect on the output of the students?

- Would it reinforce the development of certain cognitive operations?
- Could the pedagogical use of such tool help learners overcome learning difficulties related to the concept of relative chronology?

## METHODOLOGY

In order to identify the benefits of using ICT and in order to evaluate the impact of the use of simulation on learning, a semi-experimental design using a pre-test and a post-test was used. The experiment was carried at the technical school of Taza (Morocco). A sample of 32 students, from the first year of the baccalaureate, was chosen to participate in the study. The students were 17 years old. The experiment included two groups representing two different classes from the same school. The experimental group included 16 students, and the control group included 16 students.

The two groups of students received part of the course of geology corresponding to the relative dating under the same conditions of teaching respecting the official instructions. Then a pre-test (Appendix 1) was used with the two groups to make sure of their equivalence. This test is composed of five questions: the first one includes two closed sub-questions with a single choice, the second and third questions are closed – ordered answer category while the last questions are open. This instrument was developed and piloted with 15 pupils, and its reliability was estimated using the Cronbach alpha coefficient of internal consistency. It was found to have a reliability score of .780, indicating an acceptable reliability coefficient.

Then we opted for problem-based learning (PBL) to further strengthen students' cognitive skills by encouraging them to be more active and self-reliant. Students in both groups faced the same problem of reconstructing the geological history of an area from a geological section. Accordingly, the students had to apply the principles of relative dating based on an analysis of geometric relationships between geological structures to infer the relative chronology of the region. This pedagogical activity was guided by the teacher, who played a facilitating role.

During this activity, the control group solved the problem without using any computer environment, whereas the experimental group had the chance to solve the problem using a numerical simulation (Chronocoupe). This tool (cf.: figure 1) is a simulation designed to learn the methods used to establish a relative chronology. The learners are placed in a problem-solving situation to reproduce images of geological sections. This work leads them to determine the geometric relationships between geological structures, propose hypotheses on the relative dating of geological events at the origin of these structures and test these hypotheses by simulating their consequences. The educational software was exploited in binomial by a computer in the multi-media room of the establishment.

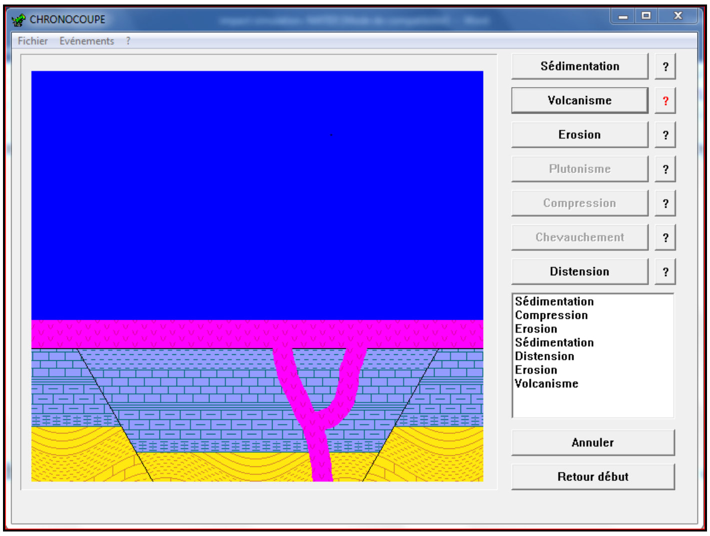



**Figure 1.** *Screenshot of Chronocoupe (simulation developed by Gilles Fuxa and Eric Sanchez)*

After finishing the teaching activity suggested, we invited the two groups to answer the questions of the post-test in a paper-pencil form (Appendix 2) to compare their answers. This post-test consists of six questions. According to Bloom's proven taxonomy, the first question, consisting of two closed multiple-choice sub-questions, is about knowledge acquisition, while the closed questions (2, 3, 4) and the open questions (5 and 6) are about application. At this level, the student must apply concepts in new situations and solve problems by investing the skills and knowledge required for relative chronology. The construction of the post-test was made by taking account of the program and the contents of the activity of PPBL suggested. This instrument was piloted with 15 pupils, and its reliability measured using the Cronbach alpha coefficient was satisfactory (α of Cronbach=0,709).

The data collected was then analysed with IBM SPSS statistics (statistical analysis software). The descriptive statistics, the Student's t-test (Gilbert *et al.*, 1992; D'hainaut, 1975) and the nonparametric Mann-Whitney U test (McKnight *et al.*, 2010; Nachar, 2008) were used to compare the groups representing two independent samples. A level of alpha of 0.05 was used throughout the analysis of the findings.

## FINDINGS

### a) Results of the pre-test

The results of the pre-test of the two groups are presented in Table 1 below:

**Table 1.** *Descriptive statistics (pre-test)*

| | Control group | Experimental group |
|---|---|---|
| N | 16 | 16 |
| Minimum | 6,00 | 8,50 |
| Maximum | 18,00 | 18,00 |
| Mean | 13,6094 | 14,0625 |
| Standard deviation | 3,41195 | 2,74393 |
| Variance | 11,641 | 7,529 |

It arises from the analysis of these results that the average score of the students of the experimental group in the pre-test is m = 14,06 (s = 2,74) whereas that of the students of the control group is m = 13,60 (s = 3,41); the difference is about 0.45. To check if this difference is significant and to reject the assumption that any significant difference did not exist between the two groups at the time of the pre-test, we used the t-test of the students to compare the averages of two independent samples having a normal distribution (p-been worth of Shapiro-Wilk is 0.068). The results of the comparison are presented in Table 2:

**Table 2.** *Independent Samples Test (pre-test)*

| | Levene's Test for Equality of Variances | | t-test for Equality of Means | | | | |
|---|---|---|---|---|---|---|---|
| | F | Sig. | t | dl | Sig. (2-tailed)) | Mean Difference | Std. Error Difference |
| Equal variances assumed | ,355 | **,556** | -,414 | 30 | ,682 | -,45313 | 1,09461 |
| Equal variances not assumed | | | -,414 | 28,680 | ,682 | -,45313 | 1,09461 |

According to this table, the p-value of Levene's test is p = 0.556, which is non-significant; the variances can be regarded as homogeneous since their difference can be explained by a pure result of the chance. The p-value of the t-test higher than the level alpha is chosen, one p-value of 0.68 does not involve rejection of the null hypothesis; one can, thus, estimate that there is not a significant difference between the groups tested, which is explained by the use of school management system, 'MASSAR', whose aim is to ensure equivalence between the groups at the time of the constitution of the classes. This result enables us to validate our experimental model based on a pre-test and a post-test.

**b) Results of the post-test**

The results of the post-test of the two groups are presented in Table 3 below:

**Table 3.** *Descriptive statistics (post-test)*

| | Control group | Experimental group |
|---|---|---|
| N | 16 | 16 |
| Minimum | 7,00 | 11,25 |
| Maximum | 18,25 | 18,25 |
| Mean | 12,5000 | 15,1406 |
| Standard deviation | 2,90689 | 2,35932 |
| Variance | 8,450 | 5,566 |

The results show that the average of the students of the experimental group in the post-test is m = 15.14 (s = 2.35) whereas that of the students of the control group is m = 12.50 (s = 2.90); the difference is about 2.64. To check if this difference is significant and to reject the null hypothesis that the tested educational device had no effect on the results of the pupils, we used the t-test of the students to test the difference between the averages of two independent samples having a normal distribution (p-value of Shapiro-Wilk is 0.315). The results of the comparison are presented in table 4:

**Table 4.** *Independent samples test (post-test)*

| | Levene's Test for Equality of Variances | | t-test for Equality of Means | | | | |
|---|---|---|---|---|---|---|---|
| | F | Sig. | t | dl | Sig. (2-tailed)) | Mean Difference | Std. Error Difference |
| Equal variances assumed | ,317 | **,577** | -2,821 | 30 | ,008 | -2,64063 | ,93596 |
| Equal variances not assumed | | | -2,821 | 28,782 | ,009 | -2,64063 | ,93596 |

According to this table, the variances can be regarded as homogeneous; the p-value of Levene's test is p = 0.577, which is non-significant. The p-value of test-t is largely lower than the level selected alpha (p < .05); one p-value of 0.008 (less than 9 chances out of 1000 to be mistaken by affirming that the two groups differ significantly between them) enables us to reject the null hypothesis and thus to admit that the integration of the digital simulation in a situation of training of the relative chronology certainly had a positive effect on the output of the students. The teaching application used in this case obviously improved the results of the students of the experimental group because it was effectively integrated at the appropriate time. This finding is in alignment with the findings of former studies conducted in the Moroccan educational context that highlighted the positive impact of the use of the digital simulations on the output of students in other experimental disciplines (Droui *et al.* 2013; El Hassouny *et al.*, 2014).

In order to determine the effect of the integrated simulation on the development of certain cognitive processes of the students in keeping with the relative dating (the acquisition of knowledge and the application), we used the Mann-Whitney U test (in this case the distribution of the values does not follow the normal distribution because p-value of Shapiro-Wilk is lower than the level selected alpha) in order to compare the results got by the students according to each item of the post-test. The results are presented in Table 5:

**Table 5.** *Mann-Whitney Test for Independent Samples (post-test)*

| | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 |
|---|---|---|---|---|---|---|
| Mann-Whitney U | 120,00 | 96,00 | 100,50 | 123,00 | 51,50 | 58,50 |
| Wilcoxon W | 256,00 | 232,00 | 236,50 | 259,00 | 187,50 | 194,50 |
| Z | -,421 | -2,099 | -1,070 | -,224 | -3,228 | -2,682 |
| Asymp. Sig (2-tailed) | ,674 | ,036 | ,285 | ,823 | ,001 | ,007 |
| Exact Sig. [2*(1-tailed Sig.)] | ,780 | ,239 | ,305 | ,867 | ,003 | ,007 |

According to this table, the difference between the groups is not significant (p = 0. 780) concerning the questions concerned with the first item; thus, the simulation used did not have an added-value in terms of the acquisition of knowledge, which highlights some limitations of the application used. Contrary to this result, Joubert *et al.* (2000) concluded in a study related to the use of simulations in teaching Newtonian mechanics that those simulations allowed an improvement of the students' knowledge and that the latter showed more precision in their reasoning.

In terms of the items testing the cognitive operation of application, the difference between the groups was non-significant (p > .01) compared to items 2, 3 and 4 including simple situations of application, with satisfactory success rates for the two groups. Equivalence between the groups in this case is probably due to the nature of the sample (it includes mathematical sciences students) or to the classical situation of training, which was also relevant and effective support the training of the students of the group of control.

On the other hand, the difference between the groups was very significant (p <.01) in favour of the experimental group with regard to the items 5 and 6, including the complex situations. Within the same lines, El Ouidadi *et al.* (2011) noted, during the use of a simulation in the teaching of the cellular division, a progress in the level of acquisition of competences related to the students' cognitive ability of application and their reasoning.

In order to determine if the used simulation made it possible for the students of the experimental group to overcome difficulties of training related to the treated contents, the answers of the pupils to the items were divided into three categories, and they are represented in the following table:

**Table 6.** *Examples of student responses to the post-test*

| | Correct answer | Partially correct answer | False answer |
|---|---|---|---|
| Question 1: Notch the correct answers? | a- A layer of sedimentary rocks is more recent than that which it recovers.<br>b- Any geological event, which recuts another him is posterior Sedimentation.<br>- To order geological events chronologically. | a- A layer of sedimentary rocks is more recent than that which it recovers.<br>b- Any geological event, which recuts another him is posterior Sedimentation. | a- Give a precise age in million years to a precise rock.<br>b- Any geological event, which recuts another him is former. |
| Question 2: Compare the age of the layers represented in this figure? | 1 (oldest) →2→ 3 | 1 (oldest) →2→ 3 →2→ 1 | 3 (oldest) →2→ 1 |
| Question 3: Establish the chronology (older with most recent) of the geological events? | E→D →C→A→ B→ F →G →H | E→D →C→H→ A→ B →G →B | E→F →H→D→ C→ A →G →B |
| Question 4: Thanks to do a rigorous reasoning, carry out a relative dating of the four events indicated on the document and visible on the geological cut presented? | a- Erosion<br>b- Sedimentation of Limestone and sandstone<br>c- Compression<br>d- Distention | a- Sedimentation of b-Limestone and sandstone<br>b- Compression<br>c- Distention<br>d- Erosion | a- Distension<br>b- Compression<br>c- Sedimentation<br>d- Erosion |
| Question 5: Identify the chronological order of the geological events observed in the photo? | a- Sedimentation<br>b- Compression<br>c- Erosion<br>d- Sedimentation | a- Sedimentation<br>b- Compression<br>c- Sedimentation | a- Compression<br>b- Sedimentation<br>c- Distension |
| Question 6: Propose a relative chronology of the geological events observed on the cut of the document? | a- Sedimentation<br>b- Compression<br>c- Erosion<br>d- Sedimentation<br>e- Distention<br>f- Erosion<br>g- Volcanism | a- Sedimentation<br>b- Compression<br>c- Sedimentation<br>d- Distention<br>e- Volcanism | a- Erosion<br>b- Sedimentation<br>c- Compression<br>d- Volcanism<br>e- Distension<br>f- Sedimentation<br>g- Compression |

Next, we compared the responses of the students in both groups (see table). The results obtained show that there are no significant differences between the students' responses to questions 1, 2, 3 and 4. However, they do show significant differences between the responses of these students to questions 5 and 6. On the one hand, the rates of correct answers by the pupils in the experimental group are higher than those of the leading group (68.75% compared with 6.25% in the fifth item and 18.75% compared with 0% in the sixth item). On the other hand, the false answers of the pupils in the experimental group are less frequent than those of the leading group (6.25% compared with 12.5% in the fifth item and 25% compared with 37.5% in the sixth item). These results confirm those of the statistical analyses conducted using Mann-Whitney's U test ($p > .01$ for items 1, 2, 3 and 4 compared to $p < .01$ for items 5 and 6).

**Table 7.** *Students' responses to the questions of the post-test.*

| Questions | Correct answers | | Partially correct answers | | False answers | |
|---|---|---|---|---|---|---|
| | Control group | Experimental group | Control group | Experimental group | Control group | Experimental group |
| Question 1 | 25,00% | 18,75% | 75,00% | 81,25% | 0,00% | 0,00% |
| Question 2 | 81,25% | 93,75% | 12,5% | 6,25% | 6,25% | 0% |
| Question 3 | 18,75% | 25,00% | 56,25% | 50% | 25,00% | 25,00% |
| Question 4 | 12,50% | 6,25% | 87,50% | 87,50% | 6,25% | 12,50% |
| Question 5 | 6,25% | 68,75% | 81,25% | 25% | 12,50% | 6,25% |
| Question 6 | 0% | 18,75% | 62,50% | 56,25% | 37,50% | 25% |

In sum, we noted during the analysis of the students' responses to the post-test that the experimental group demonstrated a better understanding of the relative chronology concept. This was confirmed, on the one hand, by statistically very significant differences ($p <. 01$) in favour of the experimental group with regard to items 5 and 6 containing complex situations, and on the other hand, by higher rates of correct answers from pupils in the experimental group, especially for the last two questions.

## DISCUSSION

In the present study, it seems that the students of the experimental group, who used the « *chronocoupe* » simulation, have generally managed to implement procedures allowing them to answer questions 5 and 6 more effectively. Students became more able to locate geometric clues on a geological section (question 6) and use them to retrieve the chronology. The post-test responses confirm that these students have also become more capable of identifying the chronology of events on an outcrop photograph (question 5) because their skills, developed as part of the work on a simulated model, are transferred for work on outcrop photography. Similarly, Sanchez (2003), who previously tested this simulation with high school students, reports that learners working independently, when facing such computer environments, are led to adopt a strategy similar to that of the geologist, and as a result, have the ability to trace the geological history of a region by analysing a geological section and a photograph taken in the field.

Thus, it can be inferred that the selected simulation positively impacted the performance of the students in the experimental group and sharpened their understanding (an essential cognitive process for the improvement of application skills) and, consequently, allowed them to overcome certain learning difficulties related to the subject of relative chronology. This result is consistent with the results of several research studies conducted in experimental disciplines which also showed an improvement in learner performance and understanding. For examples, Rutten, Van Joolingen and Van der Veen (2012), who reviewed 51 papers from 2001 to 2010, showed that classical education can be improved by using computer simulations. Similarly, a literature synthesis examines research findings on grade 6–12 student learning gains and losses using virtual laboratories and computer simulation, conducted by Scalise, Timms, Moorjani, Clark, Holtermann and Irvin (2011), indicated that about 53% of the studies (42 articles) reported overall gains, just under 18% (14 articles) reported gains under the right conditions, about 25% (20 articles) reported mixed outcomes in which some groups showed learning gains but others did not, and approximately 4% of the studies (2 articles) reported no gain.

This paper confirms the fact that the integration of a computer simulation (Chronocoupe) in a learning situation concerning relative chronology had a positive effect on student achievement. This result is in good agreement with other studies that have shown that the use of simulations can improve learning outcomes. Indeed, Huppert, Lomask and Lazarowitz (2002) declared that 10th grade biology students who used a computer simulation on the growth curve of microorganisms attained greater achievement on content-based objectives than those in a control group. As well, in the genetic topic, Gelbart, Brill and Yarden (2009) found a significantly positive influence of the computer simulation on learning results. In addition, Gibbons, Evans, Payne, Shah and Griffin (2004) reported the evaluation of computer-based simulation of practical exercises in bioinformatics, and their results indicated that performance can be improved by the use of simulations (by 7%). In another study, Kiboss, Ndirangu and Wekesa (2004) investigated the effectiveness of a Computer-Mediated Simulation (CMS) instruction program in improving secondary school pupils’ learning outcomes in cell theory lessons. Their CMS program on the biology subject led to improvements in academic achievement, students’ perceptions of the classroom environment and their attitudes towards the subject. At last, Gambari, Gbodi, Olakanmi and Abalaka (2016) found that the students using a computer simulation performed better, and they recommended that chemistry teachers should use computer simulations for improving their students' performance and motivation in the subject.

Our study proves that simulation used had a positive effect on students' understanding of the experimental group with respect to the subject of relative dating, and this result obtained is broadly consistent with the major trends in the literature as to the effect of computer simulations on students' understanding. Indeed, Torres, Moutinho and Vasconcelos (2015) revealed, in their investigation in the subject of geosciences that the majority of science teachers use simulations to observe phenomena whose observation is inaccessible due to spatial and temporal constraints and to promote a better understanding of the evolution of natural phenomena. Meir, Perry, Stal, Maruca and Klopfer (2005) pointed out that students have deep rooted confusions and misconceptions about how diffusion and osmosis function work, particularly at the molecular level. These researchers revealed that their computer simulation (OsmoBeaker) leads to improved understanding and can help to overcome some students' misconceptions. In the same sense, White and Frederiksen (2000) showed that the use of the computer simulation 'Thinker Tools' in physics enabled secondary school students to demonstrate a better understanding and interpretation of the forces acting on a moving object than higher education students who had received traditional instruction. In addition, Droui, Hajjami, Bouklah and Zouirech (2013) reported positive effects of the use of a simulation of Newtonian laws in a problem-solving context on the conceptual understanding of Newtonian mechanics. Still in the physical sciences, Jimoyiannis and Komis (2001) investigated the role of computer simulations in the development of functional understanding of the concepts of velocity and acceleration in projectile motions. Their results presented that students working with simulations exhibited significantly higher scores in the research tasks. Therefore, the researchers suggest that computer simulations may be used as an alternative instructional tool, in order to facilitate students' understanding of velocity and acceleration and develop functional understanding of physics. On his part, Zacharia (2007), compared a control group only using Real Experimentation (RE) with an experimental group using a combination of RE and Virtual Experimentation (VE). His results indicate that replacing RE with VE during a specific part of the experiment has a positive influence on students' conceptual understanding of electrical circuits. At last, Stern, Barnea and Shauli (2008) compared two groups of students, both of which were taught curriculum on the kinetic molecular theory. The experimental group subsequently spent additional class periods using the computer simulation 'A Journey to the World of Particles'. The students in the experimental group scored significantly higher than the students in the control group on a test measuring their understanding of the theory. However, in the long term these results were negligible.

Furthermore, during the use of the computer simulation by the experimental group, we observed a strong motivation among the pupils who communicated and interacted increasingly with one-another. This result is supported by those of Durán, Gallardo, Toral, Martinez-Torres and Barrero (2007) who focused on both the cognitive and affective domains in order to investigate the effects of a computer simulation on students' motivation, interaction and participation. Researchers replaced part of the traditional method in a subject titled 'Electrical Machines and Installations' with a software-based method that made use of a computer simulation. While the results for the cognitive domain could not be clearly interpreted, the results for the affective domain indicate that a synchronous software-based active methodology promotes discussion both among students and with the teacher in a brainstorming. In addition, the proposed methodology improves participation and students' initiative compared to traditional instruction.

However, other studies have reported less impressive results in using computer simulations in science education. Some of these have found no advantage to utilising simulations over traditional methods. For example, Thomas and Hooper (1991) state that in some situations the contribution of simulations is uncertain or even null. Winn, Walker, Greene and Mansell (2006) compared college undergraduates' achievement of oceanography concepts through field and simulated experiences. Results showed that there was no difference in overall learning between the fieldwork and simulation groups. Other investigations have indicated the use of computer simulations to be less effective than traditional instruction and hands-on laboratory approaches (Rieber, 1990; Michael, 2001; Marshall, *et al.*, 2006). Even more, Clark (1994) declared that improvements in student achievement are more attributed to effective instructional methods and teacher effects. In the same sense, Trundle and Bell (2010) reported: «Simply providing opportunities for students to use computer simulations without careful attention to learn support and instructional models is not likely to result in desired instructional outcomes». Thus, despite the high potentials for simulations, a general conclusion about their effectiveness is currently unwarranted (Yaman *et al.*, 2008).

In the end, even though research tasks concerning the place of ICT in the teaching of earth sciences are still largely missing (Durbin, 2002; Gobert et al 2002; Kali 2003; Linn 2003), they all underline the interest, which such means can offer to help students to represent complex phenomena, three-dimensional structures and space relations between geological objects. (Lefèvre *et al.*, 2006). Consequently, the teacher can be required to suggest computerised models in the form of animations or of simulations (Sanchez, 2008). These later give the opportunity to observe a scale model or accelerated geological events, which are not accessible to the direct observation for different reasons such as time (for example very low speed of certain geological phenomena) or space (gigantic or microscopic dimensions of certain geological objects).

## CONCLUSION

In this study, the aim is to highlight the impact that numerical simulation has on learning in the fields of relative chronology. Statistical data collected from a semi-experimental research which was conducted among students in a technical high school in the city of Taza (Morocco) using the pre-test and post-test methodology with an experimental group and a control group showed that there was no significant difference between the two groups during the pre-test [$t(30) = -0.414$, $p = 0.682$]. After completion of the proposed pedagogical activity, there was a statistically significant difference between the experimental group and the control group [$t(30) = -0.414$, $p < 0.05$] on the post-test. The pedagogical application used in this study obviously improved the results of the students of the experimental group, which confirms the fact that the integration of a digital simulation (Chronocoupe) in a learning situation concerning relative chronology certainly had a positive effect on student achievement.

On the other hand, the results obtained during the post-test, which was based on Mann-Whitney's U test, confirm that the difference between the groups was very significant ($p < .01$) in favour of the experimental group in regards to items 5 and 6, which included complex applications. Thus, it can be inferred that simulation used had a positive effect on the boosting of students' understanding of the experimental group with respect to the subject of relative dating, and thus allowed the students to overcome certain learning difficulties related to the concept of relative chronology.

No significant differences were noticed with regard to the other questions (1, 2, 3 and 4), which targeted knowledge acquisition and application in simple situations. This has been confirmed by Mann-Whitney's U test, which shows some limitations of the application utilised. Nevertheless, during the exploitation of the computer simulation by the experimental group, we noticed a strong motivation among the pupils who communicated and interacted increasingly with one-another. This concerned a discipline that is widely under-appreciated by the pupils (Gohau, 2001, Dodick *et al.*, 2003).

Numerous benefits for the use of simulations were cited by authors: higher learning gains, better conceptual understanding, decreased study time, higher student satisfaction and more participation (Smetana *et al.*, 2012; Rutten *et al.*, 2012). However, according to other researchers, learning outcomes appear to be improved when computer simulations are used in conjunction with other representations and modes of instruction (Zacharia, 2003). Indeed, in the present study, computer simulation has been used in PBL to reinforce cognitive skills by encouraging students to be more active and autonomous.

Thus, we believe that an effective and educational simulation, provided that it is appropriately implemented at the right moment, can contribute effectively to resolving certain learning problems in the field of Earth sciences. But this implies the existence of quality numerical simulations that are appropriate and adapted to the school programs.

Finally, although these findings may seem a relevant contribution to research on the use of numerical simulations, it should be noted that they are based on a single computer simulation, in a particular context, dealing with a narrowly targeted subject. The results of this work need to be confirmed in other contexts, with other simulations and for other disciplinary fields.

## REFERENCES

Agorram, B., Khzami, S., & Selmaoui, S. (2015). A la redecouverte des lois de la génétique classique par l'utilisation d'un logiciel de simulation/ [rediscovery of the genetic's laws by using a genetics program]. International Journal of Innovation and Applied Studies, 12(4), 776.http://www.ijias.issr-journals.org/abstract.php?article=IJIAS-15-097-05

Ault, C. R. (1994). Research on problem solving: earth science. In D. L. Gabel (ed.) Handbook of Research on Science Teaching and Learning (New York: Macmillan), 269–283.

Bachelard, S. (1979). Quelques aspects historiques des notions de modèle et de justification des modèles. Maloine.

Bibeau, R. (2005). Les TIC à l'école : proposition de taxonomie et analyse des obstacles à leur intégration, Revue électronique de l'EPI, EpiNet n° 79

Boughanmi, Y. (2009). Obstacles à la problématisation du temps dans une approche interdisciplinaire : l'explication de quelques phénomènes naturels par des lycéens et de futurs enseignants tunisiens. Thèse de doctorat en Sciences de l'Education-Philosophie des Sciences. Université de Bourgogne et Université de Tunis, Bourgogne, France.

Bransford, J. D., Brown, A. L., Cocking, R. R. (Eds. ). (2000). *How People Learn: Brain, Mind, Experience, and School*. National Academy Press.

Buty, C. (2003). Richesses et limites d'un « modèle matérialisé » informatisé en optique. Didaskalia, n° 23, 39-63.

Cholmsky, P. (2003). Why gizmos work: Empirical evidence for the instructional effectiveness of Explore Learning's interactive content. Charlottesville, VA: Explore Learning.

Clark, R. (1994). Media will never influence learning. Educational Technology Research and Development, 42(2), 21-29.

Clements, D. H. et McMillen, S. (1996). Rethinking "Concrete" Manipulatives. Teaching Children Mathematics. 2(5), p. 270-279.

Dalgarno, B., Bishop, A. G., Adlong, W., & Bedgood, D. R. (2009). Effectiveness of a virtual laboratory as a preparatory resource for distance education chemistry students. Computers & Education, 53(3), 853-865.

De Jong, T. (1991). Learning and instruction with computer simulations. Education and Computing, 6(3-4), 217-229.

De Jong, T., & Van Joolingen, W. R. (1998). Scientific discovery learning with computer simulations of conceptual domains. Review of educational research, 68(2), 179-201.

Depover, C., Karsenti, T., & Komis, V. (2007). Enseigner avec les technologies: favoriser les apprentissages, développer des compétences. PUQ.

D'Hainaut, L. (1975). *Concepts et méthodes de la statistique: un guide pour l'application de l'outil statistique aux phénomènes et aux situations des sciences de l'homme et de l'éducation*, ed. E. Labor.

Dodick, J., & Orion, N. (2003). Geology as an historical science: Its perception within science and the education system. Science & Education, 12(2), 197-211.

Droui, M. El Hajjami, A. Benali Amjoud, A. et Ahaji, K. (2015). Exploration des conceptions naïves à propos de la force et du mouvement chez des lycéens marocains. RADISMA, Numéro 11.

Droui, M., & El Hajjami, A. (2014). Simulations informatiques en enseignement des sciences: apports et limites. EpiNet : revue électronique de l'EPI, 164.

Droui, M., El Hajjami, A., Bouklah, M., & Zouirech, S. (2013). Impact de l'apprentissage par problème sur la compréhension conceptuelle de la mécanique newtonienne. EpiNet: Revue électronique de l'EPI, 157.

Durán, M. J., Gallardo, S., Toral, S. L., Martínez-Torres, R., & Barrero, F. J. (2007). A learning methodology using Matlab/Simulink for undergraduate electrical engineering courses attending to learner satisfaction outcomes. International Journal of Technology and Design Education, 17(1), 55-73

Durbin. J. M. (2002). The benefit of combining computer technology and traditional teaching methods in large enrolment geoscience classes. Journal of Geoscience Education, 50, 56-63.

El hassouny, E., Kaddari, F., Elachqar, A., & Alami, A. (2014). Teaching/Learning Mechanics in High School with the Help of Dynamic Software. Procedia-Social and Behavioral Sciences, 116, 4617-4621.

El Ouidadi, O., Lakdim, A., Essafi, K., & Sendide, K. (2011). Contribution à l'évaluation de l'impact de l'intégration des TICE dans l'enseignement et l'apprentissage: exemple de la division cellulaire (mitose) en deuxième année de baccalauréat sciences expérimentales.

Frodeman, R. (1995). Geological reasoning: Geology as an interpretive and historical science. Geological Society of America Bulletin, 107(8), 960-968.

Gambari, I. A., Gbodi, B. E., Olakanmi, E. U., & Abalaka, E. N. (2016). Promoting Intrinsic and Extrinsic Motivation among Chemistry Students Using Computer-Assisted Instruction. Contemporary Educational Technology, 7(1), 25-46.

Gelbart, H., Brill, G., & Yarden, A. (2009). The impact of a web-based research simulation in bioinformatics on students' understanding of genetics. Research in Science Education, 39(5), 725-751.

Gibbons, N. J., Evans, C., Payne, A., Shah, K., & Griffin, D. K. (2004). Computer simulations improve university instructional laboratories. Cell Biology Education, 3(4), 263-269.

Gibbons, N. J., Evans, C., Payne, A., Shah, K., & Griffin, D. K. (2004). Computer simulations improve university instructional laboratories. Cell Biology Education, 3(4), 263-269.

Gilbert, N., & Savard, J. G. (1992). Statistiques. Laval, Québec : Éditions Études vivantes.

Gobert J., Slotta, J. & Pallant, A., Nagy, S. & Targum, E. (2002). A WISE Inquiry Project for Students' East-West Coast Collaboration, Presented at the Annual Meeting of the American Educational Research Association, New Orleans, LO.

Gohau G. (2001), « La géologie, discipline mal aimée », in Etudes sur l'enseignement des sciences physiques et naturelles, Cahiers d'histoire et de philosophie des sciences, textes réunis par Nicole Hulin, ENS éditions

Gould, S.-J. (1990). *Aux racines du temps*, ed. G.e. Fasquelle.

Grabe, M. et Grabe, C. (1996). Integrating Technology for Meaningful Learning. Boston: Houghton Miflin Co.

Huppert, J., Lomask, S. M., & Lazarowitz, R. (2002). Computer simulations in the high school: Students' cognitive stages, science process skills and academic achievement in microbiology. International Journal of Science Education, 24, 803-821.

Jimoyiannis, A. & V. Komis. (2001). Computer Simulations in Physics and Learning: A Case Study on Students' Understanding of Trajectory Motion. Computers and Education, 36, p. 183-204.

Joubert, R., Rebmann, G., & Desmond, P. (2000). Integration of computer simulation programs in teaching sequences of Newtonian mechanics for freshmen at university. In R. Pinto & S. Surinach (éd.). Actes International Conference, Physics Teacher Education beyond.

Kali T. (2003). A virtual journey within the rock-cycle: a software kit for the development of systems-thinking in the context of the Earth's crust. Journal of Geoscience Education, 51,165-170.

Kennepohl, D. (2001). Using computer simulations to supplement teaching laboratories in chemistry for distance delivery. Journal of Distance Education, 16(2), 58-65.

Kiboss, J. K., Ndirangu, M., & Wekesa, E. W. (2004). Effectiveness of a computer-mediated simulations program in school biology on pupils' learning outcomes in cell theory. Journal of Science Education and Technology, 13(2), 207-213.

Kutluca, T., Arslan, S., & Özpinar, Ý. (2010). Developing a Scale to Measure Information and Communication Technology Utilization Levels. Journal of Turkish Science Education, 7(4), 37.

Lamarti, L., Ben-Bouziane, A., Akrim, H., & TALBI, M. (2009). La sortie de terrain: quelle place et quel rôle dans une démarche scientifique?. RADISMA, Numéro 4. ISSN 1990-3219.

Lavoie, D. R. et Good. R. (1988). The nature and use of prediction skills in a biological computer simulation. Journal of Research in Science Teaching, 25, 335-360.

Lazarowitz, R. et Huppert, J. (1993). Science process skills of 10th-grade biology students in a computer-assisted learning setting. Journal of Computing In Education, 25, 366-382.

Learn, H. P. (2000). Brain, mind, experience, and school. Committee on Developments in the Science of Learning.

LEBRUN, M. (2003). *Des technologies pour enseigner, Brussels*. 1999, Université De Boeck.

Lefèvre, O., & Sanchez, E. (2006). Géonote : un environnement informatique d'aide au travail sur le terrain pour l'enseignement des sciences de la Terre. Papier présenté à la conférence Biennale de l'éducation, Lyon.

Linn, M. (2003). Technology and science education: starting points, research programs, and trends. International Journal of Science Education, 25(6), 727-758.

Luo, W., J. Pelletier, K. Duffin, C. Ormand, W. C. Hung, D. J. Shernoff, X. Zhai, E. Iverson, K. Whalley, C. Gallaher and W. Furness (2016). Advantages of computer simulation in enhancing students' learning about landform evolution: A case study using the grand canyon. Journal of Geoscience Education, 64(1), 60-73.

Marshall, J. A., & Young, E. S. (2006). Preservice teachers' theory development in physical and simulated environments. Journal of Research in Science Teaching, 43(9), 907-937.

Martínez-Jiménez, P., Pontes-Pedrajas, A., Polo, J., & Climent-Bellido, M. S. (2003). Learning in chemistry with virtual laboratories. Journal of Chemical Education, 80(3), 346-352.

Martin, L. A. (1997). Road Map 2: The First Step. MIT System Dynamics in Education Project.

McKinney, W. J. (1997). The educational use of computer based science simulations: some lessons from the philosophy of science. Science et Education, 6, p. 591-603.

McKnight, P. E., & Najab, J. Mann-Whitney U Test. Corsini Encyclopedia of Psychology. 2010.

Meir, E., Perry, J., Stal, D., Maruca, S., & Klopfer, E. (2005). How effective are simulated molecular-level experiments for teaching diffusion and osmosis? Cell Biology Education, 4(3), 235-248.

Michael, K. Y. (2001). The effect of a computer simulation activity versus a hands-on activity on product creativity in technology education.

Mintz, R. (1993). Computerized simulation as an inquiry tool. School Science and Mathematics, 93(2), 76-80.

Monchamp A. & Sauvageot- Skibine M. (1995). Du fixisme à la tectonique des plaques. Et pourtant elles bougent. Aster, n 20, 4-20.

Nachar, N. (2008). The Mann-Whitney U: a test for assessing whether two independent samples come from the same distribution. Tutorials in Quantitative Methods for Psychology, 4(1), 13-20.

Nuhoðlu, H., & Nuhoðlu, M. (2007). System dynamics approach in science and technology education. Journal of Turkish Science Education, 4(2), 91.

Padilla, M. J., Okey. J. R., Dillashaw. F. G. (1983). The relationship between science process skill and formal thinking abilities. Journal of Research in Science Teaching, 20, 239-246.

Perreault, N. (2003). Rôle et impact des TIC sur l’enseignement et l’apprentissage au collégial–I. Pédagogie collégiale, 16(3), 3-10.

Raab, T., & Frodeman, R. (2002). What is it like to be a geologist? A phenomenology of geology and its epistemological implications. Philosophy & Geography, 5(1), 69-81.

Rassou, K. 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).

Richoux B., Salvetat C. et Beaufils D. (2002). Simulation numérique dans l'enseignement de la physique : enjeux, conditions, Bulletin de l'Union des Physiciens, n°842, 497-522.

Rieber, L. P. (1990). Using computer animated graphics in science instruction with children. Journal of educational psychology, 82(1), 135.

Roth, W. M., & Roychoudhury, A. (1993). The development of science process skills in authentic contexts. Journal of Research in Science Teaching, 30(2), 127-152.

Rutten, N., W. R. van Joolingen and J. T. van der Veen (2012). The learning effects of computer simulations in science education. Computers & Education, 58(1), 136-153.

Sanchez, E. (2003). Chronocoupe : un logiciel pour l'apprentissage du raisonnement diachronique en sciences de la Terre. Ignorances et questionnements. Chamonix: Actes JIES.

Sanchez, E. (2007). Investigation scientifique et modélisation pour l'enseignement des sciences de la Terre Contribution à l'étude de la place des technologies numériques dans la conduite d'une classe de terrain au lycée (Doctoral dissertation, Université Claude Bernard-Lyon I).

Sanchez, É. (2008). Quelles relations entre modélisation et investigation scientifique dans l’enseignement des sciences de la terre ? Éducation et didactique, 2(2), 93-118.

Sanchez, E., & Prieur, M. (2006). Démarche d'investigation dans l'enseignement des sciences de la Terre: activités-élèves et scénarios. In actes électroniques du colloque Scénarios, 71-76.

Scalise, K., Timms, M., Moorjani, A., Clark, L., Holtermann, K., & Irvin, P. S. (2011). Student learning in science simulations: Design features that promote learning gains. Journal of Research in Science Teaching, 48(9), 1050-1078.

Smetana, L. K., & Bell, R. L. (2012). Computer simulations to support science instruction and learning: A critical review of the literature. International Journal of Science Education, 34(9), 1337-1370.

Stengers, I. (1993). L'invention des sciences modernes. Éditions La Découverte, paris.

Stern, L., Barnea, N., & Shauli, S. (2008). The effect of a computerized simulation on middle school students’ understanding of the kinetic molecular theory. Journal of Science Education and Technology, 17(4), 305-315.

Strauss, R., and Kinzie, M. B. (1994). Student achievement and attitudes in a pilot study comparing an interactive videodisc simulation to conventional dissection. American Biology Teacher 56, 398-402.

Thomas, R., et Hooper, E. (1991). Simulations: An opportunity we are missing. Journal of Research on Computing in Education, 23, 497-513.

Torres, J., Moutinho, S., & Vasconcelos, C. (2015). Nature of science, scientific and geoscience models: Examining students and teachers' views. Journal of Turkish Science Education, 12(4).

Trend, R. (2000). Conceptions of geological time among primary teacher trainees, with reference to their engagement with geoscience, history, and science. International Journal of Science Education, 22(5), 539-555

Trundle, K. C., & Bell, R. L. (2010). The use of a computer simulation to promote conceptual change: A quasi-experimental study. Computers & Education, 54(4), 1078-1088.

Walker, C. O., Greene, B. A., & Mansell, R. A. (2006). Identification with academics, intrinsic/extrinsic motivation, and self-efficacy as predictors of cognitive engagement. Learning and individual differences, 16(1), 1-12.

White, B. et Frederiksen, J. (2000). Technological tools and instructional approaches for making scientific inquiry accessible to all. In M. Jacobson and R. Kozma (Eds), Innovations in Science and Mathematics Education: Advanced Designs for Technologies of Learning (p. 321-359). Mahwah, NJ: Lawrence Erlbaum Associates.

Wilensky, U. et Stroup, W. (2000). « Networked gridlock: Students enacting complex dynamic phenomena with the HubNet architecture ». Paper presented at the Fourth Annual International Conference of the Learning Sciences, Ann Arbor, MI.

Windschitl, M. A. (1995). Using computer simulations to enhance conceptual change: The roles of constructivist instruction and student epistemological beliefs. Retrospective Theses and Dissertations.

Yaman, M., Nerdel, C., & Bayrhuber, H. (2008). The effects of instructional support and learner interests when learning using computer simulations. Computers & Education, 51(4), 1784-1794.

Yoon, S. Y., & Peate, D. W. (2015). Teaching What I Learned’: Exploring students’ Earth and Space Science learning experiences in secondary school with a particular focus on their comprehension of the concept of ‘geologic time. International Journal of Science Education, 37(9), 1436-1453.

Zacharia, Z. (2003). Beliefs, attitudes, and intentions of science teachers regarding the educational use of computer simulations and inquiry-based experiments in physics. Journal of Research in Science Teaching, 40(8), 792-823.

Zacharia, Z. C. (2007). Comparing and combining real and virtual experimentation: an effort to enhance students' conceptual understanding of electric circuits. Journal of Computer Assisted Learning, 23(2), 120-132.

Zietsman, A. I., and P. W. Hewson. (1986). Effects of instruction using microcomputer simulations and conceptual change learning strategies in science learning, Journal of Research in Science Teaching, 23, 27-39.

## APPENDIX

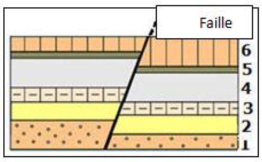
### a) Appendix 1: Pre-test

Question 1: Notch the correct answer?

- The relative dating is a dating leading to a quantified result, expressed in years.

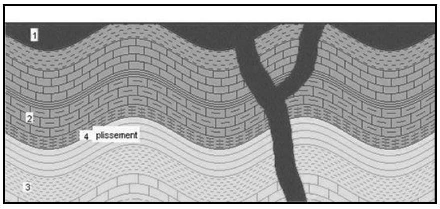
☐ True
☐ False

Question 2:




- To compare the age of the layers represented and to order the geological events?

Question 3:




- Propose a relative chronology of the geological events observed on the cut of the document

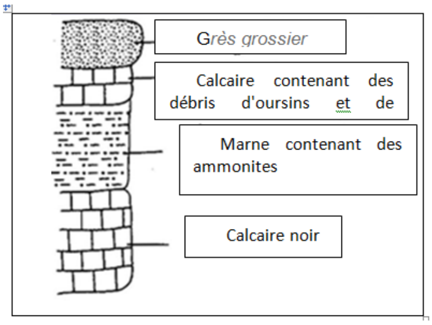
Question 4:

The document presents the geographical and chronological distribution of two fossils found in the layers of Ouled-Abdoun:

<table>
<tr><td>Fossil B (Notidanus)</td><td>Fossil A (Corax)</td><td colspan="2"></td></tr>
<tr><td>++++++++++</td><td>+++++++++</td><td colspan="2">Geographical distribution</td></tr>
<tr><td rowspan="8">+<br>+<br>+<br>+<br>+</td><td rowspan="8">+</td><td>Cenomanien</td><td rowspan="8">Chronological distribution</td></tr>
<tr><td>Turonien</td></tr>
<tr><td>Senonien</td></tr>
<tr><td>Messinien</td></tr>
<tr><td>Maastrichtien</td></tr>
<tr><td>Thaetien</td></tr>
<tr><td>Ypresian</td></tr>
<tr><td>Lutetien</td></tr>
</table>

a-Compare the geographical and chronological distribution of the two fossils.
b-what are the considerations about the stratigraphic interest of the fossils compared?

Question 5:
By using the furnished information in the document below:

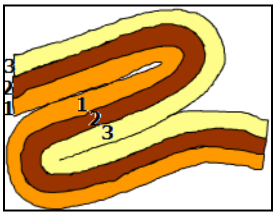



- Compare the age of the rocks represented in the document? Which is the principle which you adopted?
- Determine the age of the Marl? Justify your answer?

## b) Appendix 2: Post-test

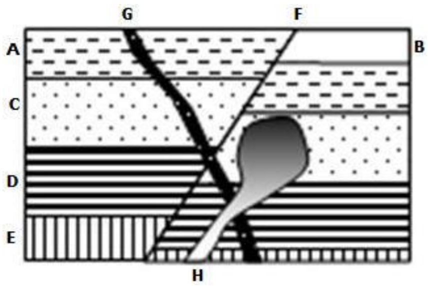
**Question 1**:
Notch the correct answers?
a- The principle of superposition it is:
☐ A layer of sedimentary rocks is more recent than that which it recovers.
☐ A layer of sedimentary rocks is older than that which it recovers.
☐ Give a precise age in million years to a precise rock.
b- The principle of stepping, it is:
☐ Any geological event, which recuts another him is posterior.
☐ Any geological event, which recuts another him is former.
☐ To order geological events chronologically.

Question 2:



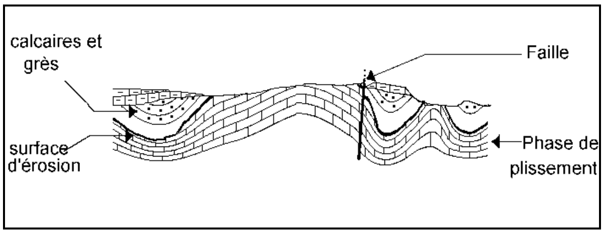

- Compare the age of the layers represented in this figure?

Question 3:




- Establish the chronology (from the old to the recent) of the geological events?

Question 4:

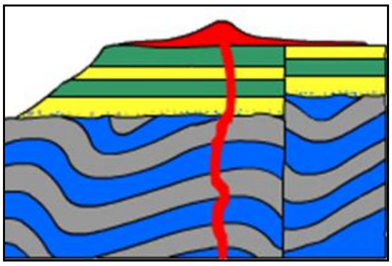



- Thanks to do a rigorous reasoning, carry out a relative dating of the four events indicated on the document and visible on the geological cut presented?

Question 5:

- Order chronologically (older with most recent) of the geological events observed on the photograph?

Question 6:



- Propose a relative chronology of the geological events observed on the cut of the document?