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# Enhancing the Teaching-Learning Process in Life and Earth Sciences through Simulated Experiments: Challenges and Solutions

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**ABSTRACT:** This study explores the significance of practical experimentation in the teaching of life and earth sciences (LES), particularly in the context of studying microorganisms. The research focuses on identifying key challenges that hinder the effective use of experiments in science classrooms and highlights the potential role of simulation as a remedial tool. A mixed-method approach was employed, including interviews with teachers and surveys targeting both teachers and students. Two main issues were identified: inadequate infrastructure for practical work in two educational institutions (a middle school and a high school) and varied student perceptions regarding experimental activities. The findings revealed that, under current conditions, the laboratories at these institutions fail to support active learning and scientific knowledge development. Most scientific activities are conducted in a theoretical context due to poor laboratory facilities and management. Additionally, students expressed a lack of motivation, partly due to their awareness of the poor laboratory conditions and the unengaging teaching methods employed. This research underscores the potential of simulations as a valuable tool to address these challenges and improve the LES teaching-learning process, without replacing traditional experiments. The study emphasizes the need for improving both the infrastructure and the pedagogical approaches to enhance the educational experience in the sciences.

**KEYWORDS:** experimentation, life and earth sciences (LES), simulation, student motivation, teaching/learning process, laboratory infrastructure.

## 1 INTRODUCTION

Life and Earth Sciences, in particular life sciences, form a functionalist discipline which aims to identify key concepts, where observation of reality and experimentation are very important, and whose interest is to make manipulate and encourage students to search by arousing their motivation and curiosity. Indeed, experimental activities, or practical work (PW) constitute an essential foundation of teaching, they are par excellence the framework for learning the experimental approach, which promotes active participation of students to build their own know.

The teaching of life and earth sciences are experimental disciplines par excellence, which are largely affected by the precarious conditions which prevail in educational establishments. The experimental approach has always been a topical subject in didactic research, official instructions and school textbooks in Morocco, just as program designers clearly express the importance of experimental practice in the teaching of experimental sciences (Develay, 1989).

In this approach, it is the student who actively participates in the development of his knowledge. Currently science teaching in high school and college is most often far removed from this approach, due to the almost total absence of the necessary equipment, the lack of specialized rooms, qualified personnel (teachers) as well as the excess of students in classes. We are then witnessing an increasingly accentuated convergence towards passive and purely theoretical teaching.

Our research focuses, initially, on the study of problems linked to experimental activities which oppose the acquisition of scientific concepts relating to the theme of the microbial world. We will focus, secondly, on the infrastructures reserved for

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experimental activities in middle and high schools (specialized rooms, equipment), as well as on the students' points of view on these activities to relate them to educational orientations. Officials, Subsequently, our task will contribute to the remediation of practical work in microbiology through simulation.

## 2 PROBLEMATIC

In our science classrooms, several challenges confront both teachers and students, including:

- Scientific concepts taught in class are treated in a dogmatic manner, which demotivates students;
- The documents used by the student are limited at the structural and anatomical level;
- A total lack of practical work;
- The practice of ICT is done in an anecdotal manner and without resorting to the educational scenario despite the presence of basic equipment in IT tools
- The problem situations are poorly formulated targeting everything that is propositional.
- Basic scientific knowledge is not mastered by most students and the explanations of scientific phenomena are very superficial.

And from the visit to the life and earth sciences laboratories of the current secondary levels, it was noted that the cupboards are filled with obsolete materials relating to experimentation with the abundance of glassware and expired chemicals, However, according to educational guidelines and official programs, observation and experimentation occupy a primordial place in the teaching of LES: If we look closely at the impact of the experimental approach in the success of the teaching/learning process of concepts LES scientists, we find a lack of experimental activities which can be considered among the main causes of the introduction of false representations among learners. However, in many cases the teacher finds himself confronted with the problems of the absence or total lack of fresh materials and equipment. We still note a limited use of ICT in the teaching of LES which can be an alternative to experimentation. These two parameters, experimentation and ICT, are recognized by several authors as an important lever in the teaching of LES (Bidari et al., 2017; Develay, 1989). It is to this question that our contribution is devoted, focusing on the place of taught experiences. We studied on the one hand why LES teachers do not use the experimental approach? And on the other hand, does the exploitation of simulations have a real impact in the conceptualization of scientific notions as long as our laboratories are still poor in the equipment necessary for experimentation? In these situations, does the use of information and communication technologies constitute, even partially, an effective and promising alternative? To resolve this problem, the following hypotheses were formulated:

- Lack of scientific materials in scientific laboratories;
- Methodological problem linked to the teacher;
- Absence of continuing training for science teachers in experimental approach and ICT integration;
- The timetables are very limited and the program too vast;
- Overload in classes;
- The introduction of simulations in the teaching of LES allows the improvement of the acquisition of skills among students and increases their motivation thanks to the opportunities offered by these technological means when they are used adequately and on the basis of 'an educational scenario.

## 3 RESEARCH METHODOLOGY

The methodology adopted in our work is twofold, first of all we carried out an interview with four teachers from the middle and high school secondary cycles: One teacher teaches at the Med VI high school in Martil, while the other three teach at the Ibn SINA college to the same city.

Regarding our interview questions, they are mainly based on the level of students and their involvement in science activities, as well as the problem or problems encountered by students or teachers during the teaching-learning process.

In order to broaden our study and to have more information on the problems linked to experimentation and their remediations mainly in the case of teaching the theme of the microbial world, we tried to write a survey in the form of a targeted questionnaire, based on the results of the interview carried out previously. This questionnaire is intended for teachers of life and earth sciences.

Remember that the first tools used were intended to conduct qualitative studies, while the second was intended to conduct quantitative studies.

*Table 1. Target population of the study*

| Level | College | High School |
|---|---|---|
| Number of teachers | 25 | 25 |

## 4 RESULTS ANALYSIS

Our interview discusses three main questions:

- Q1: What is the degree of satisfaction with student performance ?
- Q2: Are your students motivated to learn LES ?
- Q3: What problems did you encounter during your classroom practice ?

These questions are intended for four teachers, including two qualifying secondary level teachers.

The table below summarizes the results obtained:

*Table 2. Teachers' responses to the questions asked*

| Types of questions | Teacher responses |
|---|---|
| Q1 | All teachers say their students' performance is generally below average |
| Q2 | All teachers attest that most students are unmotivated to learn scientific concepts. |
| Q3 | Among the problems cited by teachers:<br>• Lack of prerequisites among students.<br>• French language problem<br>• Programs too busy.<br>• Lack of equipment to carry out experiments.<br>• Lack of student motivation.<br>• Continuous absence of students.<br>• Unavailability of real experiences and activities.<br>• The majority of students do not master certain skills relating to learning LES (Observation, description, deduction,) |

In general, we notice that our students are not motivated to learn science and that their level is not acceptable to their teachers. We also note that the teaching-learning process in our science classes suffers from a variety of problems. And during this interview all the teachers affirm that they do not carry out experiments and do not use ICT as an alternative to this practice.

Concerning the questionnaire, our study is based on work carried out with 25 high school LES teachers and 25 middle school LES teachers. We distributed an online form (Google Forms) to several groups of teachers (public and private) located in several academies in Morocco. 50 responses were collected. The questionnaire is written in French, it is individual and anonymous.

The questions are asked in two forms: closed questions and semi-open questions giving teachers more freedom of response.

- Q1: What is your professional training?

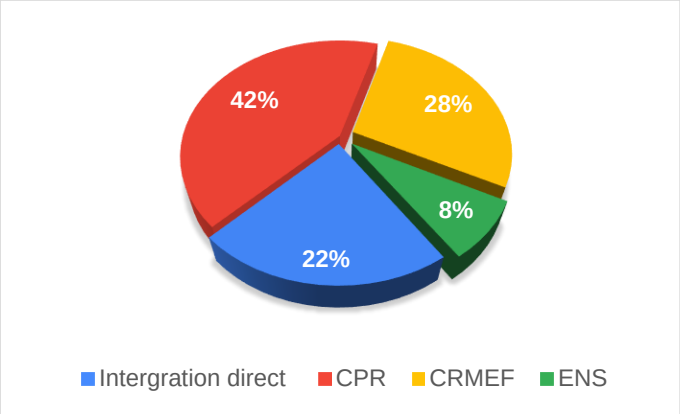



***Fig. 1. professional training of the surveyed population***

Almost half of the teachers surveyed (42%) entered the teaching profession through CPR, 28% underwent their training in CRMEF (Regional Centers for Education and Training Professions), and 22% joined directly, without professional training, 8% graduates of Ecoles Normales Supérieures,

- Q2: What is the specialty of your degree

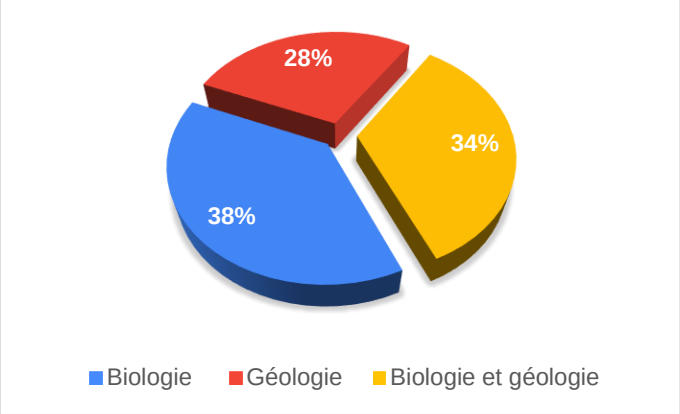



***Fig. 2. The rate of teachers according to the specialty of the diploma***

For the specialty, 38% of teachers have a degree in biology, 28% have a degree in geology and only 34% have a degree in biology and geology.

- Q3: Types of ICT training that you have already followed

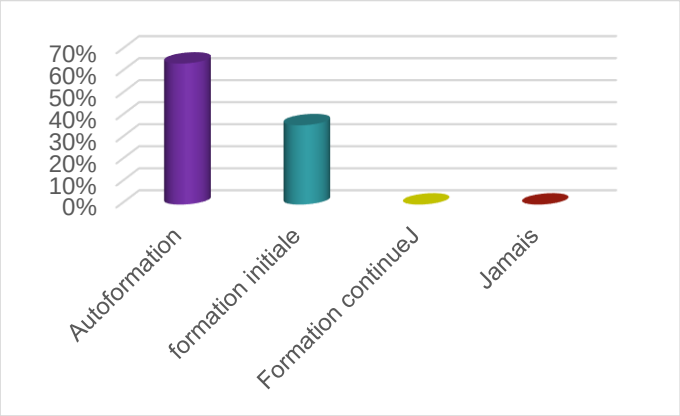



***Fig. 3. Continuing education of the surveyed population***

More than 60% of respondents are self-trained in ICT, and only 36% have followed initial training.

- Q 4: What approach do you use to teach life and earth sciences (LES).

## 5 RESULTS INTERPRETATION

The results obtained from this interview show that learning certain concepts relating to LES represents a problem. Indeed, the almost total absence of experiments makes the acquisition of scientific knowledge far from reality and therefore more abstract, demotivating our students.

Note that the teachers who participated in this survey declare that the laboratories of their establishments present a lack of materials necessary for experimentation; even the easiest experiments to perform, such as microscopic observation of cells, are impossible to perform. We also note that these teachers are not aware of the importance of ICT in experimentation, especially in these unfavorable conditions.

Let us first mention that this study is a pre-exploratory and qualitative study since it targets a very limited number of people. But to broaden our research and to reach a more or less large number of students, we carried out a questionnaire reserved for the two principals, the teachers. The writing of this questionnaire is based on the results obtained from the interview cited above.

And despite the use of the questionnaire to extend our research to a larger sample, our sample is not entirely representative. As a result, the analysis of the results obtained only concerns a small sample of the population surveyed, but in all cases we can detect numerous constraints or difficulties which hinder the practice of experimentation in our secondary science classes and mainly at the college level.

Indeed, regarding the question relating to professional training, it turned out that 42% of teachers are CPR graduates compared to 28% trained within CRMEF and 20% from ENS. All approve of having training in general didactics unlike the rest of the teachers who joined directly without professional training. Something which reveals their insufficiency of training on didactics and pedagogy, the teaching profession in general, thus affirming the difficulty of its practice in the classroom.

According to the population surveyed, the most common teaching method is the problem-based approach. None of the teachers opt for the transmissive as a teaching practice, this shows that these teachers are aware of the value of active pedagogies in the teaching-learning process which alone can promote the effective participation of students in the construction of their own knowledge as well as the acquisition of a scientific mind. But unfortunately the approach by experimentation is only approached by 16% of teachers despite its major place in the training of the scientific mind, even sometimes it seems that experimentation is the best means which facilitates the acquisition of certain concepts in LES in particular the concept of microbe. In this case the student can, for example, follow the evolution of certain microbial activities such as their rapid multiplication.

Let us recall that all the teachers surveyed agree on the fact that experimentation has a very important value in the acquisition of science, but the problem that arises is particularly the lack of scientific equipment in the laboratories, the

insufficiency of hourly volume, class size or LES school programs which often tend to be too busy, especially in high school. All these factors can only have a negative impact on the organization of experimental activities, which demotivates teachers, especially since certain activities require the use of experimentation to be masterable by students. Take the case of the rapid multiplication of bacteria, a phenomenon which shows the pathogenicity of these microorganisms. In this situation three tools are used by teachers to compensate for the absence of experiments in class, either models (drawing, diagram, etc.) or documents where the experiments are carried out and remain on "paper" and are therefore not not palpable. In the majority of cases, the final objective is not achieved. This explains the use of information and communication technologies by the majority of teachers. (Video, animation) which have become a necessity of the emergency plan.

Note again that all teachers (100%) indicate that the use of practical work promotes the acquisition of scientific concepts in life and earth sciences, particularly those which are not accessible to the naked eye and require a tool. observation such as the microscope for our case of the microbial world. Indeed, direct contact with scientific material and its manipulation by learners allows them to better assimilate and understand biological concepts.

The use of experimentation using ICT was accepted by most of the teachers surveyed, because for them ICT remains a good means of complementing experiments in the event of insufficient or total lack of materials without completely replacing the real experience. In other words, these technologies are used to save time and remedy the shortage of scientific materials and to compensate for real experiences, which motivates both teachers and their students.

It should be noted, according to the respondents, that establishments have the IT tools necessary for the integration of information and communication technologies. And the most common type of ICT use in class is generally videos and animations. However, the latter still remain insufficient as long as the students do not manipulate them and the transmissive then remains the last resort for teachers. Unlike simulations, which make the student more active and more motivated due to their active participation in the construction of their own knowledge, but which are unfortunately not used by teachers.

As we specified above, simulations interfere with numerous more or less simple phenomena that can approach this complex reality, thanks to multiple variables. It is impossible for a teacher to be able, alone, to carry out them, analyze them and produce results, but simulation software is capable of doing so. All of this makes these simulations an essential tool for learning science.

Take as an example the study of virulence, in this case the experiment consists of testing the ability of a microbe to cause an infection by infecting experimental models, such as animals or cell cultures.

Another example studied in the 3rd year of college is the cultivation of bacteria: the experiment consists of cultivating colonies of bacteria in different media to study their rapid growth, this is one of the characteristics of the pathogenicity of this type of microbes.

When teaching this topic, teachers only use videos and animations

Thus, to succeed in the educational use of ICT in general and simulation in particular, it is necessary to plan the implementation of an educational scenario. However, it is the tool that the majority of teachers surveyed neglect. However, in the field of teaching we must plan in advance the progress of scientific activities in class. Scripting is therefore necessary to manage both the content and the time and especially the time of interaction between different components in class in order to succeed in our teaching and achieve the objectives outlined.

And to better demonstrate the significant impact of simulation in the teaching of microbiology, we will exploit data from the use of a simulation platform.

#### REMEDIATION FROM A SIMULATION PLATFORM

After analysis and interpretation of the results obtained, it seems important to argue that simulation is an effective means of remediation, not only to overcome the problems that may be encountered during experimentation but also to make the more active student following better integration into the learning process.

For this reason, in what follows, we will discuss an example of simulation related to the microbial world chapter intended for 3rd year middle school students. To do this, we chose the Thyp software which is a free online tool and which works on different IT tools, such as the computer, smartphone or tablet. It requires a browser and an internet connection, but an offline version is also available. This software can be consulted from the following link: Life and Earth Sciences - THYP: simulation software (ac-creteil.fr).

### Software Features

In life and earth sciences, we are fortunate to have several software programs at our disposal to simulate experiments. We will cite as a non-exhaustive example the software of Mr. Gallerand or that of Mr. Sauvion.

Regarding the THYP software, it is inspired by the software mentioned but it has three specific features of its own with the aim of promoting the appropriation of the scientific approach by students:

- 1st characteristic: This software facilitates the processing of a lot of knowledge since it allows you to work on different guinea pigs (mice, bacteria, tomato, etc.) and with the BioLab: an airtight chamber equipped with different measuring devices. And thanks to this software we can work on: Germination, growth, pollination, vegetative reproduction, photosynthesis and symbioses (mycorrhizae) in tomatoes, the immune system, vaccination, the action of antibiotics and genetic mutations in bacteria, the nervous system, etc.
- 2nd characteristic: software that gives students complete autonomy: The diversity of experience and guinea pigs encourages significant autonomy for students and encourages them to think. This characteristic therefore forces students to think about what they want to demonstrate. At the beginning, students are most often lost and do not know what to do. They click on certain features at random or have fun injecting products into the guinea pig while studying bacterial multiplication. Students should know that a resolution strategy must be developed before handling the software.
- 3rd characteristic: THYP is software that reproduces (a little) the variability of living things.

But to use this software in our science class, the implementation of an educational scenario is essential.

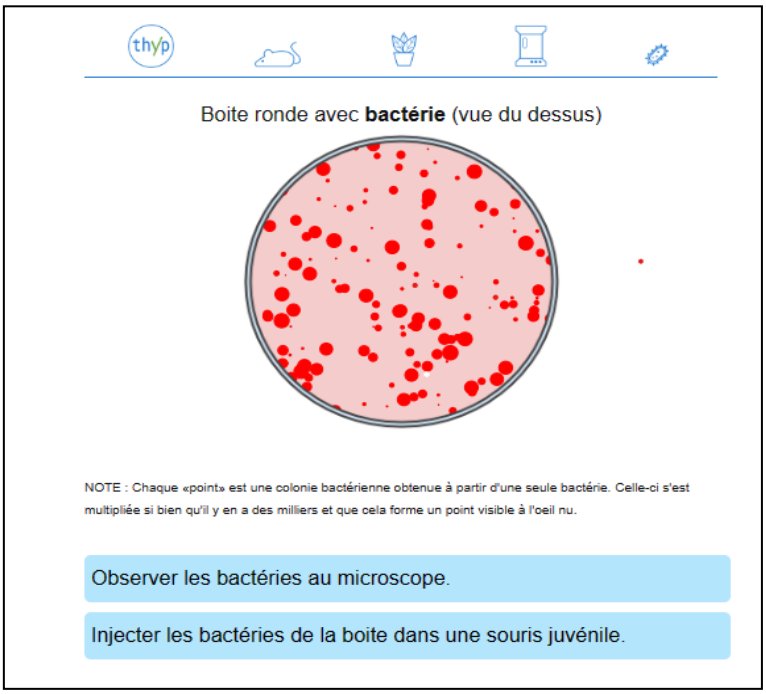
The chosen activity concerns the characteristics of pathogenic microbes that appear in the theme of the microbial world:

### Putting A Simulation Into Practice

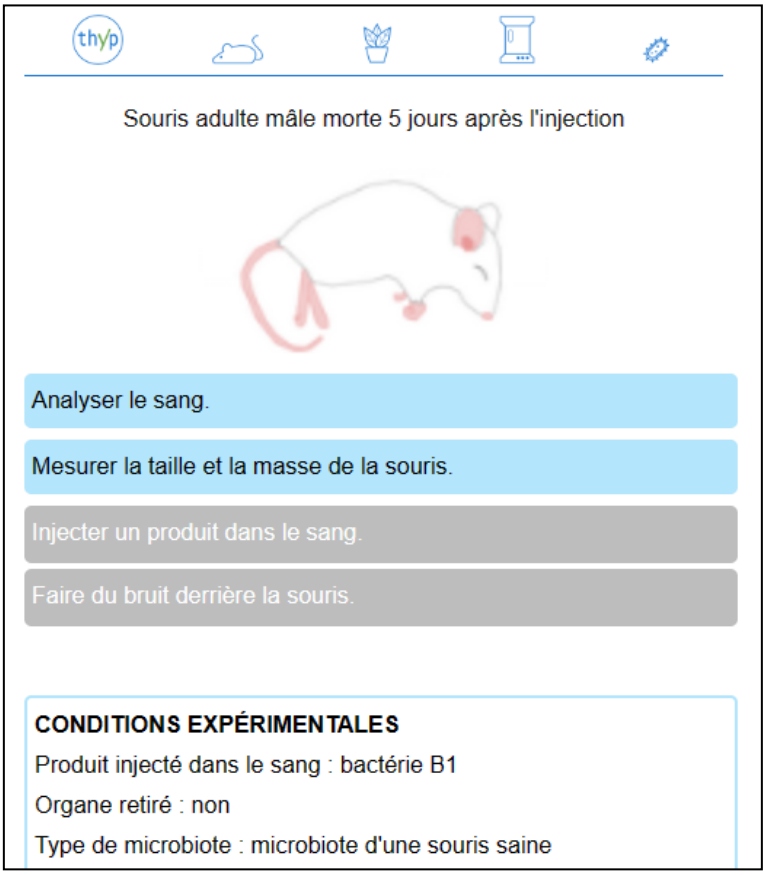
As we have indicated above, the integration of a simulation in the teaching-learning process requires the use of a pedagogical scenario. Note that this tool is turnkey and presents several models. The model that we have adopted is inspired by the TICE portal platform of the Ministry of Education and in the authors are JANATI-IDRISSI Rachid R., Zerhane.

### Development Of A Pedagogical Scenario

1. Subject of the scenario: integration of a simulation concerning rapid bacterial proliferation and another which treats the pathogenicity of certain microbes by the toxin.
2. Summary:



Rapid multiplication of bacteria




The first simulation shows the danger of certain microbes through septicemia:

- 1st step: bacteria culture
- 2nd step: colony formation (rapid bacterial multiplication)
- 3rd step: microscopic observation of proliferated bacteria

The second simulation makes it possible to determine the danger arising from certain bacteria through toxemia.

3. School level: 3rd year international college

   Target audience: all students in the 3rd year college-8 class

4. The targeted skill: the student must be able to identify the different characteristics that make certain microorganisms pathogenic by exploiting the different mechanisms by which microbes act in order to resolve the problem of their danger and subsequently arrive at the notion of the virulence of certain microorganisms.

**LEARNING OBJECTIVES**

- Describe the mode of multiplication of pathogenic viruses and bacteria
- Specify the dangers that bacterial toxin represents for health

5. Prerequisites:

❖ Les prérequis technologiques:

| | |
|---|---|
| **The teacher** | - Basic principles of computing<br>- Basic principles of surfing the Net<br>- Basic principles of using Data show |
| **The student** | - Basic knowledge of IT tools (computer; tablet; smartphone) |

❖ Scientific prerequisites:

- The cell as a functional and structural unit of living beings.
- Classification of different micro-organisms.
- Blood cells.
- Microscopic observation

❖ Skills: observation, description, connection, questioning, deduction, the ability to express the phenomenon studied in text and graph form.

6. The stages of the realization:

| Role of the teacher | Student activity |
|---|---|
| - Organizes the class (individual or group) according to the type of computer equipment available.<br>- Links the current session with the prerequisites.<br>- Presents the experimental protocol<br>- Explains the different functionalities of the software<br>- Answers students' questions<br>- Asks students to simulate following the protocol<br>- Asks questions about the simulation<br>- Guides the debate between students to reach a conclusion. | - Follows the teacher's instructions.<br>- Reminder of prerequisites<br>- Prepares for new activities<br>- Reads the protocol carefully<br>- Asks questions about the software's features<br>- Practices the simulation: either by computer or by smartphone.<br>- Observes the results<br>- Analyzes and interprets the results obtained<br>Builds his/her own knowledge |

7. Workspace:

The scientific room equipped with a Data show with use of a personal computer of the teacher, and personal use by the students under the supervision of the teacher.

8. Time volume:

We estimated 2min for each simulation, but we can reach up to 30min if we take into account the debates and the evaluations.

9. The working method:

2 minutes for each simulation, but we can exceed 30 minutes if we take into account discussions and evaluations.

The exploitation of software is done in a collective manner.

10. Technological resources:

- Preparation of the room.
- Check the status of the internet connection.
- Install the software on students' smartphones.

11. The added value of simulations:

Given the problems of actually carrying out this type of experiment that are necessary for the assimilation of certain scientific concepts, these simulations therefore have an added value since they facilitate the practice of this scientific activity, even by students at home, something that could in reality seem unlikely.

12. Evaluation:

This is a formative evaluation: we have previously prepared questions to assess students' learning:

- In the form of a diagram, show how bacterial multiplication occurs.

13. Remarks:

We noticed that the estimated time for this activity was not sufficient since some students did not have the technological tools (smartphones) necessary to simulate.

For any remediation in a subsequent activity, we must use the multimedia room, since the establishment has one, but despite all the obstacles, we have been able to see that the students who have benefited from these simulations are more motivated and more active than we

Evaluation of the impact of simulation on the learning of concepts relating to the microbial world

To evaluate the impact of the use of simulation on scientific knowledge of the microbial world, likely to be mobilized in the subjects of the regional examination of third year college; we have written a test:

- A control class: made up of students who did not use the simulation during their activities;
- An experimental class: made up of students who benefited from the simulation during their session;

The dedicated test is made up of 5 questions related to the theme taught.

To understand the results of the test, we calculated the percentages of the results of each class, showing the percentage of correct answers of each group for a possible interpretation.

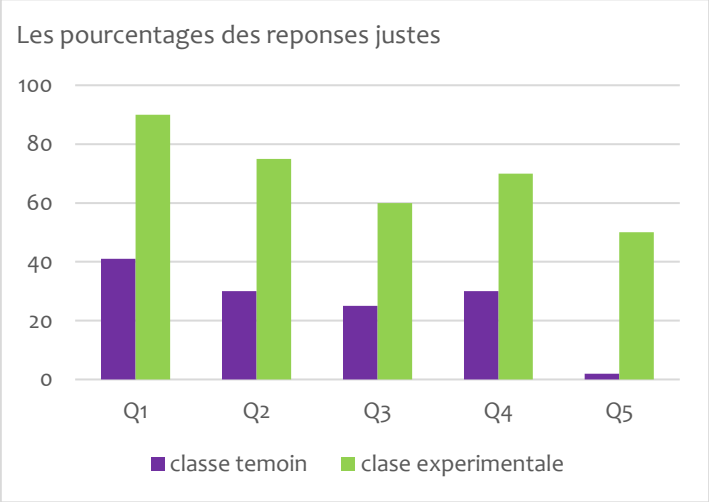



***Fig. 4. A comparison of the percentages of correct responses of the control class and the experimental class***

We note a remarkable difference between the correct answers of each of the two classes; the results obtained from the students of the experimental class who participated in our research are clearly better than those of the control class.

This simulation that we applied, allows to offer students a form of effective interactivity and consequently, a better participation in class favoring an ideal preparation for the regional exam.

It is indisputable that the simulation thus constitutes a specific pedagogical, collaborative and active domain avoiding the constraints linked to the experiment such as the lack of materials, the insufficient volume of hours, the demotivation of teachers...

## 6 CONCLUSION AND OUTLOOK

At the end of this study, we can say that the practical work session plays an important role for students in terms of acquiring new knowledge and correct and concrete notions making it possible to liven up the course, making it more attractive, stimulating the curiosity to research, manipulate, test hypotheses and analyze them; it is a link between theory and reality.

However, according to the results obtained from the analysis of the interview and questionnaires, we can deduce that the hypotheses posed at the start are almost all affirmed, in other words, real problems make it difficult to carry out the practical work. We will note as examples:

- First of all, laboratories mark an impoverishment of scientific equipment which hinders experimental activities
- Lack of carrying out practical work in class due to difficulties in the shortage of experimental materials.
- A very high number of students.
- Insufficient hourly volume which opposes an overly busy program

All these points and many others demotivate teachers towards the practices of experimental activities, which results in the implementation of a descriptive and dogmatic course. But to overcome this present problem, the use of simulation remains an effective means of improving the quality of the teaching-learning process.

Simulation is an active learning practice centered on the student and allowing the establishment of a continuous, individualized or group relationship between the student and their learning. The flexibility of simulation allows students to manage their learning to achieve their goals. This approach gives all participants the opportunity to be more active and involved.

To conclude, and in order to overcome these learning obstacles, to have a remarkable evolution in students' conceptions and in a short and long term perspective, we plan to change the way of doing the SVT course and that of the world microbial in particular, based on simulation. But this does not mean that simulation replaces real experimentation.

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