# Impact of the Use of the Physics Crocodile Simulator in the Teaching and Learning of Electricity in High School (Morocco)

Adil Hamamous and Nadia Benjelloun

***Abstract*—The integration of Information and Communication Technologies in education is no longer a "pedagogical luxury" also a search for human learning settings that are compatible with today's students' experiences. Computer animations and simulations are the most used technological tools for educational purposes, especially with the lack of experimental equipment in school laboratories, the use of interactive simulations has emerged as a real competitor to the real experience, and an effective alternative to traditional practices. This work aims to study the impact of the use of the simulator crocodile Physics 605, on the understanding and learning of students in the second year of the scientific baccalaureate option physical sciences at the high school Abdellah Laroui of the city of Fez. A comparative study was conducted between interactive simulations using the Physics crocodile simulator and the real experience, considering the acquisition and application of cognitive skills as a key performance indicator. The experiment took place with the adoption of a pre-test and post-test method with an experiment group (25 students) and a simulation group (25 students), the data were then analyzed using the statistical analysis program SPSS v 21, for the analysis of quantitative data, non-parametric Mann-Whitney U tests of independent samples were used. At the end of the session, we invited the students of the simulation group (25 students) to answer on the directive survey questions (closed questions). In addition, the directive type interview (open questions) was conducted with the teachers (10) of physical sciences of the high school Abdellah Laroui of the city of Fez, moreover the data were processed by the software SPHINX v5. The results of the descriptive statistics show that the Physics crocodile simulator has a remarkable effect on the acquisition and application of new knowledge in the lesson on the RC dipole (series association of an ohmic conductor of resistance R and a capacitor of capacitance C); these effects are comparable to those in the real experiment. In addition, the results obtained showed a considerable improvement in some other indicators such as motivation, engagement, and interaction among students compared to the classical method.**

***Index Terms*—Crocodile physics, engagement, interaction, learning; motivation.**

## I. Introduction

Throughout the last few years, information, and communication technologies (ICT) has provided innovative tools [1], [2]; it is generally considered that their integration into teaching practices can improve students' learning ability and teachers' potential. Simulations for institutional learning, or in distance education, are considered the most promising tools in teaching [3]-[5]. According to Psycharis [6], Educational computer simulation programs are considered one of the best and most powerful educational computer programs when used in science education. They are based on the constructivist philosophy, which emphasizes that students learn through scientific experience. They are also dynamic computer-generated models, consisting of animations, visualizations, and interactive laboratory experiments, which can explain the concept or simplified model of a component, phenomenon, or conceptual process in the real world.

Alessi and Trollip [7] classify simulations into four parts:

1) Physical simulations: On a computer screen, a physical element or a situation is displayed, and the user learns by evaluating it.
2) Repetitive simulations: They're similar to physical simulations in that they teach a certain element or circumstance. In recurrent simulations, however, the case is studied by altering the parameters, and the process is repeated until the desired result is obtained. This form of simulation can be used to assess cases that are too slow or too rapid.
3) Procedural simulations: Its purpose is to teach the steps necessary to achieve a goal.
4) Situational Simulations: It deals with the behavior of people or institutions in different situations and circumstances. Here, students aim to present alternative solutions in different situations and see the results.

Students' conceptual knowledge is aided by the use of computer simulations [8], [9], and their ability to predict the outcomes of experiments is improved [10]. In addition, they can influence student satisfaction, involvement, and initiative in a favorable way [11]. We also emphasize that using computer simulations in the teaching-learning process increases student engagement and improves questioning and reasoning abilities [12]. Another potential benefit of computer simulations is improving motivation and creativity and creating a stimulating learning environment improves teachers' instructions and facilitates learners' engagement [13]-[15].

In this work, a learning and teaching sequence was carried out using the Physics 605 crocodile simulator, which allows students to perform virtual experiments, tailored to their designs, on the topics of electricity (Fig. 1). Using the Physics crocodile simulator is simple as students can manipulate the activities by themselves. The topics are presented in the program. There are separate templates by topic, object, and menu that provide opportunities for experimentation. Users can form the tools, materials, and options, such as graphics,

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that they will use themselves in the program and they can use them as images and symbols. On the upper part of the screen, there are shortcut keys that allow users to make changes to the mechanism of the experiment.

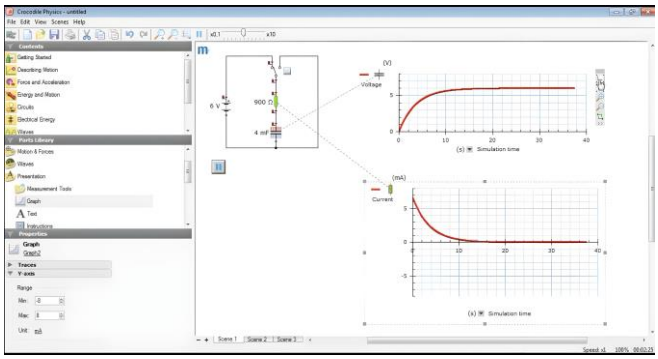


Fig. 1. The physics 605 crocodile simulator.

The purpose of this task is to compare the impact of the Physics 605 crocodile simulator on student understanding with the experimental method, as well as its effect on student motivation, inter-student relationships, student-teacher interactions, and student engagement with the traditional method.

## II. Problematic

In the classical model of teaching, the teacher holds the knowledge, explains, speaks, and demonstrates for most of the time, while regulating the learning. The teacher is ahead of the students because he or she is the only one who knows how the session will unfold. According to this model, the knowledge to be taught all passes through the teacher and is transformed according to a personal typology of didactic transposition, in order. With this methodology, the student does not contribute to the construction of the knowledge, which negatively influences his understanding and learning. With the competency-based approach adopted by the Moroccan educational system since 2000, In the teaching-learning process, the student takes center stage. As a result, the integration of information and communication technology tools into the teaching-learning process has proven to be beneficial, a new paradigm has been immersed to completely change the relationships between the elements of the didactic triangle. To address this issue, Clark and Mayer [16] developed the simulation design based on cognitive theory. According to cognitive theory, several key ideas explain learning:

- Human memory has channels for processing records: visual and auditory.
- Human memory has a limited capacity to process information.
- Learning occurs through active processing in the memory system.
- New knowledge and skills must be extracted from the memory to be transferred to jobs.

Simulation is used to make students enjoy and motivate them to improve their learning ability by making the activities more interesting, motivating, and effective. In this context, we will answer through this study the following questions:

- What are students' perceptions of the impact of using the Physics Crocodile Simulator on their learning and attitudes?
- What are students' perceptions of the role of the physics Crocodile Simulator in developing understanding?
- Does the pedagogical use of the Physics Crocodile Simulator have a positive effect on student motivation and engagement?

## III. Methodology

To involve the student in the learning process, the teacher must use a range of teaching methods. The experimental method is defined as the statement of a problematic situation that allows the student to think and activate his knowledge to solve the problem, verify the hypotheses using the experiment, collect the results and give the conclusions. This method is the most used to teach the course of the RC dipole (series association of an ohmic conductor of resistance R and a capacitor of capacity C) because the experimental device is available in the laboratory. In this part of the study, we compare two sessions of teaching the RC dipole, one using real hardware and the other using an interactive simulation employing the Physics 605 crocodile simulator. This does not mean that we are trying to find an alternative to the use of real experience in the teaching and learning process, as we know the satisfying potential provided by real experimentation. We only want to highlight the potentials that interactive simulation technology can provide, so that the teacher can use it as an alternative in the absence of the possibility to perform a real experiment. The difference between the usage of the Physics crocodile simulator and real experiment hands-on activities on concept learning was investigated using a quantitative experimental strategy of pretesting and post-testing, as well as a qualitative approach of processing the results of an interview survey. From a sample of 50 students newly enrolled in the qualifying secondary school of the second year of the scientific baccalaureate option physical sciences (PC) in the high school Abdellah Laroui of the city of Fez; it was conducted using two groups representing two different classes of the same institution during the academic year 2021-2022. The real experiment group is composed of 25 students, and the simulation group contains 25 students. In the multimedia room, we divide the students into groups of three or four students by a computer, we use a laptop to accompany the students during the learning process. After completing the proposed learning activity, we invited both groups to answer the pretest and posttest questions in a paper-and-pencil format to compare their answers. The collected data were then analyzed with IBM SPSS v 21 statistics (statistical analysis software), the non-parametric Mann-Whitney U test [17] was used to compare the groups of two independent samples, an alpha level of 0,05 was used throughout the analysis of the results. Descriptive statistics were used to summarize the data, including percentages, mean and standard deviation. In addition, the statistical theory was used to test for a significant difference between the participating groups regarding the usefulness of the computer simulation.

### A. Pretest

A pre-test (Appendix 1) was used with both groups to

ensure equivalence and to assess the degree of mastery of the pre-learned skills. This test consisted of four multiple-choice questions and one open-ended exercise. This pre-test was developed and piloted with 25 students, and its reliability was estimated using Cronbach's alpha internal consistency coefficient. The reliability score was found to be 0.71, indicating an acceptable reliability coefficient.

### B. Posttest

The posttest is based on an evaluation model meant to examine students' comprehension and application skills, which we attempted to create in them by using the Physics crocodile simulator. The detailed formulation of the post-test is given in Appendix 2. The posttest contains a multiple-choice questionnaire (MCQ) and two application exercises. This posttest was piloted with 25 students, and its reliability as measured by Cronbach's alpha was satisfactory (Cronbach's α=0.73). The main purpose of the test is to assess the following objectives:

- Know and use the relation q=c uc.
- To know the capacity of a capacitor, it is unit F.
- Determine the capacitance of a capacitor graphically and by calculation.
- Recognize the curves of variation according to the time, of the voltage uc at the terminals of the capacitor.
- Know that the voltage across a capacitor is a continuous function of time.
- To highlight the influence of R and C on the charging and discharging operations.
- Determine the time constant and the charging time.
- Know and use the expression of the electrical energy stored in a capacitor

### C. Interview

To collect the ratings and opinions of the learners in the simulation group, the data collected focuses on learner engagement, motivation, and interactions between learners, as well as between professor and learner. Students in the simulation group are asked to respond to all questions:

#### 1) Evaluation of motivation

- Do you think the Physics crocodile simulator helps you understand the course better than the traditional method?
- Do you find the Physics crocodile simulator more convenient than the traditional method?
- Do you think this course would be better using another technology tool?
- Do you like to use interactive simulations in physics more often?

#### 2) Evaluation of the commitment

- Were there any suggestions for solutions to the various problems raised by the activity?
- Did you use multiple strategies to solve the different problems identified in the activity?
- Did you feel like stopping or repeating the experience when you didn't understand?

#### 3) Evaluation of the interaction

- Compared to the traditional method, does the use of the Physics crocodile simulator help to increase the interactions between you?
- Compared to the traditional method, does using the Physics Crocodile Simulator minimize your interactions with the teacher?

The methodology adopted in this research also revolves around interviews with teachers of physical sciences of the high school Abdellah Laroui of the city of Fez.

The data processing was carried out by the software Sphinx v 5. This made it possible to carry out a presentation of the descriptive statistics for each wording.

## IV. Results and Discussions

### A. Pretest Results

The pre-test results for both groups are shown in Table I below:

TABLE I: Descriptive Statistics (Pretest)

| | | N | Mean | Standard deviation | Mean standard error |
|---|---|---|---|---|---|
| The groups | Experience group | 25 | 15,5600 | 2,67831 | ,53566 |
| | Simulation group | 25 | 15,2000 | 2,44949 | ,48990 |

Analyzing these results, the mean of the students in the experiment group at pretest is m = 15,56 while the mean of the students in the simulation group is m = 15,20; the difference is approximately 0.36. To test whether this difference is significant and to reject the null hypothesis that no significant difference existed between the two groups at pretest, we used the Mann-Whitney U test (in Table II, the distribution of values does not follow the normal distribution because the Shapiro-Wilk p-value is below the chosen alpha level 0.05) to compare the means of two independent samples. The null hypothesis is as follows:

H0: The difference between the means of students in the experimental group and the simulation group is not significant.

TABLE II: Normality Tests

| | Kolmogorov-Smirnov | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| | Statistics | ddl | Sig. | Statistics | ddl | Sig. |
| Experience group | ,177 | 25 | ,042 | ,851 | 25 | ,002 |
| Simulation group | ,188 | 25 | ,023 | ,879 | 25 | ,007 |

The results of the comparison are presented in Table III:

The asymptotic (two-sided) significance of the Mann-Whitney U test above the alpha level is chosen, Asymp. Sig (2-tailed) of 0.504 does not imply the rejection of the null hypothesis; we can thus estimate that there is no significant difference between the tested groups, this shows that both groups have the same level of skills, this result was predictable because both groups received the same course before the pre-test and allow us to validate our experimental model based on a pre-test and a post-test.

TABLE III: Mann-Whitney U Test

| | The groups |
|---|---|
| Mann-Whitney U | 278,500 |
| Wilcoxon W | 603,500 |
| Z | -,668 |
| Asymp. Sig (2-tailed) | ,504 |

### B. Posttest Results

The post-test results for both groups are presented in Table IV below:

TABLE IV: DESCRIPTIVE STATISTICS (POSTTEST)

| | | N | Mean | Standard deviation | Mean standard error |
|---|---|---|---|---|---|
| The groups | Experience group | 25 | 15,8400 | 1,77200 | ,35440 |
| | Simulation group | 25 | 16,0000 | 2,10159 | ,42032 |

The results show that the mean of the students in the simulation group at the post-test is m = 16 while that of the students in the experimental group is m = 15,84; the difference is about 0,16 check if this difference is significant and reject the null hypothesis that the tested educational device had no effect on the students' results, we used Mann-Whitney U test (in Table V, the distribution of values does not follow the normal distribution because the Shapiro-Wilk p-value is less than the selected alpha level 0.05).

TABLE V: NORMALITY TESTS

| | Kolmogorov-Smirnov | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| | Statistics | ddl | Sig. | Statistics | ddl | Sig. |
| Experience group | ,144 | 25 | ,195 | ,961 | 25 | ,444 |
| Simulation group | ,220 | 25 | ,003 | ,795 | 25 | ,000 |

The results of the comparison are presented in Table VI:

TABLE VI: MANN-WHITNEY U TEST

| | The groups |
|---|---|
| Mann-Whitney U | 274,000 |
| Wilcoxon W | 599,000 |
| Z | -,761 |
| Asymp. Sig (2-tailed) | ,447 |

The asymptotic (two-sided) significance of the Mann-Whitney U test above the alpha level is chosen, Asymp. Sig (2-tailed) of 0.447 does not imply the rejection of the null hypothesis; thus, it can be estimated that there is no significant difference between the tested groups, and to admit that the use of the Physics 605 crocodile simulator in the study of the RC dipole (series association of an ohmic conductor of resistance R and a capacitor of capacity C), had a similar effect of the study by the laboratory experiment on the learning of the students.

According to the results of the posttest (Appendix 2) presented in Table VII.

TABLE VII: CORRECT ANSWERS FOR BOTH GROUPS: CONTROL AND EXPERIMENTAL

| | The groups | |
|---|---|---|
| | Experience group | Simulation group |
| Q1 of MCQ | 81,0% | 80,0% |
| Q2 of MCQ | 79,0% | 77,0% |
| Q3 of MCQ | 80,0% | 82,0% |
| Q4 of MCQ | 89,0% | 86,0% |
| Q5 of MCQ | 85,0% | 87,5% |

We observe that most of the students in the experiment group and simulation group have correct answers to the questions (MCQ Q1, MCQ Q2, MCQ Q3, MCQ Q4, MCQ Q5) and the rate of correct answers higher than 50%. We also notice that the difference of the rate of right answers of two groups for the question Q1 of QCM which treats the variation of the voltage at the terminals of the capacitor with a load of a capacitor (1%), the question Q2 of QCM which treats the variation of the current intensity in the capacitor with a load of a capacitor (2%), QCM question Q3 which determines the value of the voltage across the capacitor (2%), QCM question Q4 which analyzes the influence of the resistance R on the charge of the capacitor (3%) and QCM question Q5 which determines the value of the time constant (1.5%). For these questions, the difference in the response rate of students from the two groups is almost equal.

### C. Interview

#### 1) Assessment of motivation

Student motivation is a major concern for researchers interested in the simulation-based learning process. According to Zimmerman [18], motivation is a set of characteristics that cause a student to actively participate in the learning process, to adopt attitudes and behaviors that are likely to lead to the achievement of learning goals, and to persevere in the face of difficulties. In the same spirit, learner motivation is a critical element in skill development [19], [20]. Indeed, it is difficult to acquire new concepts, to make the link with previous knowledge, and to persevere in the appropriation of new concepts.

The intrinsic motivation of an individual is determined by two key variables, according to the concept of self-dedication [21]: the pleasure of action and the interest that it can provide. Based on this psychological idea, we prepared the list of questions to assess the student's motivation:

- Do you think that the Physics crocodile simulator helps you understand the course better than the classical method?
- Do you find the Physics crocodile simulator more convenient than the traditional method?
- Do you think this course would be better using another technology tool?
- Do you favor using interactive simulations greater frequently in physics?

The analysis of the data collected from the interview showed that the students are quite motivated to learn using the Physics crocodile simulator. Most students enjoyed simulating the RC dipole using the Physics crocodile simulator. These findings are depicted in Fig. 2.

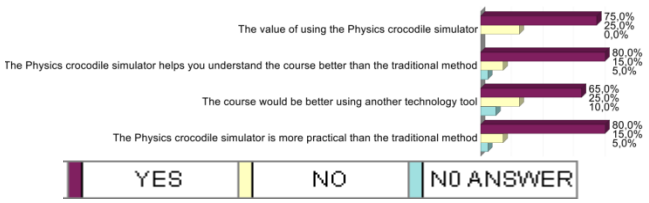



Fig. 2. Assessment of motivation to use the physics crocodile simulator.

75% of students like to use Physics crocodile simulator in this course, teaching using Physics crocodile simulator made more practical according to 80% of students, 80% of learners prefer to use Physics crocodile simulator frequently in the learning process. 65% are not interested in learning with

other technology. These results once again confirm the students' motivation to learn using the Physics crocodile simulator. Furthermore, the results confirm classroom observations and many related studies that have shown that the traditional method has no motivating effect on students [22]. Therefore, the Physics crocodile simulator can enhance the pedagogical learning process of electricity with its powerful resources, so that it can generate the required motivation for Moroccan students.

*2) Evaluation of engagement*

Most of the research aimed at assessing student engagement in the curriculum is mainly based on the strategy of self-regulation, where the student is responsible for his learning. According to Jézégou [23], self-regulation is the student's ability to control and modify their cognitive activity. Indeed, the motivated student who translates his or her motivation into a commitment is likely to promote his or her learning. Some authors, such as [24], [25], believe that commitment can take one of the following forms:

- Affective engagement: When a student finds pleasure in what he or she is doing, he or she asks whether or not the activities are worthwhile.
- Cognitive engagement: The conscious use of appropriate learning strategies.
- Behavioral engagement: The student tends to be proactive, explaining the task to other students and re-experiencing as necessary with new conditions.

With this background, we measure engagement in our study through the following questions:

- Do you have any suggestions for solutions to the various problems raised?
- Did you use multiple strategies to solve the different problems in the activity?
- Can you stop or repeat the experiment when you don't understand?

The results gathered from these questions are as follows:

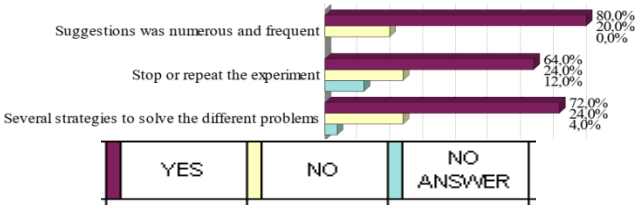



Fig. 3. Statistics on student engagement in the learning process.

The statistics presented in Fig. 3 confirm the positive effect of the Physics crocodile simulator on students' engagement in the learning process. Indeed, 72% of the students confirm that there are multiple strategies to solve the proposed problems; this allows them to develop their methodology and their ability to solve problems. Thus, 80% confirm that their suggestions were multiple. This indicates that the student feels that he/she is a valuable partner in the learning process and that he/she has a great deal of responsibility for the problems encountered. For this reason, their suggestions cannot solve the problems of the activity, the student can confirm this suggestion or correct it, which helps them to increase confidence in their abilities and improve their knowledge base. This process is rarely present in traditional methods where the student is only a receiver. In addition, the Physics Crocodile Simulator directs 64% of students to stop the experiment or to repeat it if necessary.

In summary, the course using the Physics crocodile simulator is generally motivating and engaging; the learning process has shifted from a one-way operation to a cooperative process, and the student becomes more active throughout the process. This finding is consistent with the idea that simulations are generally useful, engaging, and effective learning tools for students [26].

*3) Evaluation of the interaction*

Indeed, inter-student interactions promote the learning process and develop communication and argumentation skills. Therefore, classroom teaching and learning aim to improve the effectiveness of this type of interaction, instead of the teacher-student interactions that are normally reduced. Therefore, the evaluation of the interaction is done using two important questions:

- Does using the Physics crocodile simulator contribute to increased interactions between you and your colleagues, compared to the traditional method?
- Does using the Physics crocodile simulator minimize your interactions with the teacher, compared to the traditional method?

The data collected from these two questions are organized and presented in Fig. 4; the first glance shows that the results are quite encouraging:

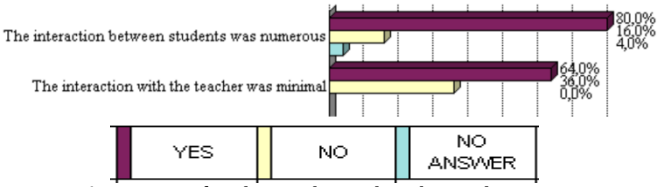



Fig. 4. Assessment of student-student and teacher-student interactions.

The results presented in Fig. 4 show that about 64% of the students stated that the use of the Physics Crocodile Simulator helped to minimize their interactions with the teacher. On the other hand, 80% of the students stated that the course was rich thanks to the exchange process between the students. In addition, the use of this pedagogical tool helps students to integrate into the social learning environment. Thus, we can confirm that the adoption of the Physics crocodile simulator improves the process of interactive exchange among students. In general, students need a tool to interact with each other. In this sense, using the Physics crocodile simulator in the classroom can be a good tool.

*4) Teachers' opinions*

In this part, we collect data from the teachers of physical sciences of the high school Abdellah Laroui of the city of Fez, who participated in the survey of the open question. From the teacher's point of view, we observed a fluidity and a significant reduction of the teaching tasks compared to the traditional method, since we are not solicited by the groups except in some specific situations, our role is thus limited to supervising and animating the session. This experience also allows us to record the students' high degree of motivation, as well as a high level of inter-teacher interaction to discuss the simulations and to respond to the exercise that we have integrated into the teaching scenario. The key to the success of this experiment lies in the facilities offered by the simulations which allow the learner to adopt the learning

pace that suits him/her, thus guaranteeing a certain autonomy of learning [27]. But the disadvantages are that the students only manipulate manually, do not draw the graphs themselves, and do not face measurement errors.

These results are interpreted with the fact that both teaching-learning methodologies allow students to improve their cognitive skills, this shows that it cannot replace the laboratory experiment by the Physics crocodile simulator; except in the case of the lack of materials and electronic components the computer simulation has a considerable interest in electricity, because it allows to carry out the experiments inaccessible because of the lack or absence of scientific equipment in the laboratories and to remedy the problem of the experiments that requires a long time to carry out [28]. The simulation method offers the learner, if necessary, the possibility of repeating the experiment using new parameters as well as the possibility of reviewing each step and thus progressing at their own pace [29]. Rebmann et al. [30] also concluded that teaching the Newtonian mechanics course using simulations helps students acquire and develop new cognitive skills.

## V. Conclusion

In this work, we demonstrate the encouraging impact of the Physics crocodile simulator in the learning of electricity, especially for the Moroccan secondary level. We have chosen the RC dipole (series association of an ohmic conductor of resistance R and a capacitor of capacity C) as the target of study. We can draw the following conclusions:

- The performance of both teaching methods (real experiment and with the Physics crocodile simulator) was convincing, especially for acquiring and applying the new knowledge related to the RC dipole course. Moreover, the difference between the methods was minimal, making the Physics crocodile simulator a true competitor to the real experiment, with comparable results. This impressive impact underscores the importance of simulations for learning, studying, and teaching complex and dynamic physical phenomena, especially when there is a lack of materials and equipment in the institution's laboratory for the real experiment. These findings are consistent with previous research [5], [31]. Combining the simulation with the real experiment allows students to experience new and more constrained pedagogies and provides an exploratory learning environment where they can learn different physics concepts [32].
- Compared to the traditional method, the Physics Crocodile Simulator enhances the learning process, motivates students during class, increases student interaction, and increases student engagement in the learning process.

Of course, the study does not allow us to formulate general results due to the small number of samples, it remains an important indicator of the benefits of integrating computer simulations, especially the Physics crocodile simulator, into electricity education in Morocco. To consolidate our results, and make them more reliable, many samples should be used in future work, also more experiments should be conducted using other simulation tools to discover more about their strengths, as well as to determine the best ways to use these pedagogical tools. Rutten et al. [33] analyzed a total of 510 papers published between 2001 and 2010 that investigated the effect of simulations on science education. It was found that all the articles analyzed reported that the use of simulations had positive effects.

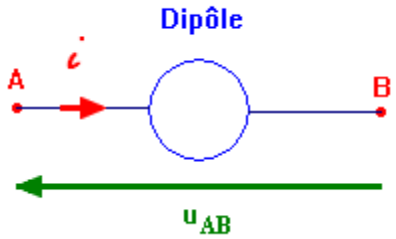
## Appendix

### A. Appendix 1

Pretest

MCQ

1 - Consider the following dipole:




In this case, we have:

a- The generator convention

b - The receiver agreement

c- Ohm's law

2- A constant current flows through a capacitor with a current I = 30 mA for a time Δt = 4 min. The charge of the capacitor is:

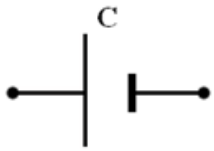
a- Q = 130 C

b- Q = 7.2C

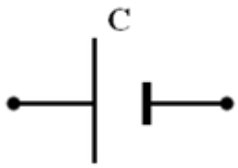
c- Q =5 C

3- the symbol of the capacitor is given by the figure:

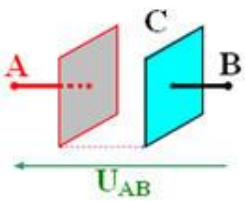
a-



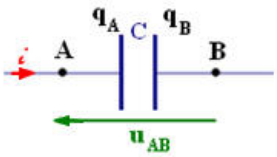

b-




c-




4- We consider the following dipole:




Choose the correct answer:

a-

$u_{AB} = \frac{q}{c}$

b-

$u_{AB} = \frac{q_A}{C}$

c-

$u_{AB} = \frac{q_B}{C}$

Exercise:

The circuit in diagram n °1 consists of a capacitor, a current generator, a switch, and an ammeter. The capacitor is preliminarily discharged at the time t = 0 s, the switch K is closed. The ammeter shows a constant value for the current I = 12 µA.

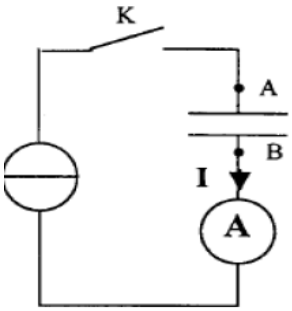


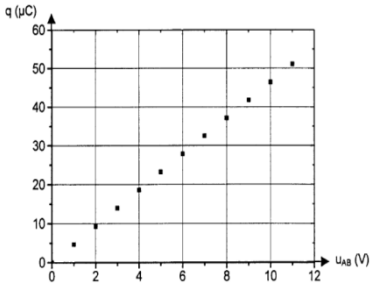

*Schéma n°1*

The voltage $u_{AB}$ across the capacitor. We obtain the following results:

| t(s) | 0 | 0,5 | 1,0 | 1,5 | 2,0 | 2,5 | 3,0 | 3,5 | 4,0 |
|---|---|---|---|---|---|---|---|---|---|
| $u_{AB}$(v) | 0,00 | 1,32 | 2,64 | 4,00 | 5,35 | 6,70 | 7,98 | 9,20 | 10,6 |

1. Give the charge q of the capacitor as a function of I. Calculate q at date t = 4 s.

2. The representation of the graph n °1 gives the charge q of the capacitor as a function of $u_{AB}$. Conclude the value of the capacitance C of the capacitor.




*graphe n°1*

*B. Appendix 2*

Posttest

MCQ

Select the correct response.

1- When a capacitor is charged:

a- The voltage across the capacitor increases.

b- The voltage across the capacitor is constant.

c - The voltage across the capacitor decreases.

2-

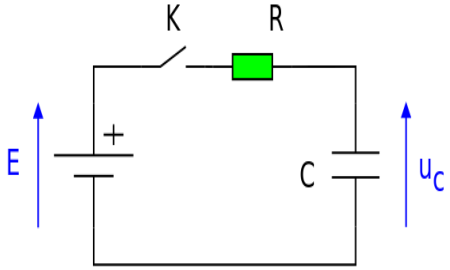
When the charge of a capacitor:

a- The current intensity in the capacitor is constant.

b- The current intensity in the capacitor increases.

c- The current intensity in the capacitor decreases.

3- E is the DC voltage of 6 V.



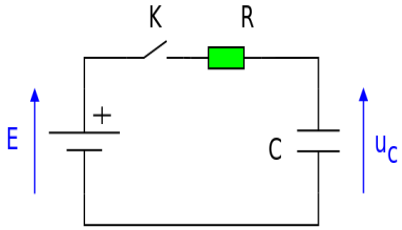

the capacitor is charged. When the capacitor is fully charged, what is the voltage $u_C$ at its terminals?

a- 6 V

b- 4V

c- 5V

4-




The capacitor charges faster if:

a- We increase the resistance R

b -The resistance R

5-

R = 2 kΩ

C = 2000 nF

The time constant τ = RC of the circuit equals:

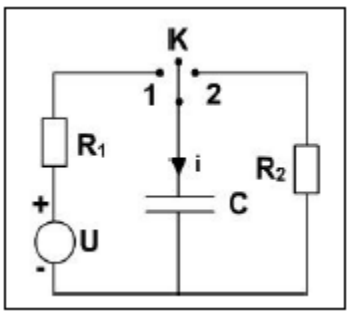
a- 4 µs

b -5 ms

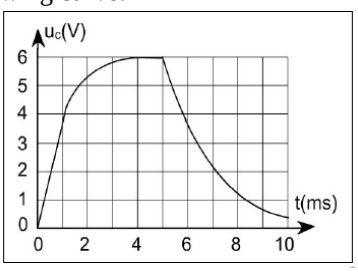
c- 2 s

Exercise 1:

We realize the assembly with an ideal voltage generator, two resistors, and a capacitor, represented by the figure below:




we record the charge of a capacitor of capacity C using the oscilloscope, through the resistor of resistance $R_1 = 21\ \Omega$ then its discharge through the resistor of resistance $R_2$ we have the following curve:




1-

a- Explain how to proceed to obtain the previous curve.

b- Give the value of E of the voltage generator.

c-Find the value of C and $R_2$.

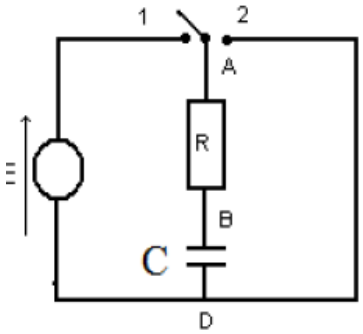
2-

a- Does $U_{C(t)}$ show a discontinuity when going from charge to discharge?

b- the same question for the intensity of the current i(t) that runs through the circuit.

Exercise 2:

Consider the circuit below.




I. The switch is in the first position.

1- With the capacitor preliminarily discharged, the switch is switched to position 1 at time t=0. What is the value of the voltage $U_{BD}$ at time t=0?

2- Calculate the numerical value of the time constant.

3- Give the curve $U_{BD}$=f(t) that can be visualized with a crocodile simulator.

II. When the capacitor is charged, the switch is switched to position 2.

1- Calculate the value of the energy stored in the capacitor.

**Data:** E=6` V; R=11kΩ and C=101nF

## Conflict of Interest

The authors declare no conflict of interest.

## Author Contributions

AH and NB conducted the research, analyzed the data, and wrote the article; all authors approved the final version.

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