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Study on the Influence of Computer Simulation on the Acquisition of Electrical Skills among Students at the Higher Institute of Applied Techniques (I.S.T.A.) in Kinshasa: Analysis of the «Circuit Wizard» Software among Future Congolese Engineers

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ABSTRACT: Computer simulation offers several advantages for electricity learning, such as visualization and interactivity. Computer simulation enables learners to interactively understand electrical phenomena by visualizing them. As a result, abstract concepts become easier for students to grasp. This study aims to determine the impact of computer simulation on students' understanding of electricity concepts at the Higher Institute of Applied Techniques (ISTA). To achieve this objective, we employed the 'Circuit Wizard' software, which was tested with 65 students randomly divided into two groups: a control group (n=30) and an experimental group (n=35), both supervised by four experienced instructors. Prior to the start of their respective courses, a pre-test was administered to each group of students. After the course period, they underwent a post-test to assess their knowledge acquisition. The first group followed the traditional approach to electric circuit learning. The second group, however, underwent the same course but with the 'Circuit Wizard' simulator. Data were collected using questionnaires and tests, which were analyzed using SPSS software. The results obtained from the Wilcoxon test, as well as the calculation of normalized learning gains for both groups, indicated a better improvement in terms of conceptual comprehension rate among students in the experimental group during the post-test (Normalized gain is 0,81 for the experimental group and 0,39 for the control group). As evidenced by the results of the Wilcoxon test, this improvement is statistically significant with $p < 0.05$ for both groups, meaning the p-value is 0.000 for each of the two groups. Consequently, we concluded that the use of computer simulation, such as 'Circuit Wizard,' in physics teaching-learning enables a better understanding of electricity concepts compared to the traditional approach.

KEYWORDS: Electric circuits, Circuit Wizard, conceptual comprehension, computer simulation, ISTA/Kinshasa, ICT.

1 INTRODUCTION

The teaching of sciences is a vital cornerstone for societal progress, especially in the formulation and implementation of policies and guidelines [1]. Given their significance to society, they should be taught in a practical manner, heavily reliant on the observation of experiments designed as evidence, enlightened understanding, and validation of laws by learners [2]. However, the entire pedagogical techniques upon which both teachers and students typically rely to teach and learn these subjects have shifted. In fact, a significant portion of established pedagogies has proven ineffective. Thus, exploring and highlighting the redesign of new innovative and pragmatic pedagogies becomes essential [3].

With the advent and rapid evolution of information and communication technologies, researchers and educational experts have been prompted to contemplate the use of these technologies or educational applications in science education [4]. Among these technological tools, computer simulation is increasingly considered a full-fledged pedagogical support within the context of science teaching and learning at school [5]. Simulations can be integrated into various pedagogical situations, including lectures, individual or small group research activities, assignments, and laboratory work [6]. They can also be used as a

complementary tool to the laboratory, thus saving time during sessions [7]. For the learning of electricity, computer simulation can be utilized to help learners observe the details of the phenomena under study or conduct experiments repeatedly [8].

According to researchers [9], [10], students consistently face difficulties in their learning of electricity concepts, particularly electric current, electric potential difference, and resistance [11]. For [12], a significant portion of students struggle to create electric circuits and assimilate corresponding diagrams. Similarly, [13] found that students also encounter difficulties in distinguishing the concept of series and parallel circuits, which contributes to diminishing their motivation for the course.

Faced with this situation, various approaches and pedagogical strategies based on conceptual changes have been tested to address this issue, but without success. Likewise, [14] highlighted a lack of practical electrical work at ISTA/Kinshasa, which compels the concerned teachers to rely heavily on theoretical teaching. This has resulted in a significant issue in the process of appropriation of electrical concepts among the students of this institution. In an attempt to circumvent this situation, the approach of simulations using the 'Circuit Wizard' software was proposed. Perhaps this approach could help resolve this problem by providing students at this higher institute with a credible alternative for genuine learning.

Our study aims to analyze the impact of computer simulation using the 'Circuit Wizard' software on the learning of electricity concepts among students at the Higher Institute of Applied Techniques (ISTA) in the city of Kinshasa. The objective of the study also includes gathering the opinions of four experimental teachers, those who assisted students during the experimentation with the 'Circuit Wizard' software, regarding the advantages associated with the use of this computer simulator by both students and teachers.

2 PROBLEM STATEMENT

Physics has long been considered a challenging subject to teach. Numerous didactic studies on physics education have confirmed that it is often taught as a collection of isolated facts, detached from the laboratory [15]. Researcher [16] asserts that physics education is: "too abstract, subordinated to its mathematical tool, outdated programs, disconnected from daily practiced physics and its technological applications." Conversely, [17] believes that the practical work usually carried out by students only minimally aids them in establishing relationships between concepts and objects in the real world. However, with the advent of information and communication technologies in physics education, particularly computer simulation or virtual laboratories, educators now have a didactic tool that can enhance the quality of their teaching. Computer simulation can help teachers effectively convey laws and concepts of physics to students. It can also address the issue of lack of experimentation or practical work in classrooms due to the absence of dedicated materials. For learners, computer simulation provides an opportunity to solve exercises in class or from the textbook. The use of computer simulation in physics education can help students bridge the gap between concepts taught in class and real-world objects.

The pedagogical approach centered around the use of computer simulation holds great significance compared to the traditional approach. This approach offers a valuable opportunity for students to become familiar with technology and access laboratory resources [18].

That said, the problem addressed in this research is based on the use of computer simulation in physics education, specifically in electricity. In this study, we aim to enhance the understanding of electricity concepts among students at ISTA/Kinshasa. To achieve this, we taught the concept of an electrical circuit using the computer simulator 'Circuit Wizard.' The simulated electrical circuit is a parallel circuit, consisting of multiple loops or branches ($n=4$). The choice of an electrical circuit is justified by its perceived complexity and difficulty for students to grasp [19], [20], [21], [22], [23], [24]. However, the simulation offered to our students allows them to explore the different components of an electrical circuit studied in class, manipulate experiment data on 'Circuit Wizard,' and finally solve the exercise presented on the simulator. This exercise enables us to conduct a quantitative analysis of the ensuing results, helping us determine the impact of this computer simulator on the assimilation of electricity concepts.

Furthermore, we formulated our research question as follows: "What is the impact of using computer simulation on the understanding of electricity concepts among future engineers at the Higher Institute of Applied Techniques (ISTA)?"

To address our research question, we formulated the following hypotheses:

H0: The use of computer simulation, such as 'Circuit Wizard,' in physics teaching and learning would not yield a better understanding of electricity concepts compared to traditional teaching and learning approaches.

H1: The use of computer simulation, such as 'Circuit Wizard,' in physics teaching and learning could result in a better understanding of electricity concepts compared to traditional teaching and learning approaches.

3 THEORETICAL FRAMEWORK

3.1 DEFINITION OF COMPUTER SIMULATION

The scientific literature provides us with several definitions of computer simulation, from which we have selected those that align with our perspective. According to [4], computer simulation corresponds to computer programs containing a simplified model of a system or process under study. It involves executing a model using computer software to provide information about the analyzed and studied system [25]. It is also a representation or model of an event or phenomenon established to present and facilitate understanding of a system's operation [26].

3.2 THE IMPORTANCE OF COMPUTER SIMULATION

Computer simulation serves multiple crucial roles [27] highlight how it aids in understanding latent phenomena and visualizing processes and their outcomes. It forms a fundamental element of the scientific approach [28]. It also enables experimentation on computers [29]. As a didactic and pedagogical tool, computer simulation or virtual laboratories ensure a better grasp of studied concepts [20].

3.3 COMPUTER SIMULATION RESEARCH IN UNDERSTANDING ELECTRICITY CONCEPTS IN PHYSICS

Numerous studies have been conducted regarding the use of computer simulation in understanding electricity concepts. These studies showcase its effectiveness from various perspectives. For instance, [30], in a study investigating the efficacy of virtual laboratories in developing concepts such as the photoelectric effect, divided a group of 50 secondary school students from India into a control group and an experimental group. The control group underwent physics laboratory sessions, while the experimental group worked with computer simulators. The study concluded that the experimental group's results were superior in terms of learning the photoelectric effect.

In their article, [20] explore the conceptual assimilation of electrical circuits in secondary vocational engineering education. This study, conducted in a virtual laboratory (computer simulation), demonstrates how to enhance the retention of electrical circuit concepts through a research-based pedagogical approach. Researchers worked with secondary vocational engineering students, dividing them into control and experimental groups. Control group students followed traditional computer-based practical exercises, while the experimental group engaged in inquiry-based learning in a virtual laboratory. Results showed that students in the experimental group, engaged in virtual laboratory conditions, achieved significantly higher scores in conceptual assimilation (Cohen's $d = 0.65$) and procedural skills ($d = 0.76$), unlike the control group.

[30] conducted a study to foster primary school students' ($n=66$) grasp of electricity concepts by combining simulation and laboratory activities. The results revealed that computer simulation enables students to understand theoretical principles of electricity.

Another study by [18] on understanding electrical circuit concepts analyzed the value of combining real experimentation (RE) with virtual experimentation (VE) in terms of changes in students' conceptual assimilation of electrical circuits. To achieve this goal, 88 undergraduate students were randomly assigned to two groups: control group (43 students) and experimental group (45 students). Control group students worked with real experiments, while experimental group participants used both real experiments and computer simulation. Researchers conducted conceptual tests after the course to evaluate students' understanding of electrical circuits. The results showed that the combination of simulation with real experiments enhanced students' conceptual assimilation more than real experimentation alone. In other words, the experimental group's results significantly outperformed those of the control group.

Furthermore, several websites offer various interactive computer simulations related to electricity. For our study, we will mention the 'PhET Interactive Simulations' website (<https://phet.colorado.edu/>). This site, owned by the University of Colorado Boulder, provides 30 electricity simulations (electric field, resistance in a wire, semiconductors, etc.).

4 METHODOLOGY

4.1 DEFINITION OF COMPUTER SIMULATION

To provide a relevant response to our research question, we conducted an experimental study based on pre-test and post-test assessments with students from the Institute of Applied Techniques (I.S.T.A.). We divided these students in two groups of

students. An experimental group (EG) (n=35) underwent a course on computer simulation using the ‘Circuit Wizard’ simulator, while the control group (CG) (n= 30) received traditional physics instruction without incorporating any computer simulation sequences.

For the experimental group, the researcher instructor, along with the two experimenters assisting, provided students with instructions to follow and a problem to solve using the computer simulator. The students then proceeded to solve the given problem (post-test). They manipulated experimental data, formulated and tested various hypotheses to arrive at the optimal solution using simulation. The instructor’s role in this learning context was to provide clear guidance to students encountering difficulties in reaching a solution. On the other hand, the experimenters provided technical assistance to students regarding the manipulation of the ‘Circuit Wizard’ software. As for the control group, as mentioned in the preceding paragraphs, the traditional method was employed. This involved the instructor conducting a regular two-hour physics class. Towards the end of the session, the instructor presented exercises to assess and evaluate students’ understanding of the lesson (post-test). In this case, the instructor explained each question in the assessment to guide students towards the correct answers.

It is worth noting that students in both groups, the control group and the experimental group, had to take a knowledge test (pre-test) before the course session commenced. This test assessed their understanding of the concept of electrical circuits and diagnosed any difficulties they had in understanding electricity.

4.2 THE USED COMPUTER SIMULATOR: “CIRCUIT WIZARD”

For our experimentation, we utilized the simulation software ‘Circuit Wizard’ to simulate the concept of an electrical circuit. This utility can be accessed through the following link: <https://www.electromecanique.net/2014/04/telecharger-circuit-wizard-gratuit.html>

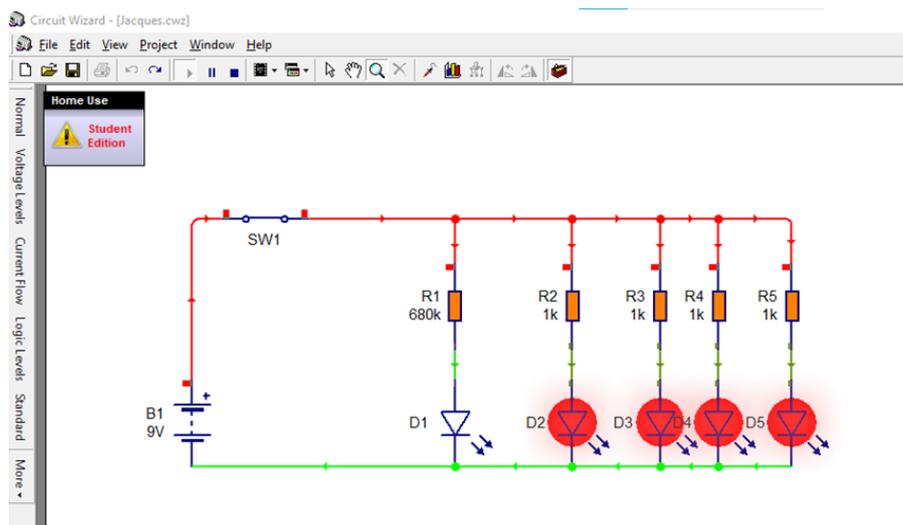


Fig. 1. Screenshots of the Electrical Circuit Simulation on the Circuit Wizard Software

Through this simulation environment, the learner has the opportunity to use tools and objects that allow them to study and simulate simple and complex electrical or electronic circuits. Indeed, we chose this software due to its versatility in terms of designing, simulating, and projecting simple and complex electronic or electrical circuits [31].

Study Sample The sample for our study consisted of 28 students (aged 18-23) from I.S.T.A./Kinshasa, in the DRC, who were randomly selected and divided into two groups: control group (CG) and experimental group (EG). Both groups comprised 14 students each, all enrolled in the electrical department of our host institution. Specifically, the participants included first-year students (17 individuals) and second-year students (11 individuals) of the bachelor’s degree program.

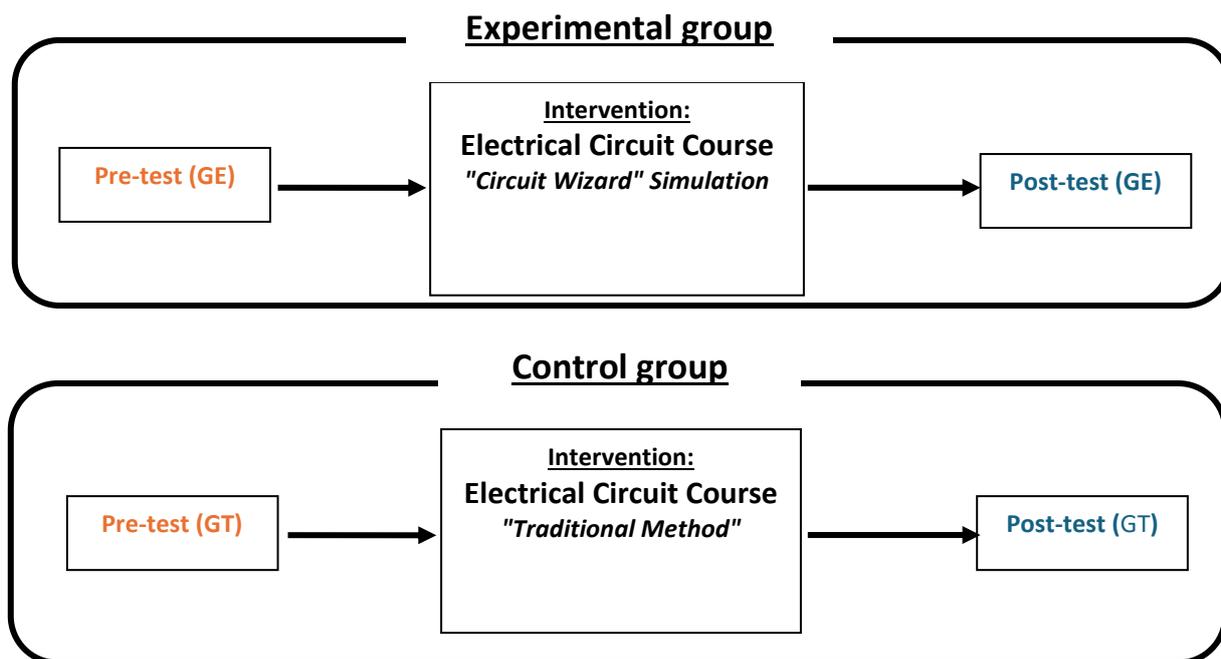


Fig. 2. Descriptive diagram of the research methodology used

5 DATA COLLECTION

Data collection for this study was facilitated through two knowledge tests named the pre-test and post-test, respectively. The results from these assessments allowed for statistical analysis of the scores for each learner, as well as for each student group. Regarding the types of questions posed in these knowledge tests, both open-ended and closed-ended questions were used. Closed-ended questions with multiple assertions were employed to assess students' knowledge of various electrical circuit concepts (Series Circuit, Parallel Circuit, or Branch Circuit, and calculation of equivalent resistance). Open-ended questions were used to evaluate the students' level of comprehension of the studied concepts.

The pre-test comprised a total of six questions, including four closed-ended and two open-ended questions. The post-test, on the other hand, consisted of eleven questions, seven of which were closed-ended or multiple-choice questions, and six were open-ended questions.

Furthermore, regarding the content validation of the pre-test and post-test, we initially developed the first versions of these documents based on the physics curriculum taught to the students at I.S.T.A./Kinshasa. Subsequently, we submitted the initial versions of these assessments to a panel of four educational physics specialists from our research laboratory. These experts evaluated the relevance of each question in relation to its respective domain. Following their evaluation, they provided feedback that helped us refine the documents and arrive at their final versions. Additionally, to ensure the reliability of our questionnaires (pre-test and post-test), we conducted a Cronbach's Alpha test, as shown in the following table:

Table 1. Cronbach's Alpha test

Tests	Cronbach's Alpha Coefficient
Pre-test	0,803
Post-test	0,807

The table above allows us to deduce that the reliability coefficients of our questionnaires are high and tend towards the recommended value of 1. This, in turn, demonstrates the reliability of these questionnaires and even their applicability, thereby ensuring the reliability of their results.

Semi-structured interview guide with the teacher who facilitated the session of the 'Circuit Wizard' simulator experimentation.

To analyze the opinions of the experimental teachers using the 'Circuit Wizard' software, gathered during interviews conducted at the end of our various experimentation sessions, we employed the method of data matrix construction. Indeed, according to [32], such a scientific approach involves the following steps: data condensation, data display in matrices, and drawing and verifying conclusions. In the coding phase, an independent expert coder intervened to simplify the thematic coding. Thus, the researcher and this independent coder worked collaboratively to verify the accuracy of the identified themes and subthemes.

6 RESULTS AND DISCUSSION

In order to determine the impact of simulation on the understanding of electrical concepts among students in our various experimental groups, the control group and the experimental group, we relied on descriptive statistics and the Wilcoxon signed-rank test. We also based our analysis on the results of semi-structured interviews conducted with the teachers who experimented with the software used throughout our study.

6.1 RESULTS OF SEMI-STRUCTURED INTERVIEWS CONDUCTED WITH THE TEACHERS WHO GUIDED THE EXPERIMENTATION SESSION OF THE "CIRCUIT WIZARD" SIMULATOR

- According to you, for the realization of this lesson, is the 'Circuit Wizard' simulator useful for students, and for you, the teacher? If the answer is affirmative, then tell us how it is useful for students? and how it is useful for you, the teacher?

According to the experimenters, this lesson was indeed beneficial for both students and teachers. For them, it was crucial for students as it allowed them to grasp the concepts of electrical circuits and all their components. In other words, this software provides students with the opportunity to perform virtual manipulations of electrical components, test circuits, and observe real-time results. This facilitates the understanding of theoretical concepts, offers a practical experience with zero potential risk related to physical manipulations, and allows students to explore various simulation scenarios.

"For students, it was a precious opportunity for them to learn about the concept of electrical circuits in a different way. They had the chance to test new simulation scenarios related to this concept, which allowed them to reinforce their understanding of the said concept..." (4 participants, engineers from ISTA/Kinshasa).

For teachers, the experimenters believe that 'Circuit Wizard' is a valuable educational tool. Indeed, it offers physics teachers a multitude of possibilities to demonstrate concepts visually and attractively. This can be motivating for students learning physics. Additionally, the teacher can use it for practical work without incurring any cost. The experimenters also argue that it is a very good pedagogical tool allowing the teacher to reconcile theory and practice.

'(...) This constitutes a very good means of articulating theory and practice for the teacher. Indeed, this tool offers several possibilities for presenting the concepts to be taught. Moreover, it allows students to carry out manipulations to better understand abstract concepts. This represents a better alternative to overcome the lack of practical physics work caused by the absence of scientific equipment in the laboratory...' (4 participants, engineers from ISTA/Kinshasa).

- Do you think this simulator allows students to learn electricity concepts effectively?

According to the experimenters, there is no doubt that the 'Circuit Wizard' simulator offered an effective opportunity for students to learn various electricity concepts. Moreover, the final results of the experimentation with this software among students proved very conclusive compared to those of the control group.

"Yes, this simulator is truly effective for learning electricity concepts. Indeed, it offers an interactive approach allowing students to perform virtual manipulations of electrical components and test circuits, which facilitates the understanding of theoretical or abstract concepts..." (3 participants, engineers from ISTA/Kinshasa).

- Did you encounter any difficulties or problems during the use of this simulator? If yes, which ones?

The majority of experimenters (3 individuals) claim not to have encountered any difficulties in using the 'Circuit Wizard' software. Only one of them confirms having encountered some difficulties with the software.

"Yes, initially, I had some technical difficulties regarding the use of this simulator. But after consulting the user guide and tutorials provided by the researcher, I managed to master this software..." (1 participant, engineer from ISTA/Kinshasa).

- How do you find the working environment (buttons, functionality, other objects represented on this software, its operation, and its role) on this 'Circuit Wizard' simulator? Is it directly and easily understandable by the user?

All the experimenters find that the working environment (buttons, functionality, other objects represented on this software, its operation, and its role) on the 'Circuit Wizard' simulator is user-friendly. They also confirm that this simulator fulfills its role as a learning tool correctly by offering students an interactive platform to experiment or simulate electricity concepts.

"(...) The working environment on this simulator is well-designed, making it easy for the user to navigate. Regarding the buttons, they are intuitively placed, making them easy to use for the users... the objects present on this simulator are easy to identify..." (4 participants, engineers from ISTA/Kinshasa).

- In your opinion, what are the most important things that students should understand during the use of this 'Circuit Wizard' simulator?

During the use of the 'Circuit Wizard' simulator, experimenters believe that students should acquire a solid understanding, both practical and theoretical, of electricity concepts. Indeed, this understanding is demonstrated through circuit manipulations, testing, troubleshooting, and interpreting diagrams.

"(...) With the 'Circuit Wizard' software, students should understand the theory and practice related to learning electricity concepts... understanding the studied concepts, how to troubleshoot electrical circuits, interpreting diagrams, (...)" (4 participants, engineers from ISTA/Kinshasa)."

- Does this 'Circuit Wizard' simulator increase the motivation of learners for learning electricity? Please support your answer with concrete examples

"Yes, the experimenters believe that the 'Circuit Wizard' simulator contributes to increasing learners' motivation for learning physics, especially electricity. This is justified by the fact that this simulator offers students an interactive approach that allows them to integrate interactive elements and receive immediate feedback. It also offers them the opportunity to carry out real-time simulations. All these elements contribute to stimulating the interest". (4 participants, engineers from ISTA/Kinshasa).

6.2 DESCRIPTIVE STATISTICS RESULTS

The table below presents the results of the descriptive statistics in our study, based on the mean scores achieved by students in each group (experimental group (EG) and control group (CG)) during the pre-test and post-test. These results are also presented in terms of the respective standard deviations for each group.

Table 2. Descriptive Statistics Results

Results of the Control Group (GT)			
Tests	Number of students (N)	Means	Standard deviations
Pre-test	30	3,60	1,102
Post-test	30	5,90	1,322
Results of the Experimental Group (GE)			
Pre-test	35	3,83	1,098
Post-test	35	8,83	0,822

According to the results presented in Table No. 2, we can observe that the average scores achieved by students in the control group and the experimental group during the pre-test were almost the same, namely 3,60 out of 10 for the CG and 3,83 out of 10 for the EG. Indeed, these results indicate that these learners had roughly the same level of understanding of electrical concepts. However, it must be noted that their level of understanding was quite low. Regarding the standard deviations of the same test, we notice that they are quite low for both groups. This implies that the population in this study was homogeneous. We can also say that these students had almost the same level of understanding of the concepts in the electricity course.

As for the post-test, we observe a significant increase in the average scores of students in the experimental group, with an estimated value of 8,83 and a very low standard deviation of 0,822. However, we also noticed a small increase of only three units in the average scores of students in the control group in the post-test, namely 5,90. When comparing it with the average score obtained by the experimental group, we observe that it is lower. Although small, we also observe a slight increase in the

standard deviation of the control group, with a value of 1,322. This means that students in the control group did not really progress in their understanding of the studied concepts compared to those in the experimental group.

6.3 RESULTS OF NORMALIZED LEARNING GAIN FOR BOTH GROUPS

To measure the conceptual improvement of students in both groups after the courses they took, we calculated the normalized gain (or Hake factor). According to [33], this measure helps avoid "ceiling" or "floor" effects [33], [34]. In fact, the normalized gain represents the ratio of the raw conceptual gain achieved to the maximum possible gain, and it is calculated using the following formula.

$$(g) = (\text{Post-test Score} - \text{Pre-test Score}) / (\text{Maximum Possible Score} - \text{Pre-test Score})$$

Table 3. Criteria for Evaluating Normalized Gain Scores

Normalized Gain (g)	Interpretation
$g > 0,7$	"High" indicates a significant improvement in student performance.
$0,4 < g \leq 0,7$	"Medium" indicates a measurable but not maximal improvement in student performance.
$g \leq 0,4$	"Low" indicates a low improvement in student performance.

Table 4. Results of the two groups in terms of normalized learning gain

Group of students	Pre-test Score	Post-test Score	Maximum Possible	Normalized Gain
Control Group	3,6	5,9	10	0,39
Experimental Group	3,83	8,83	10	0,81

Analyzing the results from Table 4, we observe that the conceptual understanding of students in the experimental group is significantly higher (0,81) than that of students in the control group (0,39). Moreover, referring to the normalized gain score criteria presented in Table 3, we can therefore conclude that students in the experimental group achieved a moderate improvement in their level of conceptual understanding. On the other hand, students in the control group exhibited a low improvement in their conceptual understanding. This observation highlights the impact or effectiveness of our experimental approach based on the use of computer simulation, specifically the 'Circuit Wizard' software, in teaching and learning electricity concepts compared to the traditional approach. This is in terms of enhancing students' conceptual understanding.

However, to draw more conclusive insights, it would be necessary to conduct appropriate statistical tests, such as the Wilcoxon test, to determine whether the observed differences are statistically significant.

6.4 RESULTS OF MEAN COMPARISON TESTS

Given the small size of our sample (n=65) and the non-normal distribution of these data, as indicated by the p-value for both groups being less than 0.05, we have opted for a non-parametric test, specifically the Wilcoxon signed-rank test for paired samples. Indeed, this test serves as an alternative to the t-test and is used to compare differences between two conditions or measurements for the same subjects (or paired samples) [35].

Table 5. Wilcoxon Signed-Rank Test Results

Group of Students	N (sample size)	Z (Normalized test statistic)	P-value (Sig.)	Significance level set
Control Group	30	-4,408	0,000	0,05
Experimental Group	35	-5,193	0,000	

The results presented in Table n°3 show that the p-values for both groups are below 0.05, which represents our significance threshold, and they are equal to 0.000. This observation leads us to reject the null hypothesis, which posits that the median difference between the post-test and pre-test is equal to zero. In other words, there are significant differences between the mean scores obtained by students in the post-test and pre-test in both groups (control group and experimental group).

This indicates that the results found for the control group and the experimental group are statistically significant. Additionally, we can notice that the absolute value of the normalized test statistic Z for the experimental group is larger than that of the control group. This allows us to conclude that the academic performance achieved by students in the experimental group is better compared to that of the control group. Moreover, it should be noted that the negative value of Z indicates that post-test scores are higher than pre-test scores.

It must be emphasized that the observed differences in the data of these two groups are not due to chance, but rather to the effect of intervention or experimental treatment. In this case, it is the use of computer simulation, specifically the "Circuit Wizard" software that was employed in the course taught to the experimental group. In essence, the results of the Wilcoxon tests indicate that the "Circuit Wizard" software had a significant impact on the learning outcomes of the experimental group students. This is evident from the fact that the post-test scores are considerably higher than the pre-test scores in this group, demonstrating that the use of this software contributed to improving the academic performance of the students.

At our level of analysis, these results are explained by the fact that students in the experimental group were more active and resourceful during their learning process. Faced with computer simulation, these students had to first understand the posed problem, identify relevant physical quantities related to the problem, establish a problem-solving strategy to analyze the problem more effectively, formulate hypotheses, introduce and manipulate data in the simulation to test the validity of various hypotheses, and then observe, analyze, and interpret the obtained results for better communication.

It should also be noted that this problem-solving approach was facilitated by the simulation environment, which provided learners with direct interactive feedback at each step of their manipulation. This enabled them to make practical modifications to the simulation data and to confirm or refute their hypotheses. We can observe that through their attitude and approach to the given problem, this simulation activity required learners to demonstrate a high level of skill and to apply their physics knowledge to arrive at the correct answer [36].

In the case of this study, this techno-pedagogical approach based on the use of computer simulation allowed experimental group students to actively explore theoretical electrical concepts, such as light-emitting diodes, voltage, electric current intensity, series circuits, and circuits with branches. All of this was made possible by the posed problem. These results coincide with those of the study conducted by [37].

To better highlight the positive effect of simulation on student learning, let's consider the example of the post-test where a simple open-ended question was posed to students in both the control group (GT) and the experimental group (GE) in order to clearly establish the difference between a closed circuit and an open circuit. By analyzing the responses obtained from those concerned for this question, we can see that many students in the control group struggled with it. In contrast, almost all students in the experimental group answered this question correctly. This is justified by the fact that it was easier for GE students to find the correct answer. They simply drew an electrical circuit in the "Circuit Wizard" software and then activated the simulation button to see if the electric current flows continuously and provides energy to the load present in the circuit or not. If so, it's a closed circuit. Otherwise, it's an open circuit (no current). Thus, they quickly and accurately answered this question. These results are logical, especially considering that [38] stated that effective technology could enhance problem-solving skills.

However, for GT students, this was more difficult, requiring a double cognitive effort. They had to first imagine the logical functioning of an electrical circuit without visualizing it, for instance, on a simulator like the students in the other group (GE). Then, they had to try to find the best answer to the posed question. This was a laborious task with no guarantee of reaching the correct answer. Furthermore, the approach of these students in the control group reflects a certain passivity in their physics learning. However, it's important to note that the passivity of these students could be attributed to the absence of simulation tools and should not be interpreted as a lack of interest in physics in general, particularly electricity. Thus, in this case, the integration of computer simulation, as highlighted by [39], [40], [41], and [42], can potentially enhance engagement, curiosity, and motivation among learners in their learning process, as simulation offers a more interactive and immersive pedagogical approach to explore physics or electrical principles more practically and visually.

In summary, this concrete example could explain why the post-test scores achieved by experimental group students are higher compared to those achieved by control group students in the same test.

7 CONCLUSION AND FUTURE PERSPECTIVES

This study aimed to determine the impact of computer simulation, particularly the 'Circuit Wizard' software, on the understanding of electrical concepts among students at ISTA/Kinshasa.

Computer simulation is widely recognized as a pedagogical approach extensively used in various scientific and engineering fields, especially for learning electricity [43], [44], [45], and [46]. The integration of this techno-pedagogical approach into the teaching and learning of electricity holds significant importance, as it enhances students' interest in this physics branch and simplifies complex electrical phenomena that are often difficult for students to grasp. It can also facilitate the learning of electric phenomena that are not easily accessible through experimentation.

The results of the experimentation conducted with students participating in this study have shown that those in the experimental group, who received instruction using the computer simulator, achieved better post-test performance compared to students in the control group, who were taught using traditional teaching methods for the same test. The Wilcoxon signed-rank test indicated that these results were statistically significant. However, the calculation of the normalized gain based on pre-test and post-test results for each group revealed that students in the experimental group improved their level of conceptual understanding to a moderate extent, while the control group exhibited only a small improvement.

Based on these findings, we conclude that this study has highlighted the positive impact of the computer simulator 'Circuit Wizard' on the learning of electrical concepts among ISTA/Kinshasa students. The use of this techno-pedagogical approach in electricity education has led to an enhancement in the quality of the learning process and has alleviated certain difficulties in grasping electrical concepts. However, with a larger and more representative sample size, encompassing other branches of physics such as mechanics, it would be possible to generalize the results regarding the impact of simulation in physics.

In the future, further investigations could explore the long-term effects of computer simulation on students' retention of knowledge and their ability to apply learned concepts in practical scenarios. Additionally, the effectiveness of simulation-based learning in various physics topics and its potential to enhance critical thinking and problem-solving skills could be studied in greater detail. Overall, this study has illuminated the promising potential of computer simulation as an educational tool in the field of physics education.

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