

Influences of the effective use of a computer simulation on learning in physical science

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ABSTRACT

One of the most attractive instruments in science education is digital simulation. The investigations were conducted utilizing a pre-test and post-test methodology with Moroccan students enrolled in the second year of the natural sciences option secondary certificate at the Abdellah Laroui High School in the city of Fez. In this paper, we assess the effects of including a digital simulation on high school students' understanding of RLC (a linear circuit containing an electrical resistance, an inductor, and a capacitor) (25 students). There is a substantial difference between the means of the tests administered to the control (M-Cont) and experimental (M-Exp) classes ($M\text{-Exp}-M\text{-Cont}=15.32-3.08=2.24>0$), based on a student's analysis of the two classes' test scores using a t-test. This study found that using a digital simulation in an educational setting allows for the acknowledgment of the added value and has a favorable impact on student learning, notably in the study of free oscillations in an RLC circuit.

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1. INTRODUCTION

Information and communication technologies (ICT), are progressively becoming significant sources of knowledge, just as reading and writing. Learning how to use computer tools is becoming more and more crucial, especially for teachers who can use them as a teaching tool, concept illustrator, or to support experiments. According to Voulgre, Wallet, and Baron [1], technology (ICT) use in Morocco has substantially increased, especially in science education and learning [2]. According to numerous research, using these technologies in the classroom effectively can offer a few advantages [3], [4], such as ICT-based chemistry learning, overcoming students' learning difficulties, and increasing learning motivation to achieve higher value [5]. ICT can help teachers achieve their educational goals by enhancing students' interest, involvement, and excitement in all classroom activities [6].

Furthermore, in science education, problem-solving has a major impact on boosting ICT literacy [7]. In other words, the impact of ICT is most apparent when there is a good correlation between real and theoretical models. For instance, the processing of data, implementation, computer-assisted experimentation, and experimental simulations are all frequently done in physics education. Furthermore, students can collect, present, and analyze the data that drove the laboratory learning design using computer-based learning, allowing them to master a coherent physics topic right away [5]. However, the main challenges that remain in the application of ICT to education are quality, equity, and efficiency [8].

Simulations for learning in institutions or online learning circumstances are among the most appealing resources for teaching experimental sciences [9]. By stimulating models or virtual experiments, these simulations can imitate real-world processes, allowing learners to validate variables, establish hypotheses, analyze data, and better grasp complicated phenomena [10]. On the other hand, a simulator can be used to substitute or complete an experiment, as well as to model and calculate scientific data [11]. According to Chernikova *et al.* [12], simulation-based learning has increased learning by removing the limitations of real-world learning and enabling students to practice complicated abilities in a classroom setting. A beneficial technique for facilitating the acquisition of difficult abilities, simulation has a good effect on learning. Simulations are also copies or imitations of how a genuine processor system works [13]. Furthermore, by bridging the gap between their past knowledge and their understanding after learning, simulation helps students increase their scientific awareness, reduce misconceptions, and create conceptual transformation physics [14].

Several types of digital simulations are used in science education, and we have chosen four types according to Rex and Elizabeth [15]: i) Experimental simulations: are used to put the cognitive or affective phase of learning; ii) Information simulations: are used to publish information to the learner; iii) Reinforcement simulations: are used to consolidate very distinctive learning objectives; vi) Integration simulations: seem more attractive in science education. Learners learn the knowledge and principles required and use the simulations to practice the knowledge.

A field of electricity is included in the present Moroccan high school's second-year scientific baccalaureate option physical sciences curriculum (dipole RLC). The ability of the student to discern between quantities is one of the primary goals of the teaching (voltage, current, load, resistance, coefficient of inductance, and capacity), a second capital point to know the periodic, pseudo-periodic, and aperiodic regimes, to exploit experimental documents. The digital simulations we present in this article are built on the following assumptions: i) A concept brought to a learner during simulation can participate in learning [16]; ii) Simulation facilitates the understanding of theories and models [16]; iii) The establishment of links between models and objects consolidates learning [17]. The study aimed to address the following question through this work: Does the pedagogical integration of a digital simulation improve high school students' performance?

2. RESEARCH METHOD

This research tried to explore the effect of learning by problem situation, using digital simulation, the research presented the empirical methodology pre-test and post-test that allowed the researchers to observe, analyze, and better comprehend how students interact with one another, while looking into the benefits of using digital simulations to teach about free oscillations in an RLC circuit. There were 50 Moroccan secondary school students who qualified for the second year of the scientific baccalaureate option in physical sciences at the high school in Fez, with an average age of 18 years. They participated in this study with two different classes in the same institution during the academic year 2021–2022 (25 students of the experimental class and 25 students of the control class).

2.1. Pre-test

Both the control class (class 1) and the experimental class were given access to the first section of the physics course, which covered the free oscillation of the RLC circuit (class 2), with teaching settings that followed the approved criteria. Then, with both groups, a pre-test was employed to ensure their equivalency and to assess their knowledge of the previous pre-learning. This test is composed of three multiple-choice questions (MCQs) and one exercise in the form of open-ended questions. Cronbach's alpha internal consistency coefficient was used to assess the instrument's reliability, which was designed and piloted with 25 students. The dependability coefficient was found to be 0.71, which is considered acceptable. Both classes were invited to respond to the pretest questions, the answers were presented in paper format.

2.2. Post-test

The first class (control) received the second part of the course on free oscillations in an RLC circuit in the traditional approach according to a collaborative learning scenario. In contrast, the second class (experimental) had the opportunity to use digital simulation in the same part of the course, the educational program was operated by the computer and simulation software in the high school laboratory. The post-test consists of four questions with true or false options and an activity with open-ended questions that assesses and regulates fundamental information and enables students to continue their education: discharge of a capacitor in an inductor, influence of pseudo-period damping, energy transfer between the capacitor and the coil and the graphical study in the case of weak damping. The reliability of this instrument was tested with 25 students and found to be satisfactory (Cronbach's alpha=0.72). Following the scheduled educational activity, we called both classes to participate in the post-testing, the responses were presented in paper format to make a comparison

of their answers. To compare the classes representing the two independent samples, statistical software was utilized to analyze the acquired data. In every treatment, an alpha level of 0.05 was applied.

3. RESULTS AND DISCUSSION

3.1. Pre-test results

Figures 1 and 2 show the descriptive findings of the pre-test data for class 1 and class 2, respectively. In these figures, the data are centered and appear to fit the normal (Gaussian) distribution curve. The average of the experimental class's students is $m=13.88$, which differs from the control class's average in the pre-test by roughly 0,68. We used the student's t-test to compare the means of two independent samples with a normal distribution in order to disprove the null hypothesis that there was no discernible difference between the two classes in the pre-test (in Figures 1 and 2, Shapiro-Wilk, p-value is insignificant, because W is greater than the chosen alpha level 0.05). The results of the comparison are displayed in Table 1.

According to Table 1, the variances are homogeneous ($F=1.06$). Since the p-value was higher than the proposed alpha level ($p>0.05$) and that a p-value of 0.43 does not lead to the rejection of the null hypothesis, researchers can draw the conclusion that there was no significant difference between the studied classes. The researchers can now test our empirical model using a pre- and post-test due to this result.

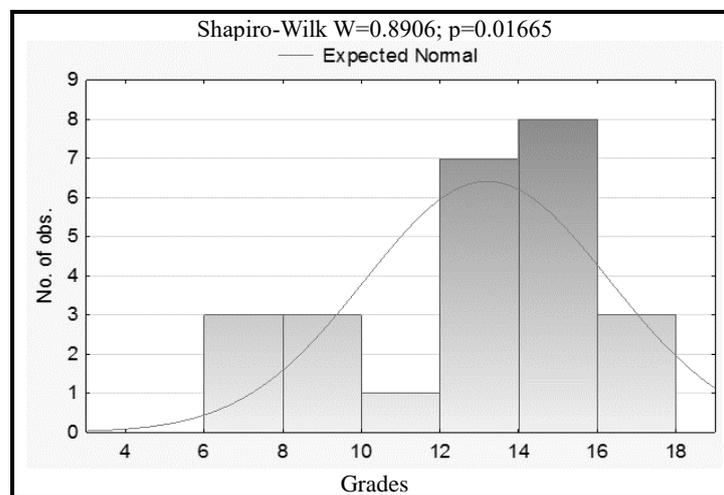


Figure 1. Descriptive statistics and normality tests (class 1) (Valid N=25; Mean=13.20; Minimum=7.00; Maximum=17.00; Std.dev=3.109126)

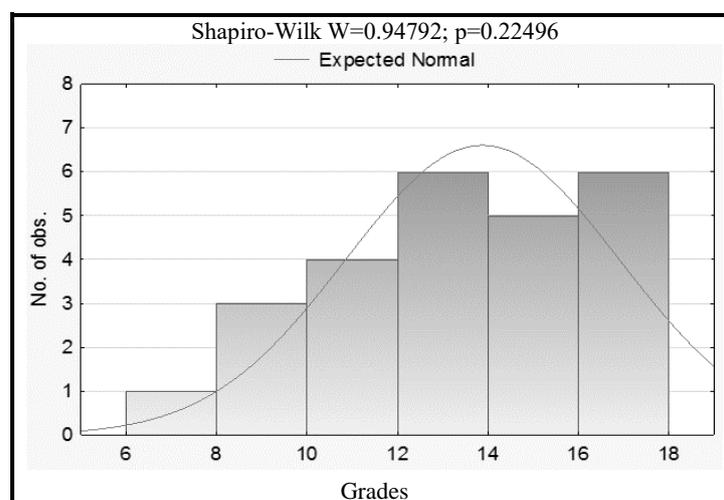


Figure 2. Descriptive statistics and normality tests (class 2) (Valid N=25; Mean=13.88; Minimum=8.00; Maximum=18.00; Std.dev=3.018278)

Table 1. Independent samples t-test by classes (pre-test)

Variable	Mean class 1	Mean class 2	df	p	Valid N class 1	Valid N class 2	Std. dev class 1	Std. dev class 2	F-ratio variances	P variances
Note	13.20	13.88	48	0.43	25	25	3.1091	3.0182	1.0611	0.8856

3.2. Post-test results

Figures 3 and 4 show the descriptive results of the post-test data for class 1 and class 2, respectively. In these figures, the data are centered and appear to fit the normal (Gaussian) distribution curve. The results offer the difference between the post-test mean of the students in the experimental class and the post-test mean of the students in the control class is in the level of 2.24. In order to rule out the null hypothesis that the pedagogy scenario had no effect on the students' performance, we employed the student's t-test to evaluate the difference between the means of two independent samples with a normal distribution (in Figures 3 and 4, Shapiro-Wilk, p-value is insignificant, because W is greater than the chosen alpha level 0.05). The results of the comparison are displayed in Table 2.

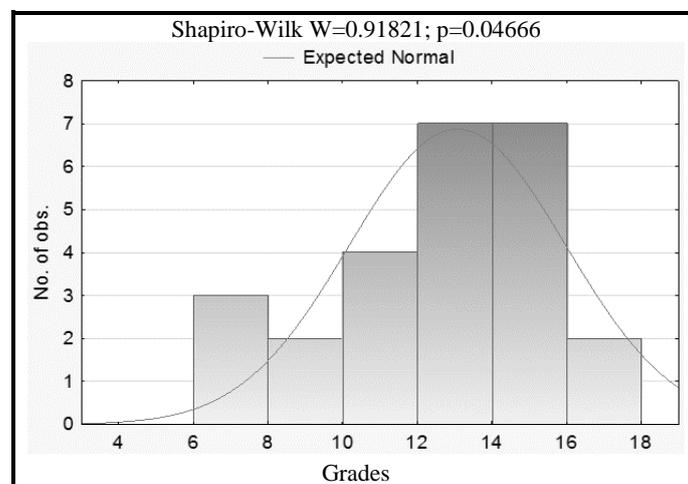


Figure 3. Descriptive statistics and normality tests (class 1) (Valid N=25; Mean=13.08; Minimum=7.00; Maximum=17.00; Std.dev=2.90)

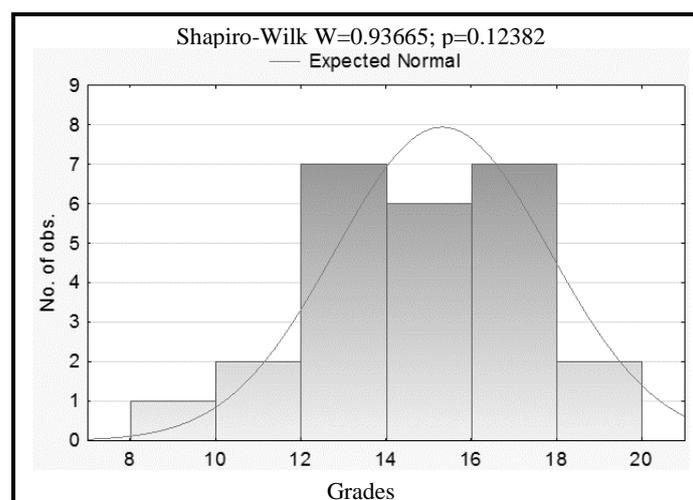


Figure 4. Descriptive statistics and normality tests (class 2) (Valid N=25; Mean=15.32; Minimum=10.00; Maximum=19.00; Std.dev=2.51)

According Table 2, the variances can be considered as homogeneous ($F=1.33$). The p-value is lower than the alpha level considered ($p<0.05$) and a p-value of 0.005 leads to rejecting the null hypothesis. It can be deduced that they considered the significant difference between the studied classes to be null and thus assume that the use of digital simulations in an experimented learning scenario had a positive effect on learning performance.

Table 2. Independent samples t-test by classes (post-test)

Variable	Mean class 1	Mean class 2	df	p	Valid N class 1	Valid N class 2	Std. dev class 1	Std. dev class 2	F-ration variances	P variances
Note	13.08	13.32	48	0.005	25	25	2.900	2.511	1.3332	0.4869

In this study, it appears that students in the experimental class who employed a digital simulation in a real-life learning setting had a significant impact on student accomplishment. This outcome is in line with the findings of previous studies [18], [19], showed that PhET simulations have positive effects on increasing physics concepts and improving learning activities, as well as Salmi, Magrez and Ziyya [20] that confirmed the simulation aids in the comprehension and perception of electromagnetic and electrical phenomena. Furthermore, Kaniawati *et al.* [21], [22] concluded that simulation lowers students' preconceptions regarding optical instruments.

In the same sense, another study [23] demonstrated that simulation increased microbiology knowledge, intrinsic motivation, and self-efficacy in microbiology areas. Furthermore, the benefits of using a simulation of Newtonian rules in a problem-solving scenario on conceptual comprehension of Newtonian physics were examined by Droui *et al.* [11]. The use of digital simulations in physics learning has typically been found to contribute to beneficial outcomes in the previous study [24]–[26]. Digital simulations can be utilized to enhance, motivate, and engage students in understanding interesting measurements [27]–[34].

Many researchers believe that incorporating simulation into the learning process can aid in the assimilation of physical notions and overcome some of the hurdles to learning [35]–[40]. According to another study, there is a strong correlation between simulation utilization and learning objectives being met [41]. In addition, the use of digital simulation can reduce the learner's cognitive overload and language skills, and academic performance [42]. Furthermore, in addition to enabling tasks that are not possible with classroom technology, simulation adds value by helping to overcome logistical challenges and a lack of laboratory equipment [43], [44]. According to earlier studies, digital simulations are less successful than conventional instruction and practical laboratory methods [45], [46]. Furthermore, other experts have claimed that there is no link between the usage of educational software and student achievement [47]. Similarly, some researchers have discovered that, when compared to other learning activities, digital simulation is not an effective motivator for Moroccan students [48], [49].

Multiple studies indicate that physics teachers lack competence in the use of simulations, because of a lack of knowledge and skills [50]–[53]. In addition, according to a previous study, the scientific classroom's absence of or inadequacy of technological equipment, as well as the lack of computer rooms, are significant barriers to effective simulation use [54]. Therefore, users' utilization of simulation technologies is insufficient [55].

4. CONCLUSION

The interest of this research work is to show the needs of the use of information and communication technologies in the teaching of sciences and in particular the use of digital simulations as a basis for the pedagogy of problem-based learning, on the one hand a response to the directives of the National Charter for Education and Training; whose orientations motivate the promotion and development of ICT as innovative pedagogical practices in Morocco, we believe that our results and conclusions demonstrate the contribution of ICT and specifically digital simulations in the improvement of the quality of learning of the learners by dominating certain obstacles of learning and comprehension attached to the teaching of physical sciences and thus by increasing the power of the learners. The results of a comparison of learning performance between learners who used computer tools and those who did not demonstrate that incorporating digital simulations into learners' learning in the physical sciences has a positive effect. We will conclude that a digital simulation is an effective tool that could be very favorable to learning and a very interesting notion for innovative understanding and learning, adapted to the needs of the students and incorporating technology when appropriate.

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