The Added Value of Integrating the Electronics Workbench Simulator in the Teaching of Electrical Concepts to Moroccan High School Students

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Abstract—In this paper, we are interested in the study of the use of the Electronics Workbench (EWB) simulator in the study of amplitude modulation and demodulation. We conducted a study with 50 Moroccan students in the second year of the scientific baccalaureate option physical sciences at the high school Abdellah Laroui of the city of Fez. Using the pre-test and post-test methodology with an experimental group (25 students) and a control group (25 students). The results of the two groups are analyzed using the student t-test. The results obtained in the post-test show that the average of the test administered to both groups, control (MG-Con) and experimental (MG-Exp), found a non-significant difference (MG-Exp – MG-Con = 15.36 – 15.08 = 0.28 > 0). In addition, using interviews, we asked students and teachers to give their opinions on questions about the use of the Electronics Workbench (EWB) simulator in learning. The results obtained show that the laboratory experiments cannot replace the simulator (EWB) which can be used as an alternative pedagogical means to help students understand the concepts in electricity.

Keywords—EWB simulator, physical science, pretest and posttest, amplitude demodulation, learning

1 Introduction

In the current era, information and communication technologies (ICT) have provided innovative tools [1–2]. With the help of ICT, learners can be more motivated and achieve better results [3]. ICT is introduced in the different areas of our society and affects, in a remarkable way, the economic, social, political, cultural, and educational scales [4–6]. [7] have noted the importance of digitization for the improvement of the educational system, the importance of ICT in children with special needs and perceptual difficulties is explored [8]. There is a new generation of students who have grown up with information and communication technologies [9].

Since the early 1970s, investigators have examined traditional teaching methods in the physical laboratory with those exploiting computer simulations in the assimilation

of scientific concepts. Most works confirm that the combination of computer simulation and traditional teaching can be the most powerful pedagogical approach for teaching science subjects [10–11], these studies declare the importance of this approach that allows the student to get used to the technology and the access to the materials of the laboratory [12].

In the literature, one discovers certain definitions of computer simulation, also called digital. These definitions prove sometimes additional, but quite different visions [13]. Indeed, simulations are based on computer programs that retain a simplified model of a system [14]. According to [15], simulation can be defined in different ways: it is an explanatory intermediary to define a system, a vector of analysis to set critical outcomes and evaluate suggested solutions.

In the physical sciences, simulations are used to:

– Before the move to the laboratory. This use is justified when the equipment that the student will find in the laboratory is complex and the risks of degradation of the material. Another use before going to the laboratory can be done in the form of pre-laboratory exercises.
– After the experiment. Computer simulation can be beneficial after the real experiment to select other experimental conditions. Conditions that were not possible during the real experiment, for example, the use of physical quantities (pressure, gravity, temperature …) that we cannot have because of material constraints.
– During the manipulation. One of the characteristics of the calculations during manipulation is the repetitiveness: the number of measurements being in general very large, the time which passes to iterative calculations, can become too large. It is often very simple to generate a computer program of assistance to the calculation, to the drawing of curves …

[14] increase the pedagogical value of simulation in physical science education. They state that these simulations are increasingly powerful if entered for the right activity. In addition, they can positively influence student satisfaction, participation, and initiative [16]. Other researchers state that learners are aware of the complexity of learning concepts in physical science and believe that the use of simulation may pose some barriers in their learning activities [17]. The lack of experiments in the laboratory and the low rate of use of educational technologies and especially simulation are among the factors that influence the assimilation of electrical concepts among Moroccan students [18]. Indeed, simulation increases students' motivation and makes electricity learning more interactive again [19]. To address the problem of lack of experiments in the lab, we simulated the amplitude modulation and demodulation setup of Amplitude via the Electronics WorkBench simulator. The experimental setup consists of two GBF generators, an oscilloscope, and a multiplier performing the modulation for the amplitude demodulation which contains an envelope detection circuit, and another one for the elimination of the constant voltage. (EWB) is an electronic circuit simulation software that allows processing circuits without exploiting real components, the user interface allows a simple and applicable edition for the measurement and analysis of circuits, the user can vary the parameters and the values of the components. Our research aims at analyzing the impact of the integration of the Electronics Workbench (EWB) simulator in the acquisition of concepts in electricity.

2   Problematic

The current program of the second year of the baccalaureate physical sciences of the Moroccan high school includes a field of electricity. One of the fundamental objectives of the teaching is that the learner should be able to know the steps of amplitude modulation and demodulation. There is a multitude of simulators available for educational purposes. We have chosen the Electronics Workbench (EWB) simulator because it is in harmony with our objectives and the context of our audience. It is simple to handle and the free version can be downloaded from https://www.electromecanique.net/2016/08/telecharger-electronics-workbench.html and it allows to simulate electronic systems. We will try through this work to answer the following questions:

- Are there any significant differences between using the Electronics Workbench (EWB) simulator and traditional teaching?
- Does the educational integration of the Electronics Workbench (EWB) simulator have a positive impact on the performance of learners in high school?
- Does the Electronics Workbench (EWB) simulator reduce the difficulties in the acquisition of electrical concepts related to modulation and demodulation amplitude among high school students?

3   Methodology

To investigate the processes of using the Electronics Workbench (EWB) simulator in the study of amplitude modulation and demodulation, we adopted a mixed methodological approach, in which we combined quantitative and qualitative data in the same study coherently and harmoniously. The approach used in this study entails comparing the responses of students in the control and experimental groups to the pretest/posttest, as well as analyzing the results of an interview survey.

3.1   Pretest/posttest

Our sample is composed of two groups among Moroccan secondary school students qualifying for the second year of the scientific baccalaureate option physical sciences at Abdellah Laroui high school in the city of Fez, who have an average age of 17 years, during the academic year 2021–2022, the control group is composed of 25 students and the experimental group is also composed of 25 students, both groups of students received part of the course of amplitude modulation in the same teaching conditions respecting the official instructions based on the classical pedagogical practice in the traditional laboratory. Then, a pretest was used with both groups to ensure their equivalence. This test is composed of two multiple-choice questions (MCQs) and one exercise in the form of open questions. To evaluate the added value of the Electronics Workbench (EWB) simulator in the course, we developed a posttest that was administered to both groups of students after using the Electronics Workbench (EWB) simulator with the experimental group in the amplitude demodulation part using a description

(Appendix 1 (Figures A1–A5)), the posttest is composed an exercise of open questions that aims at evaluating and regulating the basic knowledge that allows students to continue their learning: Knowing the steps of the demodulation, knowing the conditions allowing to obtain good quality demodulation, the role of the parallel LC dipole used and the value to be given to the inductance L of the coil to capture the waves.

After completing the proposed instructional activity, we invited both groups to answer the pretest and posttest questions in a paper-and-pencil format to compare their responses. The collected data were then analyzed with IBM SPSS statistics (statistical analysis software), Student's t-test [20] was used to compare the groups of two independent samples, an alpha level of 0.05 was used throughout the analysis of the results.

3.2   Interview

In this study, we asked the experimental group to express themselves on the questionnaire is composed of five questions, whose possible answers are of the 4-point Lickert scale type ("Strongly agree", "Somewhat agree", "Somewhat disagree" and "Strongly disagree"). The purpose of our questionnaire is to allow high school students to express their opinions regarding the following issues:

– The Electronics Workbench (EWB) simulator is easy to use.
– The Electronics Workbench (EWB) simulator is easy to use.
– The use of Electronics Workbench (EWB) requires a little background in computer science.
– The Electronics Workbench (EWB) simulator can help in understanding the concepts of electricity.
– The Electronics Workbench (EWB) simulator is a complementary tool to real experiments.

The methodology adopted also in this research revolves around interviews with teachers of physical sciences in Abdellah Laroui High School in the city of Fez, the main points of this questionnaire are:

– The Electronics Workbench (EWB) simulator highlights a cognitive conflict.
– The Electronics Workbench (EWB) simulator increases student performance.
– The Electronics Workbench (EWB) simulator simplifies real systems under study.
– The Electronics Workbench (EWB) simulator can replace some electricity experiments.
– The Electronics Workbench (EWB) simulator improves conceptual understanding.
– The integration of the Electronics Workbench (EWB) simulator can increase the performance of high school students in the physical sciences in general and electricity.

After the collection of the questionnaires, the data processing was carried out by the **Sphinx** software. This made it possible to carry out a presentation of the descriptive statistics for each wording.

4 Results and discussion

4.1 Pre-test results

The pre-test findings for both groups are shown in Table 1 below:

Table 1. Descriptive statistics (pretest)

	N	Minimum	Maximum	Mean	Standard Deviation	Variance
Control group	25	10,00	18,00	14,0800	2,34379	5,493
Experimental group	25	9,00	18,00	14,2800	2,22711	4,960

Analyzing these results, the mean of the students in the experimental group at pretest is m = 14,28 while that of the students in the control group is m =14,08; the difference is about 0,2. To test whether this difference is significant and to reject the null hypothesis that no significant difference existed between the two groups at the time of the pre-test, we used the student t-test to compare the means of two independent samples with a normal distribution (in Table 2, the Shapiro-Wilk p-value is insignificant). The null hypothesis is as follows:

H0: the difference between the averages of students in the experimental group and the control group is not significant.

Table 2. Normality tests

	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistics	ddl	Sig.	Statistics	ddl	Sig.
Control group	,173	25	,053	,932	25	,095
Experimental group	,107	25	,200	,963	25	,471

The results of the test are presented in Table 3:

Table 3. Independent samples test

	Levene's Test for Equality of Variances		t-Test for Equality of Means					95% Confidence Interval of the Difference	
	F	Sig.	t	ddl	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Equal variances assumed	,087	,769	−,309	48	,758	−,20000	,64663	−1,50014	1,10014
Equal variances Not assumed			−,309	47,875	,758	−,20000	,64663	−1,50023	1,10023

According to this table, the p-value of Levene's test is p = 0,769 which is not significant; the variances can be considered as homogeneous since their difference can be explained by a pure chance result. The p-value of the t-test higher than the alpha level is chosen, a p-value of 0,758 does not imply the rejection of the null hypothesis; thus we can 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 pretest and a posttest.

4.2   Post-test results

Table 4 shows the outcomes of the post-test for both groups:

Table 4. Descriptive statistics (posttest)

	N	Minimum	Maximum	Mean	Standard Deviation	Variance
Control group	25	10,00	19,00	15,3600	1,95533	3,823
Experimental group	25	11,00	18,00	15,0800	2,05994	4,243

The results show that the mean of the students in the experimental group at the posttest is m = 15,08 while that of the students in the control group is m = 15,36; the difference is about 0,28 check if this difference is significant and reject the null hypothesis that the tested educational device did not affect the students' results, we used the students' t-test to test the difference between the means of two independent samples with a normal distribution (in Table 5, ShapiroWilk's p-value is insignificant).

Table 5. Normality tests

	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistics	ddl	Sig.	Statistics	ddl	Sig.
Control group	,188	25	,023	,941	25	,159
Experimental group	,152	25	,137	,941	25	,155

The results of the test are presented in Table 6:

Table 6. Independent samples test

	Levene's Test for Equality of Variances		t-Test for Equality of Means							
									95% Confidence Interval of the Difference	
	F	Sig.	t	ddl	Sig. (2-tailed)	Mean Difference	Std. Error Difference		Lower	Upper
Equal variances assumed	,255	,616	,493	48	,624	,28000	,56804		−,86212	1,42212
Equal variances Not assumed			,493	47,870	,624	,28000	,56804		−,86220	1,42220

According to this table, the variances can be considered as homogeneous; the p-value of Levene's test is p = 0,616 which is not significant. The p-value of the t-test is higher than the selected alpha level (p > 0,05); a p-value of 0,624 does not reject the null hypothesis and therefore the difference between the means of the students in the experimental group and the control group is not significant and admit that the use of Electronics Workbench (EWB) simulator in the study of amplitude demodulation had a similar effect on the students' learning. This shows that it cannot replace the laboratory experiment with the Electronics Workbench (EWB) simulator except in the case of the lack of electronic materials and 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 be carried out [21].

4.3   Interview

The results of the interviews with the students are presented in Figure 1. Show that Electronics Workbench (EWB) is easy to operate for most (85%) of the interviewees, 85% of the students confirm that Electronics Workbench (EWB) simulator is easy to use, the majority (79%) of these students think that using Electronics Workbench (EWB) requires little knowledge in computer, Also (72%) of the interviewed students think that Electronics Workbench (EWB) simulator can help to understand the concepts of electricity and 98% of the students say that Electronics Workbench (EWB) simulator is a complementary tool to real experiments. Also, another research shows that Moroccan students have the necessary computer skills to manipulate the PSPICE simulator [21].
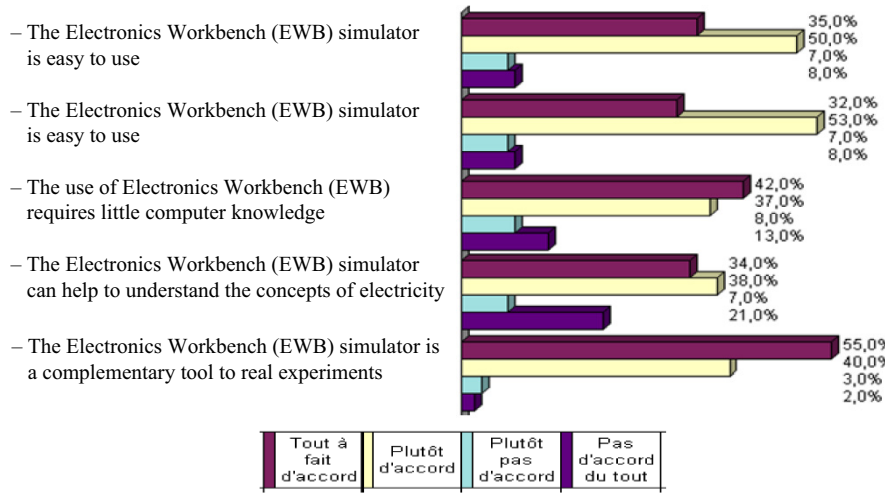
Fig. 1. The level of satisfaction of students using the Electronics Workbench (EWB) simulator

The results of interviews with teachers of physical sciences in Abdellah Laroui high school in the city of Fez are presented in Figure 2. The analyzed data show that:

The majority of the interviewed teachers (76,6%) believe that the Electronics Workbench (EWB) simulator highlights cognitive conflict, 85% of the teachers judge that the Electronics Workbench (EWB) simulator increases students' performance, 80% of the participants confirm that the Electronics Workbench (EWB) simulator simplifies real systems studied, 80% of the interviewed teachers said that the Electronics Workbench (EWB) simulator can help to understand the concepts of electricity and 81,7% of the interviewed teachers said that the Electronics Workbench (EWB) simulator is a complementary tool to real experiments. On the other hand, the teachers appreciate that the use of the software (EWB) has pedagogically motivated their students and has increased their cognitive abilities. Indeed, simulations motivate learners and facilitate their cognitive tasks [22].
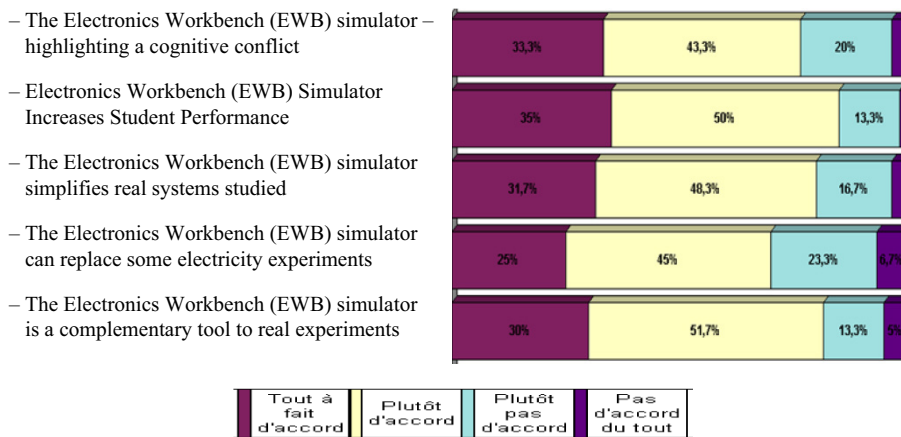

Fig. 2. Physical science teachers' valuation of the simulation

5   Conclusion

The objective of this work is to highlight the effect of using the Electronics Workbench (EWB) simulator in the study of amplitude modulation and demodulation on the learning of students. The statistical data collected from research among Moroccan students in the second year of the scientific baccalaureate option physical sciences (PC) at the high school Abdellah Laroui in the city of Fez, In the pre-test, there was no significant difference between the two groups employing the methodological pre-test and post-test with an experimental group and a control group. After using the Electronics Workbench (EWB) simulator in the post-test, also there was no statistically significant difference between the experimental group and the control group, as the p-value of student's t-test is higher than the selected alpha level ($p > 0,05$); a p-value of 0,624 allows to reject the null hypothesis and to admit that the use of the Electronics Workbench (EWB) simulator and the laboratory experiments can reach similar objectives in the study of amplitude demodulation, the Electronics Workbench (EWB) simulator will be an alternative to do the inaccessible experiments. Also, the results obtained, in this study, show that the students are very motivated to use the simulator in the process of learning the concepts of electricity, it can not replace the laboratory experiments. The interviewed students declare that the Electronics Workbench (EWB) simulator is easy to operate for most of them (85%), 85% of the students confirm that the Electronics Workbench (EWB) simulator is easy to use, the majority (79%) of these students think that the use of Electronics Workbench (EWB) requires little knowledge in computer, Also (72%) of the students interviewed feel that Electronics Workbench (EWB) simulator can help to understand the concepts of electricity and 98% of the students say that Electronics Workbench (EWB) simulator is a complementary tool to real experiments. And the majority of the interviewed teachers (76,6%) believe that the Electronics Workbench (EWB) simulator highlighting a cognitive conflict, 85% of the teachers judge that the Electronics Workbench (EWB) simulator increases the students' performance, 80% of the participants confirm that the Electronics Workbench (EWB) simulator simplifies real systems studied, 80% of the interviewed teachers declare that the Electronics Workbench (EWB) simulator can help to understand the concepts of electricity. Indeed, numerical simulation makes learning electricity more interactive [18]. In addition, simulation is critical for understanding and perception of electromagnetic and electrical phenomena [23]. [24] also revealed that the lack of technological tools, lack of in-service training, and problems related to the pedagogical approaches of the educational system are major obstacles that influence the motivation of Moroccan teachers to use interactive simulations in the classroom.

6   References

[1] B. Tarman and S. Dev, "Learning transformation through innovation and sustainability in educational practices," *Res. Soc. Sci. Technol.*, vol. 3, no. 1, pp. i–ii, 2018. https://doi.org/10.46303/ressat.03.01.ed

[2] S. Z. Salas-Pilco and N. W. Law, "ICT curriculum planning and development: policy and implementation lessons from small developing states," *in ICT-Supported Innovations in Small Countries and Developing Regions*, Springer, 2018, pp. 77–98. https://doi.org/10.1007/978-3-319-67657-9_4

[3] Y. El Ouargui, B. Gourja, M. Tridane, and S. Belaaouad, "Use of Computer-Assisted Experimentation (CAEx) in teaching science in Moroccan high schools," *Int J Web Appl,* vol. 11, no. 4, pp. 119–124, 2019. https://doi.org/10.6025/ijwa/2019/11/4/119-124

[4] C. Redecker, K. Ala-Mutka, and Y. Punie, "Learning 2.0: The impact of social media on learning in Europe," *Policy Brief* 2010. https://doi.org/10.13140/RG.2.2.29790.05446

[5] A. L. J. Omar and N. Benjelloun, "Intégration des TIC dans l'enseignement des sciences physiques au Maroc dans le cadre du programme GENIE: difficultés et obstacles," *Rev. Int. Technol. En Pédagogie Univ. Int. J. Technol. High. Educ.,* vol. 10, no. 2, pp. 49–65, 2013, https://doi.org/10.7202/1035522ar

[6] H. A. Kaikai, "Appropriation des Technologies de l'Information et de la Communication au sein de l'Université marocaine: Perceptions des étudiants," *Frantice Net,* vol. 8, 2014.

[7] M. Chergui, A. Tahiri, A. Chakir, and H. Mansouri, "Towards a new educational engineering model for Moroccan University based on ICT," *Int J Eng Pedagog*, vol. 10, no. 3, pp. 49–63, 2020. https://doi.org/10.3991/ijep.v10i3.12421

[8] A. Drigas and D. Diatsigkos, "Perception and ICTs," *Int. J. Eng. Pedagogy IJEP*, vol. 5, no. 3, p. 4, 2015. https://doi.org/10.3991/ijep.v5i3.4015

[9] Y. Zidoun, M. Talea, and R. Dehbi, "Students' perception about mobile learning in Morocco: survey analysis," *Int. J. Interact. Mob. Technol. IJIM,* vol. 10, no. 4, pp. 80–84, 2016. https://doi.org/10.3991/ijim.v10i4.5947

[10] Z. Zacharia, "Beliefs, attitudes, and intentions of science teachers regarding the educational use of computer simulations and inquiry-based experiments in physics," *J. Res. Sci. Teach. Off. J. Natl. Assoc. Res. Sci. Teach.*, vol. 40, no. 8, pp. 792–823, 2003. https://doi.org/10.1002/tea.10112

[11] Z. C. Zacharia, "The impact of interactive computer simulations on the nature and quality of postgraduate science teachers' explanations in physics," *Int. J. Sci. Educ.,* vol. 27, no. 14, pp. 1741–1767, 2005. https://doi.org/10.1080/09500690500239664

[12] Z. C. Zacharia, G. Olympiou, and M. Papaevripidou, "Effects of experimenting with physical and virtual manipulatives on students' conceptual understanding in heat and temperature," *J. Res. Sci. Teach. Off. J. Natl. Assoc. Res. Sci. Teach.*, vol. 45, no. 9, pp. 1021–1035, 2008. https://doi.org/10.1002/tea.20260

[13] B. Lehaney, H. Kogetsidis, A. Platt, and S. Clarke, "Windows-based simulation software as an aid to learning," *J. Eur. Ind. Train.*, 1998. https://doi.org/10.1108/03090599810197649

[14] M. Droui and A. El Hajjami, "Simulations informatiques en enseignement des sciences: apports et limites," *EpiNet Rev. Électronique L'EPI*, vol. 164, 2014.

[15] A. M. Law, W. D. Kelton, and W. D. Kelton, *Simulation Modeling and Analysis*, vol. 3. Mcgraw-hill New York, 2007.

[16] M. J. Durán, S. Gallardo, S. L. Toral, R. Martínez-Torres, and F. J. Barrero, "A learning methodology using Matlab/Simulink for undergraduate electrical engineering courses attending to learner satisfaction outcomes," *Int. J. Technol. Des. Educ.*, vol. 17, no. 1, pp. 55–73, 2007. https://doi.org/10.1007/s10798-006-9007-z

[17] K. Ahaji, S. Zahim, M. Droui, and B. Badda, *Schéma d'évaluation pour le choix du multimédia pédagogique approprié.* EpiNet, 2013.

[18] M. Chekour, M. Laafou, and R. Janati-Idrissi, *Comment remédier au problème du manque de matériel scientifique dans les laboratoires marocains: cas de l'électricité.* Info-CRDE, 2016.

[19] V. Ramasundaram, S. Grunwald, A. Mangeot, N. B. Comerford, and C. M. Bliss, "Development of an environmental virtual field laboratory," *Comput. Educ.*, vol. 45, no. 1, pp. 21–34, 2005. https://doi.org/10.1016/j.compedu.2004.03.002

[20] N. Gilbert and J.-G. Savard, *Statistiques*. Laval, Québec: Éditions Études vivantes, 1992.

[21] M. Chekour, M. Laafou, and R. Janati-Idrissi, "Vers l'introduction du simulateur Pspice dans l'enseignement de l'électricité: Cas du Tronc commun Sciences," *EpiNet*, vol. 175, 2015.

[22] V. Guéraud, J.-P. Pernin, J. Cagnat, and G. Cortès, "Environnements d'apprentissage basés sur la simulation. Outils auteur et expérimentations.," *Sci. Technol. Inf. Commun. Pour LÉducation Form.*, vol. 6, no. 1, pp. 95–141, 1999. https://doi.org/10.3406/stice.1999.1420

[23] K. Salmi, H. Magrez, and A. Ziyyat, "Didactic simulations for electromagnetism based on an element oriented model," *Int. J. Eng. Pedagogy IJEP*, vol. 9, no. 5, p. 24, 2019, https://doi.org/10.3991/ijep.v9i5.10696

[24] M. Ben Ouahi, D. Lamri, T. Hassouni, A. Ibrahmi, and E. Mehdi, "Science teachers' views on the use and effectiveness of interactive simulations in science teaching and learning," *Int. J. Instr.*, vol. 15, no. 1, 2022. https://doi.org/10.29333/iji.2022.15116a

7 Appendix 1

1. Amplitude modulation

Two low-frequency generators and an X-multiplier are used for modulation.

– For the carrier (G.B.F.1), U_{1m} = 7 V and f_1 = 4 kHz are chosen.
– For the modulating signal (G.B.F.2) we choose U_0 = 6 V; U_{2m} = 2 V and f_2 = 100 Hz.
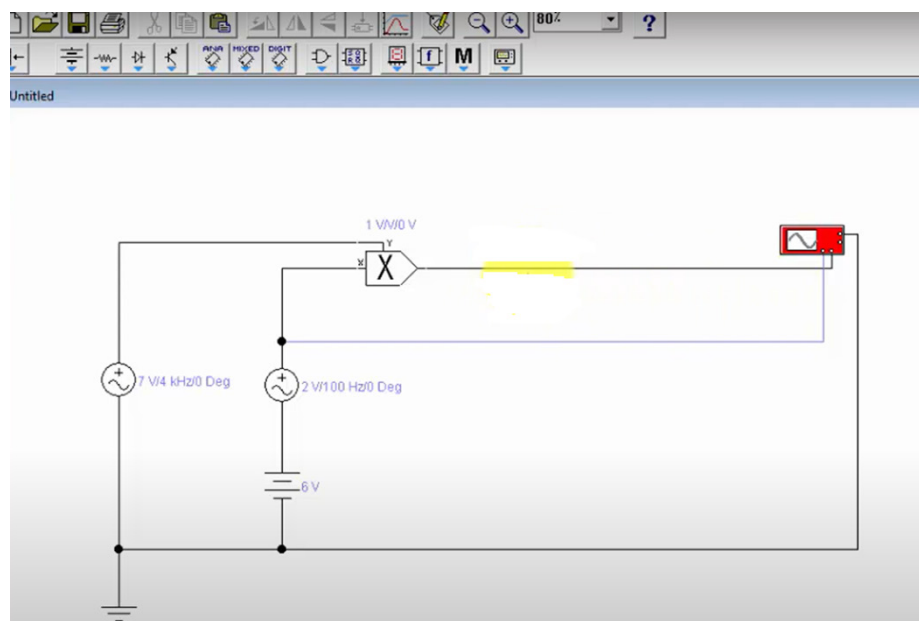– The modulated signal is realized with the X-multiplier.

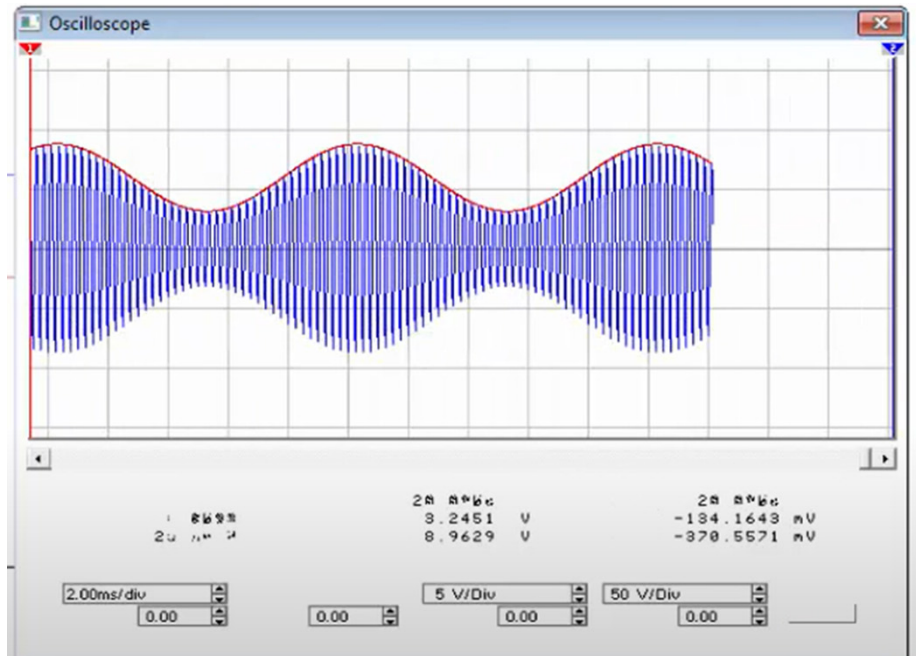**Fig. A1.** Schematic of an amplitude modulation circuit

Fig. A2. Result of the simulation of the amplitude modulation

2. Amplitude demodulation

The steps involved in performing amplitude demodulation:

– Step 1: Role of the detection diode

After the realization of the assembly of the amplitude modulation. We connect in series with the multiplier a detection diode and a resistor R_1 = 2 kΩ as shown on the following diagram:
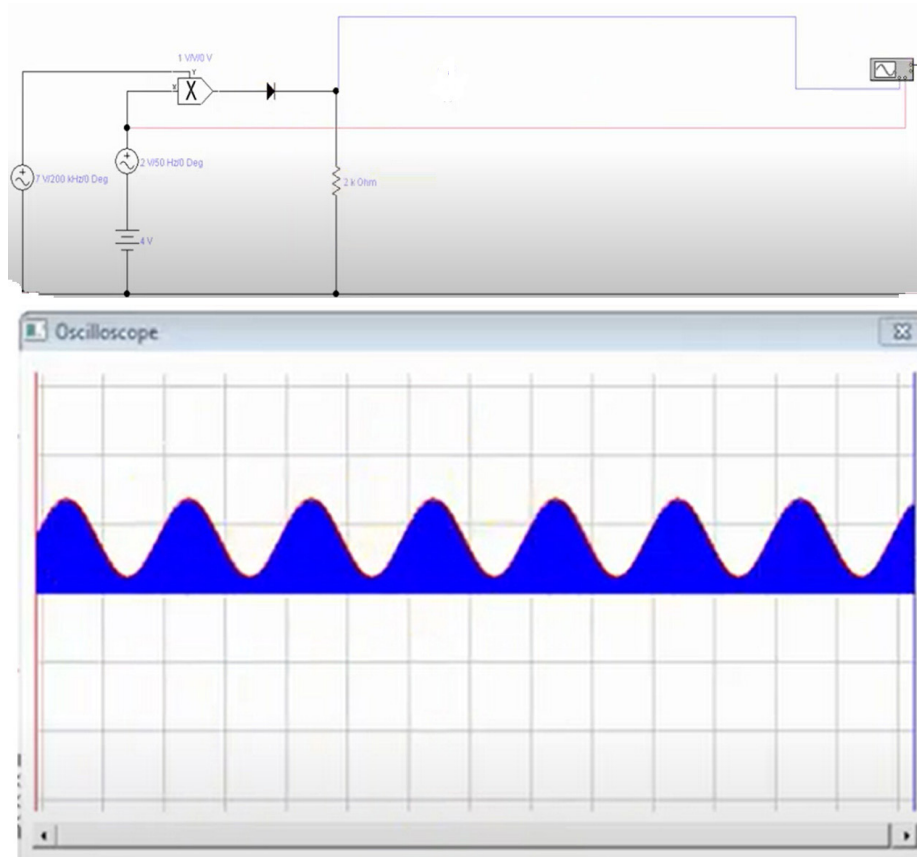
Fig. A3. The signal at the poles of the resistor R_1

– Step 2: Detection of the envelope by the dipole R_1C_1

The capacitor C_1 ($C_1 = 1$ µF) is connected in parallel with the resistor R_1 as shown in the following diagram:
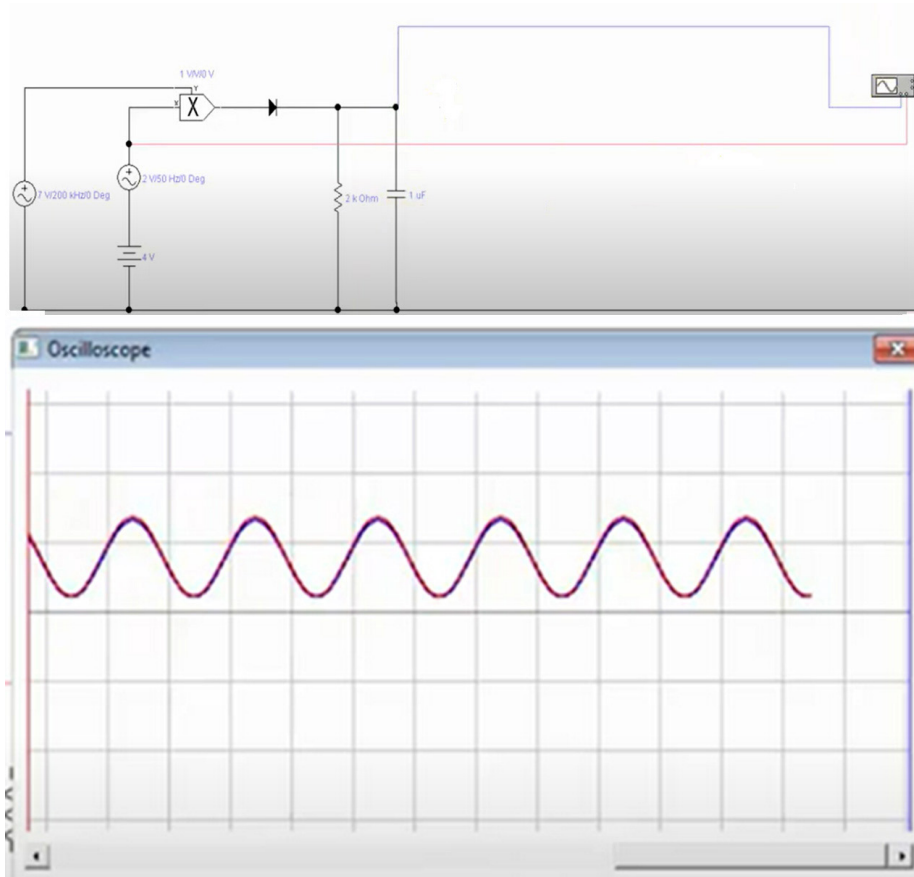
Fig. A4. The signal at the poles of the capacitor C_1

– Step 3: Removal of the DC component

We add to the previous circuit a filter $R_2 C_2$ ($R_2 = 20$ kΩ; $C_2 = 1$ µF) as shown on the following circuit:
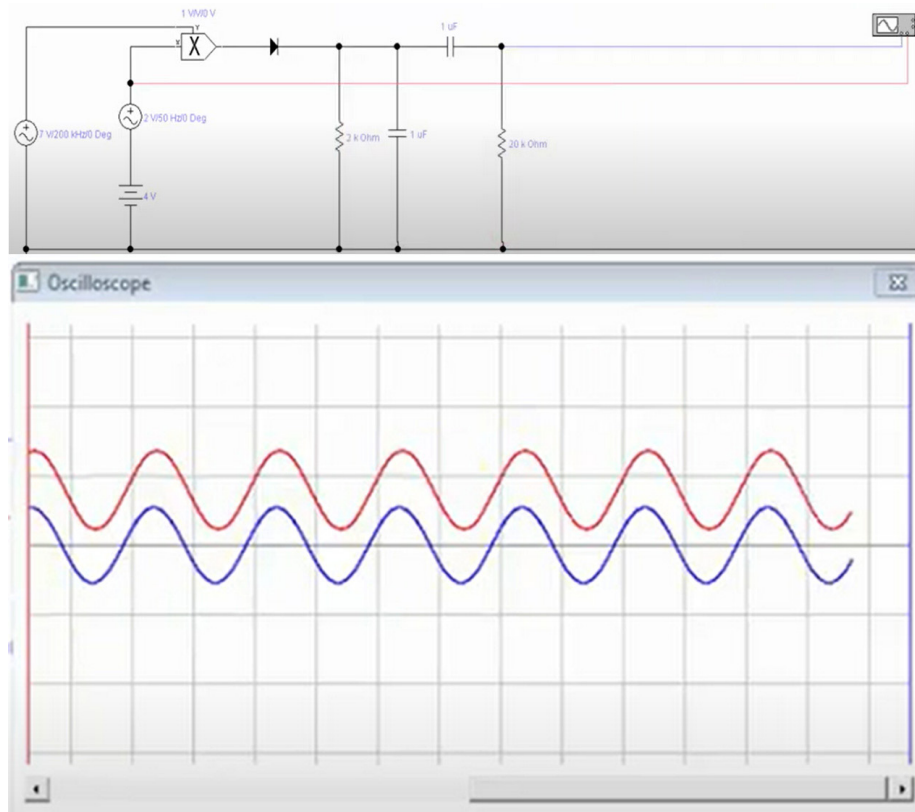
Fig. A5. The signal at the poles of the resistor R_2

8 Authors

Adil Hamamous was born in Casablanca, Morocco, in 1979. He continued his university studies at the Faculty of Sciences Dhar El Mehraz in Fez, where he obtained his bachelor's degree and his Diploma of Advanced Studies in solid-state physics, specializing in the physics of materials for the environment and nanostructures. In 2007, he was recruited by the Ministry of Education as a teacher at the High School of Physical Sciences. His research interests are focused on the integration of Information and Communication Technologies (ICT) in education. He started his current doctoral research entitled "Relations between simulations, CAEx and cognitivism in physical sciences" at the University of Sidi Mohamed Ben Abdellah, Faculty of Sciences, Dhar El Mahraz, Fez, Morocco. Doctoral Training in Science Didactics and Pedagogical Engineering, Laboratory of Computer Science, Signals, Automation and Cognitivism (Email: adil. hamamous@usmba.ac.ma).

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