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INTEGRATION OF ICT IN THE RESOLUTION OF DIFFERENTIAL EQUATIONS BY THE EULER METHOD IN PHYSICS FOR SECOND YEAR SCIENCE BACCALAUREATE CLASSES

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Abstract- This educational research aims to study the teaching practices in solving differential equations by Euler method in physics for second-year baccalaureate students in Physical Sciences and Mathematical Sciences options. The main objective of this study is to identify classroom practices to facilitate the resolution of differential equations that have no analytical solution, using a simple numerical method to handle with usual software. This research is based on the analysis of the results of a questionnaire combined with an analysis of pedagogical guidance documents and specific programs for the teaching of mathematics and physics-chemistry in the qualifying secondary education cycle and also in Al Fadae and Al Massar textbooks, in order to assess the didactic and content compatibility between teaching practices and the official pedagogical documents governing the teaching of the subject. This study allowed us to note, according to the interviewed teachers, coherence in the contents, the approaches followed, and the didactic tools used between what is programmed in the official documents and the two textbooks analyzed with the practices in classes concerning the use of Euler's method for the resolution of differential equations. We also noted, after the analysis of the official document of mathematics, the absence of this numerical method in the programs of this discipline.

Keywords: Differentials Equations, Numerical Methods, Euler Method, ICT Integration.

1. INTRODUCTION

Scientific knowledge in experimental sciences has made a qualitative leap in recent years, making impressive progress beyond other fields. Experimental science has thus gained an important place in various educational systems, especially as health, environment and space issues have become a priority of contemporary societies, due to the demands of globalization and its implications, especially those aimed at education for citizenship through education for responsibility. The subjects of experimental sciences occupy a privileged position in the pole of sciences, with the other options which allow the scientific learners to have a minimum of scientific knowledge and skills to integrate into their environment and contribute to its preservation and the development of their society as well. One of the characteristics of this option is that the learner is in direct contact with his reality through observation, experimentation, and experience in the field, and that he has general scientific knowledge through observation. And the analysis of phenomena, among the features of this option is modeling to simplify complex phenomena [1].

The modeling approach consists of constructing a representation intended to concretize an abstract situation that is difficult to access or even invisible. This approach is one of the scientific and technological approaches to be taught to students in connection with the first methodological competency Seeking answers or solutions to scientific or technological problems [2]. Physics is one of the experimental sciences that are based on the modeling of the phenomena that surround us. A set of these phenomena that evolve over time are modeled by differential equations, and many research have been carried out on this subject [3-8] to simplify their study and interpretation in order to elucidate physical laws and theories. Modeling is a scientific approach, requiring that learners are able to extract a simplified representation of reality, the degree of simplification is related to the cognitive level of the learner. Therefore, the teacher must work for the selection of teaching-learning activities that serve for the development of the adequacy of modeling for the learners contained in the program of the subject of physical sciences in secondary education of qualification. Therefore, the teacher must work on the selection of teaching-learning activities that serve the development of the adequacy of modeling for the learners, contained in the program of the subject of physical sciences in the qualifying secondary education [10].

In order to study a physical phenomenon, most of the time we obtain a set of experimental data collected manually or automatically. The physicist wants to determine a mathematical model that can then allow him

to make predictions about the phenomenon. Different methods are available to him and establishing a differential equation using the laws of physics is one of them [11]. Among these numerical methods we cite the Euler method, thus named in honor of Leonhard Euler, It is a method of calculation by interval of the successive values of the unknown function, according to a first order approximation consisting in considering the value of the derivative given by the differential equation at a given point as the rate of change of the function over the chosen interval [12]. This is the simplest method of numerical resolution of differential equations that can be used from the second year of the scientific baccalaureate. On the one hand, in this level, the pupils do not yet have sufficient mathematical knowledge to solve non-linear differential equations or of a higher order, or the latter do not have literal solutions [11]. On the other hand, even when the formal solution exists, the numerical calculation is necessary so that the results are practically exploitable [13].

The numerical processing of differential equations requires corresponding computer tools which have been the subject of numerous studies [14-17]. The current study therefore tries to answer the following main question:

What are the teaching practices used to present the knowledge related to the Euler method in physics for the classes of the second year of the Moroccan scientific baccalaureate?

This main question leads us to ask the following sub-questions:

- What is the role of Euler's method in the resolution of differential equations and therefore in the understanding and explanation of certain physical phenomena in the program of the second year of the scientific baccalaureate?
- Is the knowledge included in the textbooks relating to the Euler method considered as a didactic transposition of the objectives stated in the document of the programs and educational guidelines for the final year classes in physical sciences and mathematical sciences?
- Do second-year baccalaureate students in science options have sufficient mathematical knowledge to analytically solve differential equations? And if so, what solution do they bring to physics lessons?

– How do physical science teachers convey their knowledge of Euler's method and are there any barriers to their teaching, and what are the types of these barriers if they exist?

- What are the interactions between mathematics and physics when it comes to solving differential equations using Euler's method? Do the official programs for the two subjects refer to it?

To answer these questions, we propose three hypotheses:

➢ Hypothesis 1: Euler's method, as a computationally based numerical method for solving differential equations, has received sufficient attention in terms of presentation, detail and explanation of its use in the pedagogical orientation document and in the physics-chemistry teaching programs in high school, as well as in textbooks for the classes of the second year of the Moroccan scientific baccalaureate.

➢ Hypothesis 2: Physics and chemistry teachers agree to use ICT to teach content related to the Euler method for solving differential equations, as indicated in official teaching methods documents for the subject.

➢ Hypothesis 3: There is consistency between the mathematics and physics programs with regard to the use of Euler's method for solving differential equations for classes in the second year of the science baccalaureate.

2. RESEARCH METHODOLOGY

This article aims to examine the importance of integrating ICT in general and particularly Euler's method useful in solving differential equations in physics in textbooks and its application for students of the second year of the scientific baccalaureate.

The methodology followed in this study is based on:

- The analysis of the results of a questionnaire that we developed in the academy of Beni Mellal Khenifra during the 2020-2021 school year, and which targets teachers of physics and chemistry in the qualifying secondary level. This questionnaire contains 30 questions classified into five main axes. the first three axis are treated in previous research [18]. In this article, we will focus on the following axis:

- The first axis has been quantitatively reworked as it contains information about interviewed professors.
- Fourth axis under the title "Insertion of new technologies in the teaching of differential equations", the other axes are dealt with in the article "differential equations".

The data collected digitally were processed and analyzed by SPSS software and Microsoft Excel software. We used the 4-point Likert scale where item responses were coded as whole numbers ("Totally disagree =1"; "Disagree = 2"; "Agree = 3"; "Totally agree = 4")

- Analysis of the pedagogical guidelines document and the specific physics-chemistry teaching programs in the qualifying secondary education cycle;
- Analysis of the pedagogical guidelines document and the specific programs for teaching mathematics in the qualifying secondary education cycle;
- The analysis of two textbooks about their didactic treatment of Euler's method to find an approximate solution of differential equations. We have chosen two physics textbooks published after the last change of the program in 2007 [19]. The first textbook the name Al Massar (Ben Saddik, et al., 2007) [20] and the second is under the name Al Fadaa (Bouaouad, et al., 2007)". [21] These two textbooks are used in Moroccan high schools for students in the second year of the baccalaureate with physics and mathematics options. These textbooks are written in Arabic, and this choice is justified by the fact that the textbooks in French have not yet been approved by the Minister of National Education, until the writing of this article.

3. ANALYSIS OF RESULTS AND DISCUSSION

3.1. Personal Data of Teachers

We analyzed the answers of 125 teachers of physical sciences working in the qualifying secondary cycle at the academy of Beni Mellel Khenifra of which 84.8% are men and 15.2% are women. This difference between the number of male and female physics and chemistry teachers can be explained by the fact that the choice of respondents was made at random. Most of the teachers in question have an average age between 22 and 43 years old with a percentage of 70.4%. However, teachers who are over 43 years old have a percentage of 29.6%. With regard to seniority, a proportion of 81.6% of the respondents are under 15 years old, and this indicates that the respondents are new to the teaching profession. Consequently, the certificates obtained by teachers are diversified between ENS and CRMEF with a percentage of 58.4%, which is proportional to the age and seniority of the teachers in question.

3.2. Euler's Method in the Physical Sciences Program

According to the results in Table 1, 68.8% of the teachers answered "Agree" or "Totally agree". However, 31.2% "disagree" or "do not agree at all" with the proposed item, indicating that the incorporation of Euler's method for the approximate resolution of differential equations is properly programmed. Also, according to the answers of the teachers, the content related to this method is at the cognitive level of the learners. The teachers polled have a "agree" attitude toward the item, and the standard deviation value of 1,035 indicates that teachers' responses are not homogeneous.

Table 1. Inclusion of Euler's method in the physics program for the final science classes

	Not agree at all	Disagree	Okay	Totally agree	Arithmetic average	Median	Standard deviation	Attitude
	Frequency	Frequency	Frequency	Frequency				
	Percentage %	Percentage %	Percentage %	Percentage %				
Item 22	11	28	24	62	3.10	3.00	1.035	Okay
	8.8	22.4	19.2	49.6				

After a thorough reading of the document of educational guidelines and programs for the teaching of physics and chemistry in the qualifying secondary cycle, this method does not have an important interest in this document. It appeared for the first time in the secondary qualifying cycle in (2007) for the physical sciences and mathematical sciences options in the chapter "applications of Newton's laws", and exactly in the paragraph entitled "vertical fall with friction", where it was discussed in the table of contents and especially in the column about knowledge and competences. After having approached the two models of forces of friction $f= kv$ and $f=kv^2$, this method is defined and applied to obtain an approximate solution of the differential equation, using a spreadsheet .
Euler's method was mentioned again in the same document in the guidance section with the following statement: "The iterative numerical method for solving the characteristic differential equation of motion of a solid body in a vertical fall with friction, using a spreadsheet or a programmable graphing calculator. The validity and adequacy of the curves obtained with the experimental results (the importance of the choice of the resolution step, the proposed model of the friction force) are discussed" [22].

3.3. Euler's Method in Physics Lessons

❖ Through the results collected in Figure 1, we see that the majority of teachers questioned with a percentage of 96% answer that the use of the Euler method is linked to the vertical fall path with friction. However, with very low percentage of observations, the teachers questioned answered by Euler's method in other courses which contain the differential equations such as the RC dipole with a percentage 18.40% and in the chapter RL dipole by 17.60%, At a very weak rate 13.60% the professors questioned used the same method in another lessons.
- The result obtained through the teachers' answers shows, to a large extent, the compatibility between what was stated in the pedagogical orientations, as mentioned in the previous paragraph, and the teachers' pedagogical practices.

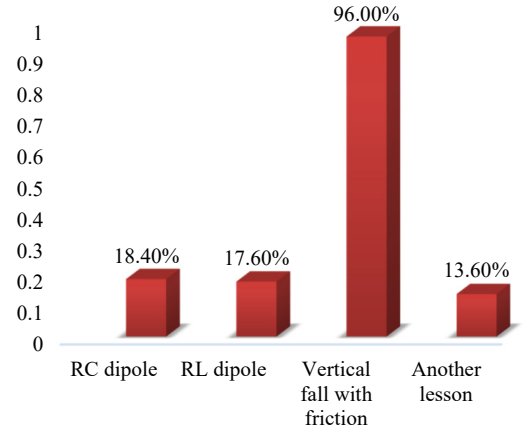

Figure 1. The use of Euler's method in lessons

Through careful reading of the two textbooks mentioned in the research methodology, we noted the following:
- In Al Fadae textbook, Euler's method appears for the first time in unit 2 entitled "Some applications of Newton's laws" (pp. 206-207 and 215-219) of the fourth part "Mechanics". This unit begins with an experimental activity (activity 1, pp. 206-207) followed by part of the lesson (pp. 215-219). In the part of the exercises no significance of this method.

- In the Al Massar textbook, the Euler method appears in chapter 14 "Application: vertical fall of a solid" (p. 200), this chapter begins with an activity (pp. 201-202). Part of the lesson deals in detail with the study of movement (pp. 203-208). On page 209 there is an appendix which explains the procedures for using a spreadsheet and the curve designer. The exercises' part contains a single solved exercise which deals with Euler's method.

3.4. Teaching Practices in Use of Euler Method (EM)

To treat the lesson entitled "motion of a solid in vertical fall with friction", teachers tend to achieve two objectives: the first objective is to numerically solve the differential equation using the method of Euler by a tool adequate computing and the second objective is to model the force of friction.

Figure 2 shows the way and the software for processing Euler's method by teachers. The results displayed in this figure show that the use of Excel office software for the processing of differential equations by the Euler method is the most useful with a percentage of 68.1% followed by other software with a percentage of 17.5%. But 14.5% of teachers answer that they use Euler's method theoretically to solve differential equations.

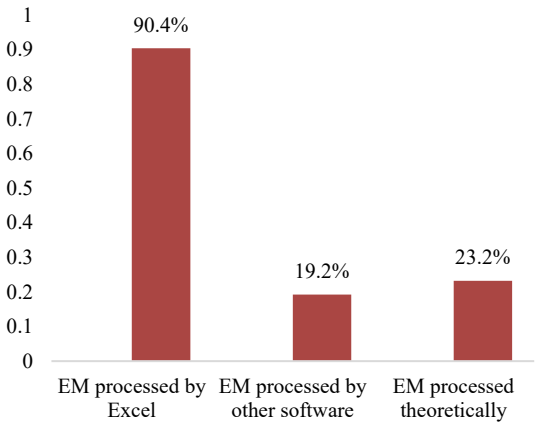

Figure 2. The way and software for Euler's method processing

❖ In Al Fadae textbook, the first part of manipulation in the activity under the title "Determination of the characteristic quantities of movement and modeling of the friction force", use to Excel software used to calculate velocity values (Figure 3). Several screenshots of both software are shown in the textbook.

	A	B	C
1	t(s)	z(m)	V(m/s)
2	0	0	0
3	0.03	0.00324	0.019
4	0.06	0.00114	=(B4-B2)/(A4-A2)
5	0.06	0.023	

Figure 3. Entering the easing relation in the Excel window [21]

From the numerical values obtained by Euler, an approximate curve is constructed on Excel, as Figure 4. This figure represents the variations in speed as a function of time in 3 cases: (1) $f=kv$, (2) $f=kv^2$ and (3) experimentally (Figure 5).

	C	D	E
1	V(m/s)	VEuler(m/s)	a(m/s^2)
2	0	0	8.2
3	0.019	0.246	=8,2-13.67*D3

Figure 4. Writing of the coaching relationship in the Excel window [21]

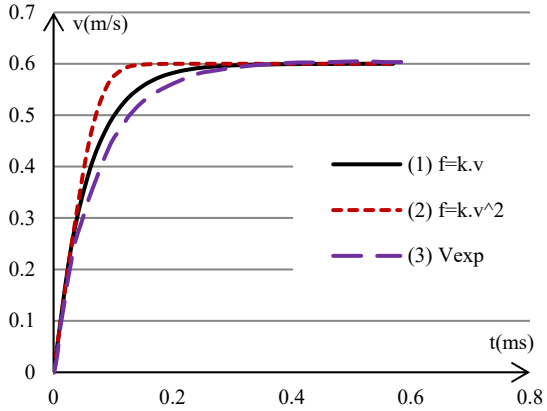

Figure 5. The experimental and the theoretical curves obtained by the Euler method [21]

After analyzing the curves of Figure 5, we notice that the closest to the experimental curve is curve (1). The friction force is modeled by the expression $f=kv$. For the Almassar manual, the authors of this manual have established a velocity-verified differential equation for a frictional force, where n is a natural number. This differential equation is written in the form [21]:

$$\frac{dv}{dt} + Bv^n = A \quad (1)$$

where, A and B are two constants of the problem studied.

To plot the variations of the velocity v as a function of time, the authors of the manual treated an activity in two parts: the first part of the activity is an experimental part called the step of making and recording the video tape, they referred to the use of a digital camera connected to a computer. In the second part, entitled the step of investment of the videotape, it was mentioned "Using the Avimeca program, we open the video file and we carry out the process of determining the points corresponding to the positions of the center of gravity of the ball (pointing), with the selection of an axis directed downwards, so that the values of the pairs (t, z) are written automatically » "We send the measurement table to the program (Regressi) dedicated to the acquisition and graphic processing of experimental data, and after having defined the coordinate $v = \frac{dz}{dt}$ of the velocity vector $\vec{V}_G$ the program calculates the velocity values v, then draws a curve of the variations of v as a function of time on the screen $v=f(t)$, then save the file".

The appendix page 209 provides the stages of use of the Regressi software until the construction of the curve in detail. Together with the explanations on the parameters of the differential equation as Figures 6 and 7, the use of the Euler method by introducing the data, and the insertion of the numerical data in the window. Several screenshots are shown in the textbook.

Page n°1	A $m.s^{-2}$	n
1	1	1

Figure 6. Entering experimental parameters in the Regressi window [20]

	Begin	End	Step	Active	Exp
A	0	10	0.1	Yes	No
n	0	10	0.1	Yes	No

Figure 7. Values to draw the theoretical and experimental curves [20]

The authors plotted the two curves in Figure 8 which represent the theoretical and experimental results. The theoretical results are obtained using Avemica and Regressi software, considering that the friction force is $f=kv$. It is observed that the modeling in this case is perfect.

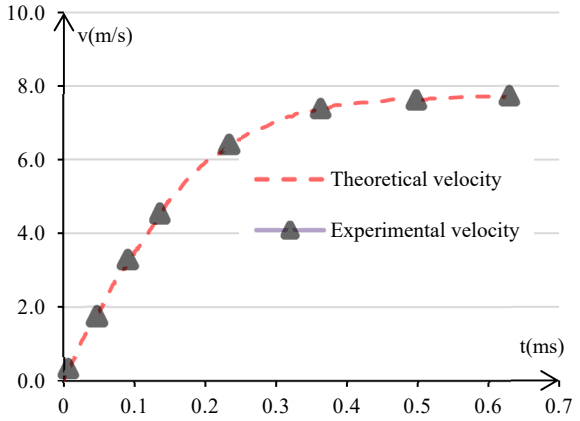

Figure 8. The theoretical and experimental variation of velocity as a function of time [20]

3.5. ICT Integration in Differential Equations Teaching

From the results displayed in Table 2, we see that 77.6% of the teachers questioned "Agree" or "Totally agree". However, 22.4% "disagree" or "do not agree at all" with the proposed item, which means that the integration of new information technologies to process learning associated with differential equations contributes to their good acquisition by the learners.

The results displayed in Table 2 also show that the teachers questioned adopt the attitude "Agree" with the proposition, thus the low value of the standard deviation of 0.881, signifies the homogeneity of the answers of the teachers.

Several computer hardware and software that are related to the treatment of differential equations are cited in the two school textbooks analyzed: Digital camera, computer interface, Spreadsheet and curve designer, together with Esao, Regressi, and Avemica software.

But we note the lack of tutorials for using this software in the two textbooks, except for the Al Fadae textbook where we only find on page 314 an appendix which represents how to use some software such as Regressi and DYNAMIC; and in the Al Massar textbook, there is only an appendix on page 209 which provides the steps for using the Regressi software.

Table 2. Integration of information technology to process learning associated with differential equations in relation to learner acquisition

	Not agree at all	Disagree	Okay	Totally agree	Arithmetic average	Median	Standard deviation	Attitude
	Frequency	Frequency	Frequency	Frequency				
	Percentage %	Percentage %	Percentage %	Percentage %				
Item	3	25	23	74	3.34	4.00	0.881	Totally agree
	2.4	20.0	18.4	59.2				

3.6. Euler's Method to Mathematics-Physics Interaction

We note the absence of Euler's method in the document of pedagogical guidelines and mathematics teaching programs in the qualifying secondary cycle, and also in school textbooks.

Among the factors that make it difficult to teach physics in qualifying secondary school, particularly at the level of the second year of the baccalaureate, is the difficulty of transferring students' knowledge of mathematics to physics, due to the lack of coherence of certain contents. in physics and mathematics, both at the level of their temporal programming. The differential equations in mathematics are programmed at the end of the second-year baccalaureate, while a group of lessons taught depend on the differential equations since the first semester or do not include some of them definitively in mathematics as is the case with the Euler's method, these are some of the factors that make it dialectically difficult to provide such knowledge in physics.

4. VERIFICATION OF HYPOTHESES

The importance of the hypothesis in educational research is reflected in the direction of the researcher, The verification consists in confronting the degree of validation, from the analysis of the data of the questionnaire, the educational guidelines documents, the mathematics and physics-chemistry programs and two school textbooks of physics-chemistry.

4.1. Verification of Hypothesis 1

After the analysis and discussion of the results in the previous paragraph, especially sub-paragraphs 3.1 and 3.2. At first a question arises on the designers of the programs, why the method of Euler was programmed only in the paragraph of "Vertical fall with friction" in the chapter "some applications of the laws of Newton" included in the part "mechanics" even if we can use this method in several chapters of electricity like the RC dipole, the RL dipole… and in the mechanics like the mechanical oscillators and even in the part of nuclear physics like the radioactive decay.

We note the consistency between what is stipulated in the document of educational programs and guidelines for the teaching of physics and chemistry and what was included in the textbooks analyzed. In addition, the teachers interviewed confirmed that they adopt Euler's method to solve differential equations with a large percentage in the study of vertical drop with friction. The results of our study show that hypothesis no. 1 has been confirmed.

4.2. Verification of Hypothesis 2

The use of computer tools has been mentioned in official documents as follows: "using a spreadsheet or a programmable graphic calculator". The analysis of the results obtained in paragraph 3.4 shows that the Excel office software is the most useful for the presentation knowledge related to the Euler method with a percentage of 68.1%, it also meant the use of the Excel spreadsheet in the Al Fadae textbook. The Regressi spreadsheet is the software adopted in the Al Massar textbook for the treatment of differential equations by the Euler method, but the reason for this choice is not explained in the two textbooks. The reasons for choosing Excel software can be summarized as follows: the ease of use of this tool for students, Excel has features that allow a large number of calculations to be carried out in a short time and also allows several curves obtained by stepping in Euler's method. Another cause is that the ministry of National Education has already organized ongoing training and certified some Microsoft software for teachers. According to the results obtained, we can confirm hypothesis No. 2.

4.3. Verification of Hypothesis 3

As we saw in paragraph 3.6, the analysis of the official mathematics document shows the absence of Euler's method. After reviewing some textbooks, such as Al-Moufid in Mathematics, and the textbook" "In Rihab of Mathematics", and more particularly in the lesson "differential equations" we also noted the absence of Euler's method for the resolution of differential equations, while the resolution is done totally by an analytical method. After reading a few documents for foreign educational systems, we have recorded the adoption of Euler's method in mathematics and physics and chemistry curricula. For instance, it is noted in a thesis in France as follows: "Euler's method is supposed to do part of the mathematical knowledge of pupils in "terminal S" level, taking into account the first notions covered in first class (in mathematics). The proposal for a timetable made by the group of experts on school programs (GEPSF) for physics and chemistry (GEPSF) supposes that the teaching of the first notions of mechanics, requiring the method of Euler, intervenes when this one has already been the subject of a revision in mathematics" [23].

From the results obtained above, it becomes clear that there is no consistency in the inclusion of Euler's method in physics and mathematics, since it was not adopted in the last subject, which inevitably leads to the difficulty of teaching it and using it to solve differential equations in the subject of physics, and therefore the third hypothesis cannot be confirmed.

5. CONCLUSION

At the conclusion of educational research, we can say that the results obtained from the methods, one quantitative based on questionnaire results, and the other qualitative based on the analysis of documents of educational guidelines and specific programs in the teaching of mathematics and physics-chemistry, and also on the analysis of the two textbooks of physics-chemistry, these results answer the questions posed in the research problem. Indeed, most of the physics-science teachers questioned are aware of the importance of integrating information and communication technologies to deal with content related to the resolution of differential equations in general, and adopting them as well, especially in Euler's method. Also, we note the coherence between the official documents which frame the teaching of physics- chemistry, and what is included in the textbooks on the one hand, and on the other hand the teaching practices expressed by the teachers questioned, that relate to the adoption of Euler's method, either through the course or how it was programmed and taught. In addition, teaching practices show the use of software to process Euler's method, although teachers only use Microsoft Excel software which can be considered very difficult to handle for learners.

Euler's method is an iterative numerical method that is very useful in solving differential equations. It was scheduled for the first time in 2007 in the physics-chemistry curricula for the options of physical sciences and mathematical sciences. And the reasons for adopting this method are neither explained in official documents nor in textbooks. In this context several questions can be asked:

- Why we use Euler's method for an approximate solution in the case where the exact algebraic solution exists, in the case of the frictional force such that $f= kv$ or v is a speed, that is to say in the case where the differential equation is linear of order 1, the speed can be calculated analytically as we saw in the part of electricity (dipole RC, dipole RL)?
- Why is this method not programmed in the chapters of nuclear and electricity or these chapters approach differential equations?

As regards the role of the Euler method, we can notice that this method intervenes in the case of the resolution of a nonlinear differential equation like the case of a vertical fall with friction such that the force of friction is in kv^2 whose analytical resolution is not on the program for students in the baccalaureate in physical and mathematical sciences. Euler's method must not only allow the construction of an approximate curve but also make it possible to decide on the choice of model of friction forces.

For a good integration of information and communication technologies, by adopting advanced numerical methods and easy-to-learn programs such as the Runge- Kutta methods of order 2 (RK2) and 4 (RK4) , and by introducing programming into the study programs of learners in the resolution of differential equations, certain challenges must be overcome such as the insufficiency of hardware and software equipment within the schools, the lack of software and applications adapted to the programs taught, and finally the qualification and training of

teachers. Insertion of logico-algorithmic reasoning using appropriate programming languages such as Python for learners of the common core level in computer science is also advisable.

Finally, how can we achieve the communication of knowledge between physics teachers themselves, or between teachers of various related disciplines such as mathematics, life and earth sciences, with the aim of facilitating the teaching of scientific knowledge? How can we achieve cognitive integration between mathematics and physics and other subjects close to them as a means of developing human knowledge and facilitating the teaching of these subjects and not as a goal? These and other questions We will try to answer in future articles. How to verify the interdisciplinarity between the subjects of STEM (Science, Technology, Engineering and Mathematics), and can we form interdisciplinary teaching? These and other questions will be addressed in future research.

APPENDICES

Appendix 1. Preamble

Through this questionnaire, we seek to know the point of view of the professors of physics and chemistry in the qualifying secondary school in the matter of integrating information technology to facilitate the teaching of differential equations for the level of the second year of the baccalaureate for the Division of Physics and the Division of Mathematical Sciences. We would also like to know the extent to which the professors' practices in the classroom agree with what is prescribed in the physics and chemistry program regarding the adoption of Euler's method for solving differential equations.

Appendix 2. Personal Information

❖ Gender

Women Men

❖ Professor's age

$22 \leq$ age ≤ 32 (years)
$33 \leq$ age ≤ 42 (years)
$44 \leq$ age ≤ 53 (years)
$54 \leq$ age ≤ 63 (years)

❖ Seniority in the teaching profession

Seniority ≤ 5 (years)
$6 \leq$ Seniority ≤ 15 (years)
$16 \leq$ Seniority ≤ 25 (years)
Seniority ≥ 25 (years)

❖ Professional certificates obtained

ENES
CRMEF
CPR
CFI
Othre

Appendix 3. Axis: Using Information Technology to Teach Differential Equations

❖ The inclusion of Euler method in the 2007-Second-High School physics program as an approximation method for solving differential equations was appropriate at the cognitive level of the learners.

Totally agree Okay Disagree Not agree at all

❖ Euler's method is used to solve differential equations in the following lessons:

RC dipole
RL dipole
Vertical fall with friction
Another lesson

❖ The contents associated with Euler's method for solving differential equations are processed

Excel spreadsheet Another software Theoretically

❖ The adoption of information technology to process the knowledge associated with differential equations contributes to its acquisition in a way

Totally agree Okay Disagree Not agree at all

NOMENCLATURES

1. Acronyms

EM	Euler Method
STEM	Science, Technology, Engineering and Mathematics
GEPSF	Group of Experts on School Program in France
RK2	Runge-Kutta methods of order 2
RK4	Runge-Kutta methods of order 4

2. Symbols / Parameters

$\vec{V}_G$: The velocity vectors
n: Coefficient of friction force (n=1 or n=2)
k: Constant relating to the nature of the fluid
A, B: Constants of velocity-verified differential equation

REFERENCES

[1] Minister of National Education, Commissions for the Revision of Moroccan School Programs for Primary, "White Paper, Middle and High School Education, Pedagogical Curriculum of the Scientific Pole", Part 7, Morocco, June 2000.

[2] P. Roy, A. Hasni, "Models and Modeling as Seen by Secondary School Science and Technology Teachers in Quebec", McGill Journal of Education, Vol. 49, No. 2, pp. 349-371, Montreal, Canada, 2014.

[3] K. Rezapour, "Availability Analysis of a Bi-Fuel Si Engine Model for Improvement Its Performance", International Journal Technical and Physical Problems of Engineering (IJTPE), Issue 11, Vol. 4, No. 2, pp. 115-121, June 2012.

[4] E.A. Saafan, T. Lazimov, "Investigation the Dependence of Transitional Voltages at Switching-Off Unloaded Transformer on Its Input Capacitance", International Journal on Technical and Physical Problems of Engineering (IJTPE), Issue 46, Vol. 13, No. 1, pp. 51-56, March 2021.

[5] H.A. Ariani, I. Iskender, M. Karakaya, "Performance Analysis of a Distribution Transformer Using Ansys Maxwell" International Journal on Technical and Physical Problems of Engineering (IJTPE), Issue 45, Vol. 12, No. 4, pp. 57-63, December 2020.

[6] H.A. Mammadov, "Development of Pulse Method in Transition Processes of Linear Electric Circuits" International Journal on Technical and Physical Problems of Engineering (IJTPE), Issue 45, Vol. 12, No. 4, pp. 69-75, December 2020.

[7] Z.A. Mamedova "Numerical Simulation of Transients Processes in Nonlinear Electric Drive System with Induction Electromagnetic Clutch", International Journal on Technical and Physical Problems of Engineering (IJTPE), Issue 6, Vol. 3, No. 1, pp. 53-56, March 2011.
[8] R.S. Akbarli, "Waves Propagation in the Fluid Flowing in an Elastic Tube, Considering Viscoelastic Friction of Surrounding Medium", International Journal on Technical and Physical Problems of Engineering (IJTPE), Issue 35, Vol. 10, No. 2, pp. 39-42, June 2018.
[9] A. Alfi, M. Khosravi, "Optimal Power System Stabilizer Design to Reduce Low Frequency Oscillations via an Improved Swarm Optimization Algorithm", International Journal on Technical and Physical Problems of Engineering (IJTPE), Issue 11, Vol. 4, No. 2, pp. 24-33, June 2012.
[10] Minister of National Education and Vocational Training, "Directorate of Curricula", Programs and Pedagogical Orientations for the Teaching of Physical Sciences, p. 141, Morocco, 2007.
[11] J. Winther, R. Coste, "Scientific Terminal Differential Equations: A Study Theme Common to the Physical Sciences and Mathematics Promoting Interdisciplinary Work", Bulletin de l'APMEP, No. 450, pp. 44-59, Paris 2004.
[12] M.F. Malonga, D. Beaufils, "Modeling and Semiotic Registers: Examples of the Study of Terminal Physics Textbooks", Research in Didactics of Sciences and Technologies, pp. 293-316, 2010.
[13] Z. Fazarinc "A Viewpoint on Calculus", Communication to the Mathematical Panel of the American Association for the Advancement of Science, Published by the Hewlett-Packard Journal, Vol. 38, No. 3, March 1987.
[14] A. Durey, "Towards Didactic Activities for the Development of Physics Models with Microcomputers", Aster, No. 8, pp. 161-185, 1989.
[15] D. Beaufils, "The Computer as a Tool for Scientific Investigation in High School: Didactic Proposals and Implication" Didaskalia, Vol. 1, pp. 123-130, 1993.
[16] J. Winther, "Didactic Study of the Use of Data Processing for the Modeling and the Manipulation of Models in Physical Sciences", Doctoral Thesis, University of Paris, 1992.
[17] A. Guillon, "Scientific Approaches in Practical Work in DEUG Physics at Cergy-Pontoise University", Didaskalia, No. 7, pp. 113-127, 1995.
[18] S. Dachraoui, K.A. Bentaleb, E.M. Al Ibrahmi, T. Hassouni, A. Taqi, "Interaction Between Physical Sciences and Mathematics-Case of Differential Equations in The Curricula of Final science Classes", International Journal on Technical and Physical Problems of Engineering (IJTPE), Issue 51, Vol. 14, No. 2, pp. 167-175, June 2022.
[19] Ministery of National Education and Vocational Training, Directorate of Curricula, Programs and Pedagogical Guidelines for the Teaching of Physical Sciences, Morocco, 2007.
[20] A. Ben Saddik, M. Lamsaoueb, A. Chouidra, "Al Massar, Physics, Course of Physical Sciences, Course Mathematical Sciences A-B", Textbook in Arabic, Printing Nadia Edition, Rabat, Morocco, 2007.
[21] A. Bouaouad, M. Zarkouni, A. Sarghini, S. Elaafi, A. Hamim, "Al Fadae, Physics, Course of Physical Sciences, Course Mathematical Sciences A-B", Textbook in Arabic, Printing El Maarif Al Jadida, Rabat, Morocco, 2007.
[22] Minister of National Education and Vocational Training, "Directorate of Curricula", Programs and Pedagogical Orientations for the Teaching of Physical Sciences, p. 123, Morocco, 2007.
[23] F.M. Mongabio., "Interactions Between Mathematics and Physics in Secondary Education in France: Case of First Order Differential Equations Doctoral Thesis", Paris Diderot University, p. 231, Paris, France, July 2008.

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