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INTERACTION BETWEEN PHYSICAL SCIENCES AND MATHEMATICS - CASE OF DIFFERENTIAL EQUATIONS IN THE CURRICULA OF FINAL SCIENCE CLASSES

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Abstract- The present study aims to explore the practices of teachers of physical sciences to teach students of terminal high school science classes in Morocco to model certain physical phenomena by first and second order linear differential equations with constant coefficients, and also to present the new symbols to facilitate the introduction of these new concepts to students. This study also examines the interaction between physical sciences and mathematics, in order to see to what extent there is synergy and cooperation between teachers of the two disciplines to overcome certain difficulties that arise for students at this level. We adopted a questionnaire which was distributed to teachers of physical sciences at the regional academy of education and training of Beni-Mellal-Khenifra in Morocco, which enabled us to collect 125 responses. Thanks to the findings of the study, we noted the importance of differential equations in the program of second year baccalaureate science streams, especially in the modeling of some systems which evolve as a function of time. We also noted the difficulties associated with the lack of consistency in the programming of certain chapters between mathematics and physical sciences, together with the poor communication between the teachers of the two subjects.

Keywords: Modeling, Differential Equations, Interdisciplinarity.

1. INTRODUCTION

A broad Physics as a science, was originally proposed to explain natural phenomena. It has evolved from antiquity to allow the construction of machines that have changed the face of the world. Physics is also an explanation of the world based on some fundamental principles and on mathematical tools [1]. Mathematics is commonly referred to as "the language of science", and physics-chemistry teachers typically require students to master mathematics as a prerequisite for studying physics. But the use of mathematics in science (and in particular in physics) is not only to engage in mathematical exercises. It has a different purpose, that of representing the meaning of physical systems rather than expressing abstract relationships. It almost seems that the "language" of mathematics we use in physics is not the same as that taught by mathematicians and that there are many notable differences between the two [2].

Most research in the didactics of mathematics and the physical sciences is concerned with the teaching of differential equations since it plays an important role in understanding physical phenomena, such as heat transfer Yaagoubi [3] or the study of elasticity Badirov [4] of the process of modeling Rodriguez [5-6]. It should be noted in this connection that the practices of teachers have taken on growing importance in the teaching of mathematics. Some researchers like (Robert and Rogalski [7] and Altet [8], Robert [9], Roditi [10], analyze them in depth through their work. On the other hand, Tuminaro study concluded that students' primary mathematical skills have a great impact on the possession of skills in physics [11].

Physics is taught through consecutive teaching stages, in which certain scientific observations of the primary learner are developed, and the learner progressively advances to knowledge of the principles of physics and then to the different areas of specialization. Secondary education is considered to be the pupil's stage of specialization [12], as it enables him to acquire the scientific and technical concepts necessary to access higher education or vocational training and thus be able to integrate the world of work [13].

Teaching and learning of ordinary differential equations has undergone a radical change in the past two decades both in secondary education and in university education in a range of educational systems [14-32]. In Morocco since (2007) [33], the Physics and Chemistry program for the last year of the scientific baccalaureate branches had become focuses on a set of chapters having for object the modeling of certain physical phenomena with linear differential equations of the first and second order with constant coefficients, and how to solve them algebraically or numerically or to verify some proposed solutions.

Differential equations are also of great importance in the national standardized examination, as they have been included in a group of components of the frames of reference for the baccalaureate exams for all options and all science streams[34].

My practice as a physics-chemistry teacher for nine years in qualifying secondary school, especially for final science classes, and my two-year experience in pedagogical supervision, enabled me to become aware of the lack of consistency between this, which is necessary to teach certain content and knowledge of mathematical tools in physics and the mathematics program, because some mathematical tools are approached in physics-chemistry before being treated in mathematics. The problematic of this study consists, on the one hand, in questioning the practices of teachers concerning the teaching of differential equations in physics, and on the other hand in studying and analyzing the physics / mathematics synergy especially in relation to differential equations for the final scientific classes.

This study therefore attempts to answer the following questions:

- What are the teachers' practices for presenting students in final high school science classes with new knowledge linked to the modeling of physical phenomena by differential equations, and to the writing and solving of these equations?
- Do students in final high school science classes in Morocco have sufficient mathematical knowledge to be able to use partial derivative symbols, writing and solving first-order or second-order differential equations with constant coefficients?
- Is there a consistency between the physics and mathematics curricula for the final high school science classes, especially for the teaching of differential equations?

We make three hypotheses to answer these questions:

- Hypothesis 1: students in final high school science classes do not encounter any difficulty (thanks to the help of their physics-chemistry teachers) in modeling certain physical phenomena with first-order or second-order linear differential equations with constant coefficients, then write and find solutions to these equations and use them.
- Hypothesis 2: Physics teachers are interested in anything related to the teaching of linear differential equations in mathematics and coordinate with mathematics teachers before addressing the same subject for students in terminal high school science classes.

2. RESEARCH METHODOLOGY

This research was carried out during the 2020-2021 school year. The tool of our research is a questionnaire (appendix) which has five axes made up of 21 Items. This questionnaire was sent digitally via Google Forms (due to the spread of the Covid-19 epidemic in Morocco) to our target population and which is made up of about 350 qualified secondary school physics-chemistry teachers working in different secondary schools from the Regional Academy of Education and Training of Beni Mellal - Khenifra in Morocco. 125 teachers provided responses.

Before adopting the final version of the questionnaire, we submitted it to a qualitative evaluation which followed two stages:

- A judgment of experts in the field. They provide an objective assessment of the writing, planning, logical order of items, understanding of questions by the target population.
- A pre-test was carried out on the questionnaire by showing it to 10 teachers outside the study sample, where they were asked to comment on it, to clarify vague, ambiguous, or incomprehensible questions, and suggest additional questions needed for the study that were not included in the questionnaire. where the flux linkages are:

3. ANALYSIS OF RESULTS AND DISCUSSION

In this article we will deal with the first three axes plus an item proposed by the teachers. The data collected digitally in the form of a Microsoft Excel file will be processed and analyzed by SPSS (24th edition) software, and some results will be processed by Microsoft Excel software.

Responses on items in the form of the 4-point Likert scale were coded by integers (1=Strongly disagree; 2=Disagree; 3=Agree; 4=Strongly agree)

3.1. Axis No. 1: Personal Data of Teachers

In the table below we present some professional information of the teachers responding to the questionnaire, such as gender, age, professional seniority and diplomas obtained.

Table 1. the personal information of the teachers interviewed

Factor		Frequency	Percentage %
Sex	Men	106	84.8
	Women	19	15.2
Age	22 to 32 years old	45	36.0
	33 to 43 years old	43	34.4
	44 to 53 years old	27	21.6
	54 to 63 years old	10	8.0
Professional Experience	Under 5 years	35	28.0
	6 to 15 years old	67	53.6
	16 to 25 years old	9	7.2
	Over 25 years	14	11.2
Professional Qualification	ENS	49	29.2%
	CPR	8	4.8%
	CFI	3	1.8%
	CRMEF	49	29.2%
	Another certificate	59	35.1%

❖ For item 01 relating to gender, we note that the majority of teachers are men (84.8%), on the other hand women represent 15.6%. This difference between the rates of men and women can be explained by the fact that the choice of respondents was made in a random manner, in addition to the reduced number of physics-chemistry teachers in high schools in Morocco.

❖ For item 02, which concerns the age of the target population, we note that the age group between 22 and 32 years old represents 36% (this is the highest percentage), followed by a group between 33 and 43 years old, which constitutes 34%. Thus, the proportion of less than 43 years old represents more than 70%, which shows that the proportion of rather young teachers is the highest.

❖ Item 03 concerns seniority in teaching. We can see here that the proportion of teachers whose seniority is between 6 and 15 years represents more than half of the sample covered by the study, i.e., 53.6%, while the category of new teachers (less than 5 years of seniority) constitutes 28%. As for the proportion of teachers with more than 16 years of service, it constitutes less than 20%. These results correspond perfectly to what was obtained in the previous question relating to the age of the target population.

❖ For item 04 which is linked to the diplomas obtained, we see that most teachers have at least two professional diplomas (134.4%>100%), we also observe that a significant percentage (47.2%) has different degrees from those which are the most well-known (ENS, CPR, CFI, CRMEF), even if the teachers graduate from ENS and CRMEF constitute a significant percentage (39.2%) compared to teachers from CPR (6.4%) and (CFI (2.4%).

3.2. Axis No. 2: Teaching Differential Equations in Physics-Chemistry

This axis brings together 7 Items, each one is subject to a Likert-type scale in four modalities, which is why we will adopt a single table which includes the calculation of frequencies, means, standard deviations and attitude (Table 2).

Table 2. Teaching of differential equations in physics for science terminal students

ITEMS		Not agree at all	Disagree	Okay	Totally agree	The arithmetic mean	Standard deviation	Median	Attitude
Item 5	Frequency	0	2	79	44	3.34	0.507	3	Okay
	Percentage %	0	1.6	63.2	35.2				
Item 6	Frequency	2	14	43	66	3.38	0.507	4	Totally agree
	Percentage %	1.6	11.2	34.4	52.8				
Item 7	Frequency	0	7	60	58	3.41	0.597	4	Totally agree
	Percentage %	0	5.6	48	46.4				
Item 8	Frequency	1	6	55	63	3.44	0.627	4	Totally agree
	Percentage %	0.8	4.8	44	50.4				
Item 9	Frequency	3	29	41	52	3.14	0.855	3	Okay
	Percentage %	2.4	23.2	32.8	41.6				
Item 10	Frequency	1	17	38	69	3.4	0.751	4	Totally agree
	Percentage %	0.8	13.6	30.4	55.2				
Item 11	Frequency	0	19	44	62	3.44	0.731	4	Totally agree
	Percentage %	0	15.2	35.2	49.6				

Through the results of Table 2, we noticed that the arithmetic mean of all the items is between 3.14 and 3.44, which gives the attitude "Agree" or "Totally Agree", this indicates that the modeling of certain physical phenomena with differential equations, whether first or second order, is a new topic for students in the second year of the baccalaureate level. This situation obliges the teachers to use a simplified explanation to present the concepts and the knowledge related to this object. Furthermore, the way of presenting the solutions of these equations is not done in a direct or dogmatic way, but instead teachers present solutions by making them appropriate for each type of equation to adapt to the level of the pupils. Regarding the standard deviation, its values are similar for all the tests (between 0.507 and 0.855), moreover its value is close to zero, which indicates the homogeneity of the responses of the teachers questioned.

3.3. Axis No. 3: The Teaching of Differential Equations Between Physics and Mathematics

The following two items are used to know whether physical science teachers have Knowledge of the mathematics program, particularly with regard to the mathematical tools used in physics by viewing it or teaching mathematics.

❖ For item 12, 117 teachers out of 125, that is 94% answered with "No", 8 teachers out of 125 that is 6% answered with "Yes". So, for this question, the survey reveals that the majority of teachers have not received in-service training in mathematics' didactics, which will inevitably affect the way some mathematical knowledge is taught (Figure 1).

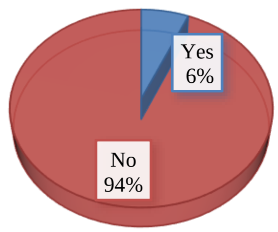

Figure 1. Training of physics and chemistry teachers in mathematics didactics

Table 3 opposite shows that there is a no relationship between continuing education in in mathematics and length of service in the teaching profession, because the value of χ^2 is 0.054, i.e., the benefit of in-service training in mathematics by physics and chemistry teachers is independent of the seniority of the teachers questioned.

Table 3. Relationship between continuing education in mathematics and seniority in teaching professions

		Continuing education in mathematics: Yes	Continuing education in mathematics: No
Seniority in the teaching profession	Under 5 years	0	35
	From 6 to 15 years old	4	63
	16 to 25 years old	2	7
	Over 25 years	2	12
Total		125	
ddl = 3		$\chi^2 = 0.054$	

❖ For item 13, among the teachers questioned 114 teachers out of 125, that is 91%, answered with "No", and 11 teachers out of 125, or 9%, answered with "Yes". As a result, a large proportion of physics-chemistry teachers has not previously taught mathematics in the second-year baccalaureate science level (Figure 2).

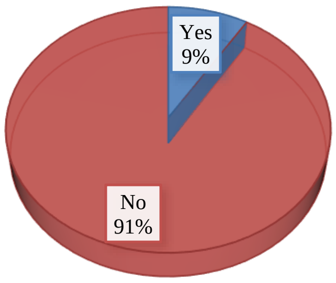

Figure 2. Mathematics instruction for senior classes by physics teachers.

From Table 4, we see that none of the physics-chemistry teachers taught mathematics in final science classes, so the value of (χ^2 = 0.141) which means that the independence is not significant between both parameters.

Table 4. Relationship between the teaching of mathematics by physics and chemistry teachers and their gender

		Mathematics education		Total
		Yes	No	
Gender	Men	11	95	106
	Women	0	19	19
Total		11	114	125
ddl = 1		χ^2 = 0.141		

❖ For item 14, from the results displayed in Table 5, we see that 96% of the teachers questioned "Agree" or "Completely Agree", however 4% do "Not Agree" or "Strongly Disagree" with the proposed item, which means that the low level of use of mathematical tools by pupils negatively affects their learning in physics and chemistry.

The results displayed in Table 5 show that the questioned teachers adopt the attitude "Agree" with the proposition, so the low value of the standard deviation 0.514 signifies the homogeneity of the teachers' responses.

Table 5. Impact of the low level of students in mathematics on the learning of physics

	Not agree at all	Disagree	Okay	Totally agree	Arithmetic average	Median	Standard deviation	Attitude
	Frequency	Frequency	Frequency	Frequency				
	Percentage %	Percentage %	Percentage %	Percentage %				
Item 14	1	4	91	29	3.18	3.00	0.514	Okay
	0.8	3.2	72.8	23.2				

❖ For item 15, through the results collected in Figure 3, it was observed that the majority of the teachers questioned recognized the relationship between the differential equations included in some of the subject's contents, and that they are strongly linked to a set of math lessons. Indeed, 96% of them confirmed the relationship between these equations and the study of exponential and logarithmic functions. In addition to this, 97.6% of the respondents emphasized its relationship with the study of differential equations and 86.4% recognized its relationship with the integral calculus lesson.

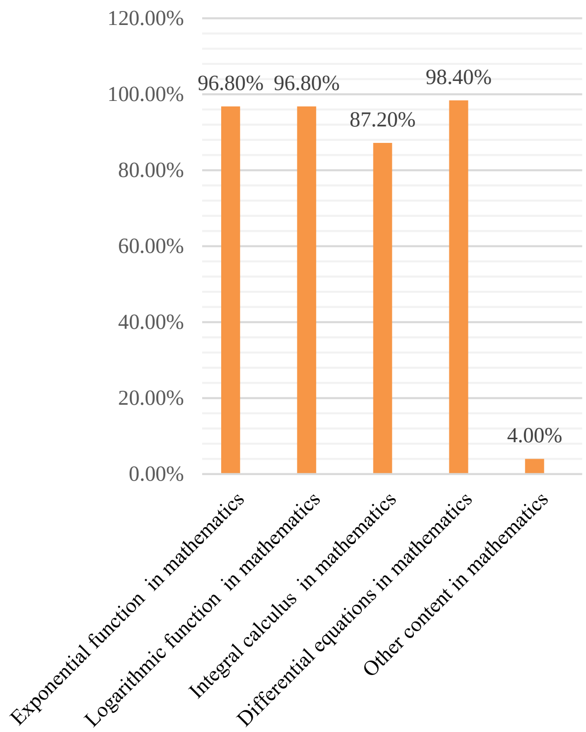

Figure 3. the relation of teaching differential equations with mathematics courses for the second baccalaureate classes

❖ In item 16 which is represented in Table 6, the responses collected show that the majority of teachers (i.e., 96%) "Agree" or "Completely Agree" with the proposition which says: "Learners are first introduced to exponential functions and the natural logarithm in physics before seeing it in mathematics. On the other hand, 4% do not agree. This imposes on the teachers of the subject a particular treatment to define the two functions by simplifying the explanation, by presenting the basic properties in a flexible way and by giving some applications to help students understand these properties.

Table 6. Teaching of Exponential and Logarithmic functions in math and physics

	not agree at all	Disagree	Okay	Totally agree	Arithmetic average	Median	Standard deviation	Attitude
	Frequency	Frequency	Frequency	Frequency				
	Percentage %	Percentage %	Percentage %	Percentage %				
Item 16	0	5	91	29	3.19	3	0.487	Okay
	0	4.0	72.8	23.2				

❖ The responses to Item 17 presented in Table 7 show that almost half (53.6%) of the physics-chemistry teachers questioned spend half an hour to introduce exponential and logarithmic functions**,** whereas a percentage of 23.2% only spend 15 min on the same task, while a similar percentage to the previous one (23.2% of teachers surveyed) need around forty-five minutes or more to present both functions.

Table 7. The private duration at the definition of the exponential and logarithmic functions

	Frequency	Percentage %
15 min	29	23.2
30 min	67	53.6
45 min	14	11.2
60 min	8	6.4
More than an hour	7	5.6
Total	125	100

The Table 8 shows the relation between the value of χ^2 is 0.082 that is to say there is independence between the time necessary to define the exponential and natural logarithm functions and the length of service of the teachers, that is to say their experience in the profession.

Table 8. the relationship between seniority in professions and the time required to define the functions $e^{(x)}$ and $\ln(x)$

	15 min	30 min	45 min	60 min	More than an hour	Total
Under 5 years	10	21	3	1	0	35
6 to 15 years old	17	31	10	6	3	67
16 to 25 years old	0	8	0	0	1	9
Over 25 years	2	7	1	1	3	14
Total	29	67	14	8	7	125
	ddl = 15			χ^2 = 0.082		

❖ Items 18 and 19 through two items 18 and 19, we want to know the opinions of the interviewed professors regarding the difficulty of teaching the exponential function and the logarithm function for students of the final scientific classes and the possibility of coordination with mathematics teachers who teach the same classes.

❖ On reading Table 9, the responses collected show that almost half (48%) of physics-chemistry teachers "totally agree" and 17.6% of teachers "agree" with the proposition. This shows that teachers have mathematical knowledge on this subject. The attitude is "Agree" with the proposition. The value 0.957 of the standard deviation shows the existence of an insignificant homogeneity of the responses of the teachers questioned.

❖ The data represented in the same table 9 concerning item 19 reveal that half (49.6%) of the teachers questioned "Agree" while 32% "Totally Agree" with the proposition. In addition, 5.6% of respondents "totally disagree" and 12.8% "Disagree". The median is equal to 3 and the attitude is "Agree" with this proposition, the value of 0.819 of the standard deviation shows the existence of an insignificant homogeneity of the responses of the teachers questioned.

❖ For item 20, in Figure 4, 80% of teachers answered with "Yes" and 20% answered "No". So, for this question, the survey reveals that for most of the teachers' students of the second year of the baccalaureate level have already seen the lesson of differential equations in mathematics, which facilitates the task of presenting the knowledge and attitudes related to the content of physics.

Table 9. teaching of functions $e^{(x)}$ and $\ln(x)$ and coordination between teachers of Mathematics and physics-chemistry

		Not agree at all	Disagree	Okay	Totally agree	Arithmetic average	Median	Standard deviation	Attitude
Item 18	Frequency	4	39	22	60	3.10	3.00	0.957	Okay
	Percentage %	3.2	31.2	17.6	48				
Item 19	Frequency	7	16	62	40	3.08	3.00	0.819	Okay
	Percentage %	5.6	12.8	49.6	32				

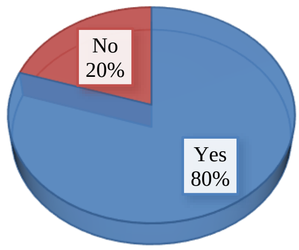

Figure 4. Studying differential equations in mathematics for professors of physics and chemistry

❖ Item 21, From the results presented in Figure 5 of this item, we find that 89% of respondents "No" and 11% "Yes". We understand as well that all the respondent answers are against the programming of the chapter on differential equations at the end of the second semester for students in final science classes in mathematics. These results therefore confirm the lack of programming consistency between mathematics and physics for knowledge related to differential Equations.

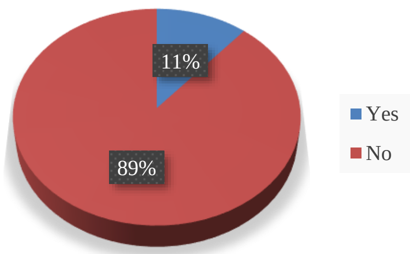

Figure 5. Programming of the chapter on differential equations at the end of the second semester for students in final science classes in mathematics

4. VERIFICATION OF HYPOTHESES

The verification of the hypotheses will take into account the frequencies, the percentages, the means, the medians, the attitudes and the chi-square value of the responses provided by the items.

4.1. Verification of Hypothesis 1

In view of the frequencies, averages and attitudes of teachers given in the responses to the 7 items of axis 2, we are led not to affirm Hypothesis 1. On the one hand, 109 of the teachers questioned (87.2%) said that students have difficulty knowing symbolic representations which are used in writing differential equations. On the other hand, 118 of the teachers participating in the study (94.4%) confirmed that the students did not even know the concept of differential equation, and the same proportion confirmed that the students had great difficulty in modeling some physical phenomena with differential equations. Moreover, a significant proportion of the teachers who answered the questionnaire confirmed that the students did not understand the proposed solutions for the first order linear differential equations with constant coefficients (74.4%) and that they could not relate ascending or descending curves to the proposed solutions (85.6%), and that they also had difficulty accepting the proposed solutions for second-order linear differential equations with constant coefficients (84.8%).

4.2. Verification of Hypothesis 2

To verify the second hypothesis, we will study the results of the third axis of the questionnaire, and mainly we will focus on some of the results. On the one hand, in items 12 and 13, 117 of the teachers questioned (94%) declared that they had never received continuing or initial training in mathematics didactics, and 114 of them (91%) have never taught in the final classes of the scientific baccalaureate in mathematics. On the other hand, and through the results of the 15th item, the teachers questioned agreed that the teaching of differential equations in physical sciences is closely linked to a set of mathematics lessons such as the lessons of exponential functions, natural logarithm, calculus of integrals, differential equations, and other lessons. In addition to this, the teachers who responded to the survey confirmed the lack of coordination with mathematics teachers before addressing the knowledge and content related to differential equations in the physical sciences (items 16 to 19), and a large percentage of them do not agree with the programming of the lesson of differential equations in mathematics at the end of the second semester. Hence the second hypothesis could not be verified.

5. CONCLUSIONS

At the end of this study, we can say that the results obtained allow us to answer the questions that we formulated at the outset. Indeed, the vast majority of physics teachers interviewed stressed the importance of differential equations, as well as the importance of modeling certain physical phenomena in the curriculum of final science classes, and they fully agreed that it was necessary to deal with exceptionally a fact that the students had never dealt with this type of equations, without forgetting the fact that they never knew the partial differential symbols used and the functions to which their solutions were related, in particular the exponential function and the logarithmic function. The study shows that students in final science classes encounter difficulties in modeling certain physical phenomena with first-order or second-order linear differential equations with constant coefficients, as well as in writing and finding the solutions of these equations and to exploit them.

Linear differential equations and in particular of the first order with constant coefficients appear in both the physics and mathematics programs of the final S class. The comments of the programs of the two disciplines explicitly encourage the two teachers of the same class to work together on this subject [14]. The results obtained in this study clearly show the lack of consistency between the programs of the two subjects with regard to the contents related to the teaching of differential equations, as well as the lack of coordination between the teachers of the two subjects of secondary education. This can lead to difficulties in teachers' practices for teaching what is related to differential equations.

To deepen this study, we recommend integrating the numerical approach through Euler's method in solving first order differential equations with constant coefficients. Likewise, we will try to study the mathematics/physics interdisciplinarity from a qualitative approach to complement the questionnaire already dealt with in this article and from the analysis of the training system for physics-chemistry teachers in the Regional Centers for Education and Training Trades, we will also try to study the possibility of inter-didactic physics/mathematics training for trainee teachers in these same CRMEFs.

APPENDICES

This questionnaire is addressed to physics and chemistry teachers who teach at the qualifying secondary level in order to know their opinions and orientations on modeling certain physical phenomena by adopting differential equations, writing and solving them and investing the results for the last year of the scientific baccalaureate branches. In addition, we would like to know the possibilities of communication with mathematics teachers and the extent of compatibility of the scheduled mathematics courses with the prescribed physics and chemistry courses that deal with the same subject.

Appendix 1. Personal Information

1. Gender:
   Men, Women
2. Age
   From 22 to 32 years
   From 33 to 42 years
   From 43 to 52 years
   From 53 to 63 years

3. Seniority
Less than 5 years
6 years - 15 years
16 years - 25 years
Over 25 years
4. Professional certificates obtained
ENES
CRMEF
CPR
CFI
Other

Appendix 2. Pedagogical Practices of Teachers for the Introduction of Differential Equations in the Physics-Chemistry Subject

5. The resources in differential equations play an important role in the physics-chemistry program of the last year of the science baccalaureate.
Totally agree Okay Disagree Not agree at all
6. Learners have difficulty understanding the symbolic representations d/dt and d^2/dt^2 used to write differential equations.
7. Students have difficulty modeling and writing physical phenomena as differential equations.
○ Totally agree Okay Disagree Not agree at all
8. Because students are unfamiliar with the concept of a differential equation, it is helpful to present it as a mathematical equation whose solution is not a numerical value but a function of a variable.
○ Totally agree Okay Disagree Not agree at all
9. Barely learners understand that the solution of the first-order linear differential equations $df/dt + af = b$ is written as $f(t) = Ae^{\propto t} + B$.
○ Totally agree Okay Disagree Not agree at all
10. Learners have difficulty relating rising or falling curves to the appropriate exponential function.
○ Totally agree Okay Disagree Not agree at all
11. Learners do not readily understand that the functions $\cos(\omega t+\varphi)$ and $\sin(\omega t+\varphi)$ are solutions of second-order linear differential equations $d^2 f/dt^2 + \omega^2 f = 0$.
○ Totally agree Okay Disagree Not agree at all

Appendix 3. The Teaching of Differential Equations between Mathematics and Physics for the Last Year of the Scientific Baccalaureate

12. Have you ever received continuing education in mathematics didactics?
○ Yes No
13. Have you ever taught mathematics in the last year of the science baccalaureate?
○ Yes No
14. Learners' low level in mathematics has an unavoidable impact on their learning in physics and chemistry.
○ Totally agree Okay Disagree Not agree at all
15. The teaching of a set of contents in physics and chemistry is linked to a set of units in mathematics, what are they?
☐ Teaching relationship of differential equations with the exponential
☐ Function
☐ Teaching relationship of differential equations with the neperian
☐ logarithmic function
☐ Teaching relationship of differential equations with the calculate integral
☐ Relationship of teaching differential equations with the same
☐ Chapter in mathematics
☐ Relationship of teaching differential equations to other mathematics content
16. Learners are first introduced to the exponential functions $f(t) = \mathrm{e}^{at}$ and the natural logarithm $g(t) = \ln at$ in physics before seeing these in mathematics.
○ Totally agree Okay Disagree Not agree at all
17. how much estimated time you will need to define the functions $f(t) = \mathrm{e}^{at}$ and $g(t) = \ln at$.
15 min
30 min
45 min
60 min
More than hour
18. You have difficulty defining and explaining some properties of the functions $f(t) = \mathrm{e}^{at}$ and $g(t) = \ln at$.
○ Totally agree Okay Disagree Not agree at all
19. it is necessary to coordinate with mathematics teachers who teach the same learners while introducing the two previous functions.
○ Totally agree Okay Disagree Not agree at all
20. Have you ever studied programmed differential equations in mathematics for the last year of the science baccalaureate?
○ Yes No
21. Do you think that scheduling this course at the end of the second semester of mathematics is appropriate for the last year of the science baccalaureate?
○ Yes No

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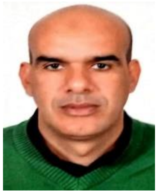

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