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IDENTIFICATION OF SOME MATHEMATICAL DIFFICULTIES IN LEARNING PHYSICS: THE CASE OF FINAL-YEAR SCIENTIFIC BACCALAUREATE PUPILS IN MOROCCO

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Abstract:
This study analyses the mathematical difficulties encountered by second-year scientific baccalaureate pupils in Morocco in learning physics. Based on a combined questionnaire-test administered to a sample of 125 students, the results show that these difficulties mainly concern the mobilization of mathematical tools in physical contexts, particularly the use of formulas, the distinction between mathematical and physical symbols, and the use of mathematical notions that have not yet been formally studied. The data also reveal a close relationship between mathematical difficulties, the understanding of physical phenomena, and problem-solving performance. The analysis highlights the fact that certain concepts, perceived as intuitive when approached qualitatively, become problematic as soon as they require explicit mathematical formalization, especially through graphical and functional representations. These findings confirm that the observed difficulties arise from a complex interaction between mathematics and physics rather than from isolated deficiencies in mathematical knowledge. The study thus emphasizes the central role of mathematics as both a language and a structuring tool in physics education, particularly in mechanics and electricity. It underscores the need for better coordination between mathematics and physics teaching, as well as for a

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harmonization of curricular progression, to reduce the identified difficulties and improve students' academic achievement.

Keywords: Mathematical difficulties; Physics learning; Scientific baccalaureate; Mathematics–physics relationship; Mathematical modeling

1. Introduction

Physics learning very often requires pupils to mobilize mathematical tools. Formulas, graphs, functions, derivatives, and relationships between quantities are not merely objects of calculation; they are used to describe, explain, and model physical phenomena. In mechanics, as in electricity, understanding a phenomenon often means being able to move from a physical situation to a mathematical expression, and then to give meaning to that expression.

However, this transition between physics and mathematics is not always straightforward for pupils. A mathematical concept may be known in mathematics class but become difficult to use when it appears in a physics problem. This can be explained partly by the fact that the two subjects are often taught separately, with different objectives, notations, and ways of reasoning. The progressive formalization of mathematics, particularly under the influence of the modern mathematics movement and the Bourbaki group, has contributed to reinforcing this separation between mathematics as an autonomous discipline and its uses in the natural sciences (Munson, 2010). Arnol'd (1998) specifically criticizes this distance between mathematics and physics and argues for mathematics teaching that is more closely connected to natural phenomena. In the same vein, Tzanakis (2016) points out that mathematics and physics have a deep historical and epistemological relationship, but that teaching them separately can make knowledge transfer more difficult for pupils.

Several studies in didactics have shown that pupils encounter difficulties when they have to use mathematics in physics situations. These difficulties particularly concern isolating variables, proportionality, numerical applications, graph interpretation, and the transition from one register of representation to another, for example from verbal language to a formula or from a table of values to a curve (Genin et al., 1987; Samson, 2004; Rodríguez Gallegos, 2007; Malonga Moungabio, 2008; Ba, 2011; Trudel & Métioui, 2011; Adjibi et al., 2016; Raouf et al., 2016; Bodinier & Sévrain, 2017; Di Fabio et al., 2021). These studies show that the problem is not limited to a lack of mastery of calculations. It also concerns pupils' ability to understand the role of mathematics in interpreting a physical phenomenon.

In the Moroccan context, several reforms have sought to improve curricula, teaching practices, and teacher training (Chafiqi & Alagui, 2011). Despite these efforts, national and international assessments continue to report persistent difficulties in scientific learning, particularly in mathematics and physical sciences (CSEFRS, 2009, 2014; MENFP, 2014; Martin et al., 2012; UNESCO, 2014). The 2015–2030 Strategic Vision therefore emphasizes the need to move beyond the simple transmission of knowledge and to develop pupils' abilities to transfer, mobilize, and reinvest knowledge in new situations (Lauzon, 2000; Meirieu, 1991; Péladeau et al., 2005).

From this perspective, the use of mathematics in physics becomes a central issue. International surveys, particularly PISA, show that pupils' performance does not depend only on their knowledge, but also on their motivation, their perception of their own skills, and their ability to use this knowledge in varied contexts (OECD, 2001; OECD, 2014). Bodinier and Sévrain (2017), for their part, highlight frequent difficulties in the use of mathematics in physical and chemical sciences, particularly in proportionality, isolating variables, and exploiting graphical representations. These findings are consistent with those of Chaik et al. (2025), who show, among upper secondary pupils in Morocco, a gap between mathematical knowledge learned in mathematics classes and its effective mobilization in physics contexts.

The present study is situated within this problem area. It focuses on the difficulties encountered by final-year scientific baccalaureate pupils when they have to use mathematical tools in learning physics. The aim is therefore not only to determine whether they know certain mathematical concepts, but also to understand how they use them when they are integrated into a physical situation : interpreting a formula, distinguishing between symbols, recognizing a function, using a derivative, reading a graph, or translating a statement into a mathematical relationship.

The central research question is therefore the following: What are the main difficulties encountered by final-year scientific baccalaureate pupils when they have to mobilize mathematical tools in physics learning situations ?

This main question is divided into three specific questions :

- What difficulties do pupils report encountering in the use of formulas, symbols, and mathematical concepts in physics?
- What difficulties can be observed through their responses to diagnostic tasks involving the translation of statements, the identification of functions, the use of derivatives, and graph interpretation?
- To what extent do these difficulties reflect a problem of transfer between mathematical learning and its mobilization in a physics context?

The hypothesis adopted is that pupils' difficulties do not stem solely from a lack of mathematical knowledge. Rather, they are mainly related to the difficulty of giving physical meaning to the mathematical tools being used. In other words, some pupils may recognize a concept in a mathematics exercise, but struggle to interpret and use it as a modeling tool in a physics situation or activity.

2. Conceptual Framework

2.1 Competency-based Approach in Physics Teaching

In learning physics, mathematics is not simply a set of calculation tools to be applied automatically. It must be mobilized to understand a situation, interpret a phenomenon, construct a relationship between quantities, or make use of a graphical representation. This mobilization corresponds to a transfer competency, since the pupil has to reuse knowledge learned in mathematics in a different context, namely physics.

However, a competency cannot be reduced to the mere possession of knowledge; it involves the ability to select, organize, and use that knowledge appropriately in a complex situation (Le Boterf, 1994; Perrenoud, 1997; Tardif, 2006). From this perspective, a competent pupil is not only one who knows a formula, a function, or a derivative, but one who is able to give it physical meaning and use it to solve a problem or explain a phenomenon.

The competency-based approach therefore emphasizes the ability to reinvest school learning in new and meaningful situations (Roegiers, 2000; Perrenoud, 1999). Thus, when a pupil translates a physical statement into a mathematical relationship, isolates a variable, recognizes a function in a physical law, or interprets a derivative as a velocity or an acceleration, they are not merely doing mathematics; they are building a link between two disciplines.

The difficulties encountered in these tasks can therefore be understood as difficulties of transfer between mathematical learning and its mobilization in a physics context.

2.2 Semiotic Registers in Physico-Mathematical Modeling

Duval's semiotic approach distinguishes mental representations from semiotic representations: "*Mental representations are the set of mental images or conceptions that an individual may have of an object or a situation, and of what is associated with it. Semiotic representations, on the other hand, are productions formed using signs belonging to the same system of representation, such as a statement in natural language, an algebraic formula, a graph, or a geometric figure. They appear to be how an individual externalizes their mental representations, that is, makes them visible or accessible to others*" (Duval, 1995). A semiotic system becomes a register of semiotic representation when it allows the fundamental cognitive activities of formation, treatment, and conversion of a representation.

The formation of a semiotic representation is "t*he use of one or more signs to actualize the intended object or to replace the intention directed toward that object*" (Duval, 1995). The activity of formation must follow the conformity rules specific to the system used, to make possible the use of the treatment operations offered by that system. Treatment consists of transforming one representation into another without changing register. Expansion rules produce a representation within the same register as the initial one (Duval, 1995). For example, the expression $f(x) = e^x$may be considered as the treatment of the relation "$f' = f$ with $f(0) = 1$".

Conversion is the transformation of a representation into a representation belonging to another register. For example, this may involve transforming a table of experimental data into a graph, or a differential equation into a vector field. The rules of conversion differ according to the direction of the change of register (Duval, 1995). Duval distinguishes between two categories of objects: accessible objects, which can be perceived directly or through instruments such as telescopes, microscopes, or spectrometers, and inaccessible objects, which can only be perceived through semiotic activities, such as mathematical objects (Duval, 2005).

The modeling of physical phenomena mobilizes both categories of objects, giving rise to a physico-mathematical approach in which the treatment and conversion of semiotic representations rely on knowledge of both physics and mathematics. For example, graphs represent both the temporal evolution of a physical quantity and mathematical properties such as tangency or the calculation of characteristic values.

2.3 Difficulties Related to the Mobilization of Mathematical Tools in Physics Learning

Several studies have shown that mastery of mathematical tools is an important factor in learning physics. In this regard, Meltzer (2002) examined the relationship between students' mathematical preparation and their conceptual learning gains in physics. His results show that mathematical skills can influence the way learners' appropriate physical concepts, even in interactive teaching settings. This study therefore highlights that the difficulties encountered in physics are not only related to the understanding of phenomena, but also to the ability to correctly mobilize the mathematical knowledge needed for their modeling and interpretation.

The study by Al Mamouri and Al Khaldi (2002), conducted in Iraq, analyzed the difficulties encountered by 136 female teacher-preparation students in solving physics problems. The results revealed difficulties in correctly communicating problems, language-related comprehension difficulties, a lack of knowledge of the sequence of steps required to reach solutions, and a weak mathematical foundation. The researchers recommended encouraging students to reformulate problems in their own words, solve them in several ways, and involve newly appointed teachers in courses on physics teaching methods.

The Ofsted report (2011), devoted to the evaluation of science education in England between 2007 and 2010, highlights several factors influencing the quality of science learning, including the clarity of teaching objectives, mastery of scientific knowledge, the role of practical activities, and the importance of developing scientific inquiry skills. These elements show that the difficulties encountered by pupils in science are not only related to disciplinary content, but also to the way knowledge is taught, organized, and mobilized in learning situations.

Many studies have shown that the difficulties encountered by pupils in solving physics problems do not stem solely from a lack of isolated mathematical knowledge, but also from the way this knowledge must be mobilized in complex physico-mathematical contexts. For example, Levi, Merzel, and Lehavi (2025) studied what they call "*physmatic difficulties*," that is, specific problems related to the interaction between mathematics and physics among secondary school pupils. They showed that pupils adopt various types of reasoning — context-oriented, purely mathematical, or immature — which negatively affects their performance in physics. Similarly, Brahmia et al. (2016) show that the difficulties encountered by learners in physics are not only related to the mastery of mathematical procedures, but also to their ability to use algebraic reasoning, proportionality, and symbolization to make sense of physical situations. Furthermore, Maries, Lin, and Singh (2020) showed that, among novice physics students, mathematical problem-solving strategies reflect a phase of cognitive transition in which learners do not yet mobilize mathematical tools expertly to interpret physical expressions. This calls for more structured pedagogical approaches to promote a more effective integration of mathematical and physical knowledge. In line with earlier studies, these works confirm that the difficulties related to the mobilization of mathematical tools in physics learning are multidimensional and persist beyond secondary education, highlighting the need for pedagogical interventions specifically oriented toward the physico-mathematical integration of knowledge.

3. Research Methodology

To achieve the objectives of this study, we adopted a descriptive approach aimed at identifying the difficulties encountered by final-year scientific baccalaureate Moroccan pupils when they mobilize mathematical tools in learning physics. Data were collected using a combined questionnaire-test, designed to gather both pupils' perceptions and diagnostic information on certain physico-mathematical competencies.

3.1 Study Sample

The study was conducted with 138 pupils enrolled in the second year of the baccalaureate, Physics-Chemistry track-Morocco. After checking the responses collected, 125 questionnaire-tests were retained for analysis, while the others were excluded because they were incomplete or difficult to use. The final sample included 65 girls, representing 52%, and 60 boys, representing 48%. This distribution made it possible to consider the responses of pupils of both sexes, without claiming that it alone guarantees the statistical representativeness of the sample.

3.2 Research Tools

Data were collected using a combined questionnaire-test, written in French and specifically designed for final-year scientific baccalaureate pupils, corresponding to the second year of the baccalaureate (see Appendix). It includes, on the one hand, questionnaire items intended to collect pupils' perceptions of the mathematical difficulties encountered in learning physics and, on the other hand, diagnostic items aimed at assessing certain knowledge and competencies mobilized in physico-mathematical situations.

This tool was developed in consultation with three physics teachers to identify the mathematical prerequisites essential for understanding the physical concepts studied. Most of the questions are closed-ended, which facilitates the quantitative processing of responses and provides indicators of declared or observed difficulties.

The open-ended questions, for their part, invite pupils to produce brief and targeted responses, making it possible to assess their conceptual understanding, their ability to translate a physical statement into a mathematical relationship, and their ability to argue concisely.

3.3 Data Processing

We used Microsoft Excel to process and analyze the collected data.

4. Study Results

This section presents the results of the study, in accordance with the objectives defined above, in order to identify the main mathematical difficulties encountered by final-year scientific baccalaureate pupils in learning physics.

In this analysis, a distinction is made between the difficulties reported by pupils and the difficulties observed from their responses to the diagnostic tasks. The percentages are therefore interpreted according to the nature of each item: as indicators of perception in the case of declarative questions, or as indicators of success or error in the case of diagnostic tasks.

Table 1: Results of Questions 1 to 4 of the test concerning difficulties related to mathematical formulas and symbols in physics

Questions		Responses	Percentage
1	Do mathematical formulas cause problems when learning physics?	Yes	54 %
		No	46 %
2	Is the difference between mathematical symbols and physical symbols an obstacle to your learning?	Yes	54 %
		No	46 %
3	Does using mathematical symbols in physics before studying them in mathematics constitute an obstacle to understanding physical concepts ?	Yes	74 %
		No	26 %
4	Have you ever received poor grades in physics because of mathematical errors?	Yes	42 %
		No	58 %

Analysis of the results of the first three questions of the test, all of which are closed-ended, reveals significant difficulties related to the use of mathematical tools in physics. The first question, concerning mathematical formulas, shows that 54% of pupils consider them to be an obstacle, indicating that their application in a physics context remains problematic. The second question, which explores the distinction between mathematical and physical symbols, reveals that 54% of pupils perceive this difference as a source of confusion, highlighting the cognitive challenge involved in transferring notations.

The third question, focused on the use of mathematical symbols in physics before they are studied in mathematics, shows that 74% of pupils find this practice difficult for understanding concepts. Finally, the fourth question reveals that 42% of pupils believe they have obtained poor grades in physics because of mathematical errors, suggesting that these difficulties may be associated with academic performance in physics. Overall, these results highlight the important role of mathematical competencies in understanding and succeeding in physics.

Table 2: Pupils' reported preferences regarding physics activities

Question 5	Responses	Percentage
What do you prefer: understanding experiments and physical phenomena, or solving exercises?	Understanding experiments and physical phenomena.	50 %
	Solving exercises.	50 %

Question 5 reveals an equal distribution of pupils' preferences: 50% report preferring to understand experiments and physical phenomena, while 50% prefer solving exercises. This result does not, on its own, identify a mathematical difficulty, but it provides insight into pupils' general relationship with the activities proposed in physics.

Table 3: Distribution of difficulties encountered by pupils
when reviewing lessons and solving physics exercises

Questions		Type of difficulty	Percentage
6	What difficulties do you encounter when reviewing physics lessons?	Mathematic	48 %
		Conceptual	14 %
		Experimental	32 %
		Linguistic	6 %
7	What difficulties do you encounter when solving physics exercises?	Mathematic	48 %
		Conceptual	16 %
		Experimental	28 %
		Linguistic	8 %

The results show that mathematical difficulties are the most frequently reported obstacle by pupils, both when reviewing lessons and when solving exercises, with a rate of 48% in both cases. Experimental difficulties come in second place, with 32% when reviewing lessons and 28% when solving exercises.

Conceptual and linguistic difficulties are less frequent, but they should not be overlooked, as they may also hinder the understanding of physical situations. These results suggest that the difficulties encountered by pupils are mathematical, experimental, conceptual, and linguistic in nature, although the mathematical dimension appears to be dominant.

Table 4: Distribution of pupils according to their ability to
translate physical statements into simple mathematical relationships

Question 8		Responses	Percentage
Express the following statements in the form of simple mathematical relationships.	A is proportional to B, where k is the constant of proportionality	$A = Kb$	24 %
	Velocity $\boldsymbol{v}$is the derivative of the curvilinear abscissa $\boldsymbol{S}$with respect to time $\boldsymbol{t}$.	$\upsilon = \frac{dS}{dt}$	24 %

	Pressure $\boldsymbol{P}$ is the magnitude of the force $\vec{\boldsymbol{F}}$ applied per unit surface area $\boldsymbol{S}$.	$P = \frac{F}{S}$	24 %

The results show that only 24% of pupils correctly translated the proposed physical statements into simple mathematical relationships. In other words, a large majority of pupils, approximately 76%, did not succeed in this translation task. This result highlights an observed difficulty in moving from verbal language to mathematical language. It is therefore not merely a calculation difficulty, but an obstacle related to connecting a physical situation, the quantities involved, and their mathematical formalization.

Table 5: The physics teacher's approach to new mathematical concepts.

Questions 9	**Responses**	**Percentage**
How does the physics teacher approach new mathematical concepts?	With explanation	6 %
	Reminder	50 %
	Without explanation	44 %

The results show that 50% of pupils perceive that the teacher provides only a simple reminder of mathematical concepts, while 44% report receiving no explanation. This reveals insufficient support in introducing new mathematical tools in physics.

Table 6: Identification of functional or relational expressions in mathematics and physics

Question 10	**Choices**	**Percentage**
Put a cross next to what you consider to be a function.	$U - RI = 0$	0 %
	$PV - nRT = 0$	0 %
	$P = mg$	0 %
	$T = k\Delta l$	2 %
	$y = f(x)$	100%
	$y = x(t)$	98 %

Pupils easily recognize explicit school-based functional forms, such as $y = f(x)$ and $y = x(t)$. However, they almost never consider the proposed physical relationships as functions. This result may reflect a difficulty in transferring the school-based mathematical notation of a function to the relationships used in physics.

Nevertheless, this interpretation should be nuanced, since some relationships, such as $P = mg$ or $T = k\Delta l$, can be interpreted as functional if the dependent variable, the independent variable, and the constants are clearly specified. The item would therefore benefit from being reformulated so as to ask pupils to explicitly identify the quantity that depends on another.

Table 7: Identification of derivatives in physics and mathematics

Question 11	Choices	Percentage
Put a cross next to what you consider to be a derivative.	$\lim\limits_{dt \to 0} \frac{\vec{v}(t+dt) - \vec{v}(t)}{dt}$	0 %
	$\frac{\Delta x}{\Delta t}$	8 %
	$\frac{dx(y)}{dy}$	94 %
	$\frac{df(t)}{dt}$	94 %
	$x'(t)$	100 %
	$\dot{x}(t)$	64 %

The results show that pupils mainly recognize the usual school-based notations of the derivative, such as $x'(t)$, $\dot{x}(t)$, $\frac{df(t)}{dt}$, or $\frac{dx(y)}{dy}$. However, they recognize the structure of the derivative much less when it is presented in limit form or in a physical situation.

This result does not mean that these expressions are less mathematical, but rather that pupils have difficulty identifying the same mathematical object when it changes form or context. This difficulty relates to the transition between registers of representation and to the physical contextualization of the derivative.

Table 8: Kinematic parameters and mathematical modeling of motion

Question 12		Choices	Percentage
The motion of bodies S_1 and S_2	The nature of the motion of bodies S_1 and S_2.	Accelerated	94 %
		Slowed down	0 %
		Changing regularly	0 %
		Ordinary	6 %
	The type of acceleration.	Zero	0 %
		Constant	82 %
		Variable with respect to time	12 %
	The fastest body.	Body (s_1)	94 %
		Body (s_2)	6 %
	The velocity equation of the two bodies.	$v(t) = kt$	94 %
		$v(t) = k$	6 %
	The initial velocity of the two bodies.	$v_0 = 0$	100 %
		$0 < v_0$	0 %
		$v_0 < 0$	0 %

The responses related to kinematics should be interpreted with caution, particularly because of the wording of the item. The proposed graph represents velocity $v(t)$as a function of time. In this case, a relationship of the form $v(t) = kt$, where $k$is constant, corresponds to uniformly accelerated motion, characterized by constant acceleration and zero initial velocity. Thus, pupils' responses concerning accelerated motion, constant acceleration, and zero initial velocity appear overall coherent.

Table 9: Understanding voltage and its temporal evolution in an RC capacitor.

Question 13		Choices	Percentage
The voltage across a capacitor in an RC circuit	The monotonicity of this function over the interval [0,2τ].	Increasing	100 %
		Decreasing	0 %
		Constant	0 %
	The maximum voltage value.	Value of the voltage in steady state	42 %
		E	58 %
		$U_c(0)$	0 %
	The line whose equation is: $\boldsymbol{U_C(t)) = U_{c\,max}}$.	Tangent to the function at the point $t = 0$	100 %
		Asymptote near infinity	0 %
	The initial state of the capacitor.	Charged	2 %
		Discharged	98 %

The results related to the RC circuit show that pupils master certain qualitative aspects of the evolution of the voltage across the capacitor. Indeed, all pupils, that is, 100%, recognize that this voltage is increasing over the interval [0,2τ]. Similarly, 98% of pupils correctly identify the initial state of the capacitor as discharged, while only 2% consider it to be charged.

Regarding the maximum value of the voltage, 58% of pupils choose the answer E, while 42% choose "the value of the voltage in steady state." No pupil selects the answer $U_C(0)$. However, this result should be interpreted with caution because, in the ideal case of charging a capacitor under a constant voltage E, the maximum value reached by the voltage corresponds precisely to its steady-state value. Thus, the two answers, $E$and "the value of the voltage in steady state," may refer to the same physical quantity, which shows that the wording of the item needs to be clarified.

By contrast, the graphical interpretation of the line whose equation is $U_C(t) = U_{C\max}$reveals a clearer difficulty. All pupils, that is, 100%, associate it with a tangent at the initial point, whereas none of them identify it as an asymptote as $t$approaches infinity. This result reveals significant confusion between a tangent and an asymptote. It shows that even when pupils have an overall understanding of the evolution of the phenomenon, the precise mathematical interpretation of the graph remains fragile, particularly when it comes to giving physical meaning to an exponential representation.

Table 10: Identification and interpretation of trigonometric functions representing oscillations

Question 14	Choices	Percentage
The function represented in the figure	$u(t) = 5\,cos(2t)$	22 %
	$u(t) = 5\,sin(2t)$	68 %
	$u(t) = \ -5\,sin(2t)$	10 %

The results in Table 10 show that 68% of pupils correctly identify the trigonometric function represented, indicating a majority success in this task. However, 32% of pupils choose an incorrect expression, which reveals persistent difficulties in interpreting the initial phase and distinguishing between sine and cosine functions. This difficulty should therefore not be attributed to all pupils, but rather to a significant part of the sample.

5. Discussion

The analysis of the results is conducted by clearly distinguishing between the difficulties reported by pupils and those observed in their responses to the diagnostic tasks. Reported difficulties reflect the way pupils perceive their own obstacles, whereas observed difficulties appear when they are confronted with specific tasks, such as translating a statement into a mathematical relationship, recognizing a function, identifying a derivative, or interpreting a graph. This distinction is necessary because the instrument used combines declarative items and diagnostic items. The percentages should therefore be interpreted according to the nature of the items: some provide information about pupils' perceptions, while others reflect their actual performance in physico-mathematical tasks.

The results obtained show that the difficulties encountered by pupils are not limited to calculation errors or to a partial lack of knowledge of certain mathematical concepts. They appear mainly when pupils have to mobilize mathematical knowledge in a physical situation. This finding is consistent with the competency-based approach, according to which competence is not limited to the possession of knowledge, but involves the ability to select, organize, and use this knowledge appropriately in a complex situation (Le Boterf, 1994; Perrenoud, 1997; Tardif, 2006). From this perspective, the observed difficulties can be interpreted as difficulties of transfer between mathematical learning and its mobilization in a physics context, which is also consistent with the analyses of Roegiers (2000) and Perrenoud (1999) on the reinvestment of school learning in new situations.

Table 11 below highlights several levels of difficulty. The reported difficulties mainly concern the use of formulas, the differentiation between mathematical and physical symbols, and the use of mathematical concepts in physics before their formal study in mathematics. These results show that pupils are not only confronted with mathematical content, but also with its use in another disciplinary context. In other words, they must move from mathematical knowledge learned as a school object to a modeling tool used to interpret a physical phenomenon.

The diagnostic tasks reveal, more specifically, difficulties in translating physical statements into simple mathematical relationships. The fact that only 24% of pupils succeeded in this task shows that the transition from verbal language to mathematical language constitutes a major obstacle. In light of Duval's theory of semiotic registers, this difficulty can be interpreted as a difficulty of conversion between registers of representation. Translating a verbal statement into a formula, reading a graph, or recognizing a function in a physical relationship requires moving from one semiotic register to another. According to Duval (1995, 2005), the understanding of a mathematical or physico-mathematical object strongly depends on the ability to process and convert representations.

The results concerning functions confirm this difficulty. Pupils easily recognize explicit school-based forms, such as $y = f(x)$or $y = x(t)$, but they identify physical relationships as functions much less frequently. This result suggests that the concept of function remains attached to a familiar school form and is not easily transferred to the types of expressions used in physics. It is therefore not only a problem of knowledge of the function concept, but also a difficulty in recognizing the same mathematical object when it changes register, notation, or context.

The same interpretation can be applied to derivatives. Pupils mainly recognize the usual school-based notations of the derivative, but they recognize its structure much less when it is presented in limit form or in a physical situation. This difficulty relates both to a change in register of representation and to the physical contextualization of the mathematical object. Interpreting a derivative as a velocity or an acceleration requires pupils to go beyond the formal recognition of notation and assign it physical meaning. This result confirms that mobilizing a mathematical tool in physics requires a genuine articulation between mathematical meaning and physical meaning.

The results related to kinematics show majority success in several diagnostic tasks. Most pupils correctly identify the accelerated nature of the motion, the fastest body, the velocity equation $v(t) = kt$, and the zero initial velocity. These successes indicate that some simple graphical elements can be interpreted when the relationship between velocity and time is explicitly represented. However, they do not allow us to conclude that pupils have fully mastered kinematic modeling, because the proposed tasks remain guided. From the perspective of physico-mathematical modeling, pupils may recognize certain graphical clues without necessarily mastering the entire process linking the physical situation, the quantities involved, the graph, and the mathematical expression.

The item related to the RC circuit also shows the importance of distinguishing qualitative understanding of a phenomenon from its precise mathematical interpretation. Pupils correctly identify certain qualitative aspects, such as the increasing nature of the voltage and the initially discharged state of the capacitor. However, the interpretation of the line $U_C(t) = U_{Cmax}$reveals confusion between tangent and asymptote. This difficulty shows that graphical processing remains fragile, particularly when pupils have to give physical meaning to a mathematical representation. According to Duval's framework (1995), it can be understood as a difficulty related to the processing and conversion of graphical and algebraic representations.

The results concerning the sinusoidal function point in the same direction. Although 68% of pupils correctly identify the represented function, 32% choose an incorrect expression. This difficulty concerns the transition from the graphical register to the algebraic register, particularly the identification of amplitude, the initial phase, and the distinction between sine and cosine. It confirms that using a graphical representation is not limited to visual reading: it requires conversion into a mathematical expression and physical interpretation of that expression.

Table 11: Summary of pupils' responses to the questionnaire-test items

Item Description	Indicator type	Observed percentage	Interpretation
Mathematical formulas in physics learning	Reported difficulty	54%	Difficulty reported by more than half of the pupils
Differentiating between mathematical and physical symbols	Reported difficulty	54%	Reported confusion between mathematical and physical notations
Use of mathematical concepts in physics before their formal study in mathematics	Reported difficulty	74%	Significant reported difficulty related to the mismatch between disciplinary progressions
Preference for understanding experiments and physical phenomena	Contextual data	50%	Descriptive result, not directly measuring a mathematical difficulty
Preference for solving exercises	Contextual data	50%	Descriptive result, to be interpreted as pupils' general relationship with physics activities
Translating physical statements into simple mathematical relationships	Observed success	24%	Strong observed difficulty: approximately 76% of pupils failed in this task
Identification of the nature of motion	Observed success	94%	High success rate
Identification of the type of acceleration	Observed success	82%	Majority success, with residual difficulty among some pupils
Identification of the fastest body	Observed success	94%	High success rate
Identification of the velocity equation	Observed success	94%	High success rate
Identification of the initial velocity	Observed success	100%	Full success in the sample
Identification of the initial state of the capacitor	Observed success	98%	Very high success rate
Determination of the maximum value ($U_{c\,max}$)	Ambiguous response	58% for (E), 42% for steady state	Inconclusive item, as both answers may refer to the same physical quantity
Identification of the sinusoidal function represented graphically	Observed success	68%	Majority success, but approximately 32% of pupils still encounter difficulty

These results are consistent with the work of Meltzer (2002), which shows that learners' mathematical preparation influences conceptual learning in physics. They also confirm that the difficulties encountered are not only due to a lack of mastery of mathematical procedures, but also to the ability to use them in physical situations. Similarly, Brahmia et al. (2016) emphasize that difficulties in physics also concern symbolization, proportionality, algebraic reasoning, and the mathematization of physical phenomena. The low success rate in translating statements into mathematical relationships therefore confirms the importance of teaching that explicitly addresses the transition from a physical situation to its mathematical formalization.

Beyond isolated mathematical gaps, the results suggest that pupils' difficulties stem from a complex interaction between mathematics and physics. This interpretation is consistent with the work of Levi et al. (2025), who highlight physico-mathematical difficulties related to the articulation between mathematical reasoning and physical reasoning. Pupils may oscillate between decontextualized mathematical reasoning and intuitive physical reasoning that is insufficiently formalized. The main difficulty then lies in coordinating mathematical structures, physical quantities, and the meaning of the phenomenon being studied.

The results can also be related to the work of Maries, Lin, and Singh (2020), according to which novice physics learners go through a cognitive transition phase during which mathematical tools are not yet mobilized expertly to interpret physical expressions. This idea sheds light on the difficulties observed in our study: pupils may know certain mathematical expressions, but they do not always manage to use them as tools for interpretation, modeling, and problem solving in physics.

In conclusion, the difficulties identified in this study are multidimensional. They concern the mastery of mathematical tools, but also their transfer, their mobilization in a physics context, their conversion between different semiotic registers, and their use in modeling phenomena. In the Moroccan context, these results highlight the need for better coordination between mathematics teaching and physics teaching. Such coordination could help pupils build more explicit links between mathematical concepts, graphical representations, relationships between quantities, and the physical phenomena studied, while also promoting the development of genuine physico-mathematical competence.

6. Study Limitations

The study is based on a limited sample of 125 pupils and therefore does not allow the results to be generalized to all scientific baccalaureate pupils in Morocco. In addition, the tool used combines declarative items and diagnostic items, which is a strength, but requires a clear distinction between pupils' perceptions and the observed difficulties. Finally, the data processing is essentially descriptive; it makes it possible to identify trends but does not make it possible to establish causal relationships between mathematical difficulties and success in physics.

7. Conclusion

This research work has shown that mathematics occupies a very important place in physical science education through the nature of the relationship between mathematics and physical sciences. Through the analysis of the role played by mathematics in physical sciences, it appears that mathematics maintains a constitutive relationship with physics, both as a language and as a tool. The study of mechanics and electricity made it possible

to identify several mathematical elements whose mastery conditions the learning of these disciplines, particularly temporal derivatives, functions, relationships between quantities, and graphical representations. The results obtained show that the absence of reminders or mathematical supplements for certain concept not yet studied, as well as difficulties in mobilizing mathematical tools, may constitute one of the factors contributing to the difficulties encountered by pupils in physical sciences.

Declaration of Conflict of Interest
The authors declare that they have no conflicts of interest.

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Appendix: Pupil questionnaire/Test

Gender: ☐ Male ☐ Female

This questionnaire-test aims to better understand the mathematical difficulties that pupils may encounter when learning physics. Your responses will help us identify the obstacles that may hinder the understanding of physical concepts. We thank you for answering carefully and sincerely.

1. Do mathematical relationships constitute an obstacle for you in the study of physical sciences?
☐ Yes ☐ No

2. Does the difference in symbols between mathematics and physics constitute an obstacle to understanding physical concepts?
☐ Yes ☐ No

3. Does the use of certain physical relationships before they are studied in mathematics constitute an obstacle to understanding physical concepts?
☐ Yes ☐ No

4. Have you ever received a below-average grade on a physics test because of mathematical errors?
☐ Yes ☐ No

5. What do you prefer?
☐ Understanding experiments and physical phenomena ☐ Solving a set of exercises

6. What difficulties do you encounter when reviewing physics lessons at home?
☐ Mathematic ☐ Concepts ☐ Experimental ☐ Linguistic

7. What difficulties do you encounter when solving physics exercises?
☐ Mathematic ☐ Concepts ☐ Experimental ☐ Linguistic

8. Express the following statements using simple mathematical relationships:

- Quantity A is directly proportional to quantity B; the constant of proportionality is K ……………………………………
- Velocity v is the first derivative of position $S$with respect to time t. ……………………………………
- Pressure $P$is the magnitude of the force Fapplied per unit surface area S. ……………………………………

3. How does the physics teacher introduce new mathematical concepts, such as integration and logarithmic functions?

4. ☐ Detailed explanations ☐ Reminder ☐ Use without explanation

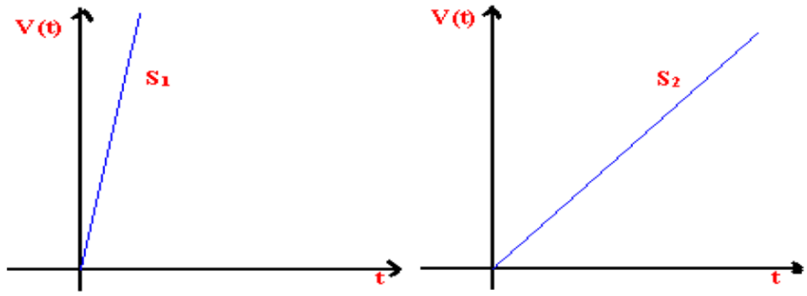
10. Tick what you consider to be a function:

☐ $U - RI = 0$ ☐ $PV - nRT = 0$ ☐ $P = mg$ ☐ $T = k\Delta l$ ☐ $y = f(x)$ ☐ $y = x(t)$

11. Tick what you consider to be a derivative:

☐ $\lim_{dt \to 0} \frac{\vec{v}(t+dt)-\vec{v}(t)}{dt}$ ☐ $\frac{\Delta x}{\Delta t}$ ☐ $\frac{dx(y)}{dy}$ ☐ $\frac{dx(y)}{dy}$ ☐ $x'(t)$ ☐ $\dot{x}(t)$

12. The observation of the velocities of two bodies $S_1$and S_2in rectilinear motion on an air track produced the following graphical representations:



- What is the nature of the motion of bodies $S_1$and S_2?

☐ Accelerated ☐ Decelerated ☐ Uniformly varied ☐ Uniform

- Is the acceleration:

☐ Zero ☐ Constant ☐ Variable over time

- Which body is the fastest?

☐ S_1 ☐ S_2

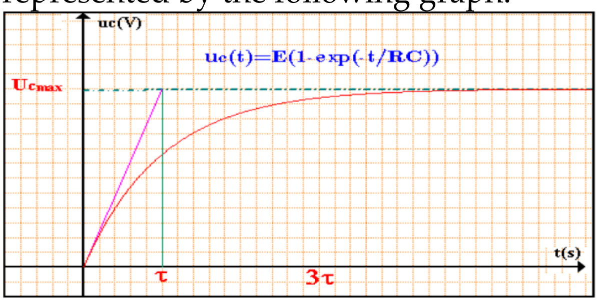
- The velocity equation of the bodies is:

☐ $v(t) = kt$ ☐ $v(t) = k$

The initial velocity $v_0$of the two bodies is:

☐ $v_0 = 0$ ☐ $0 < v_0$ ☐ $v_0 < 0$

13. The voltage $U_C$across a capacitor in an RC circuit during exponential charging is represented by the following graph:



- What is the behavior of the function over the interval [0, 2τ] ?

☐ Increase ☐ Decrease ☐ Constant

- The maximum value U_{Cmax} is:

☐ $U_C(0)$ ☐ Limit of the function as t ⟶ ∞ ☐ E ☐ Steady-state value

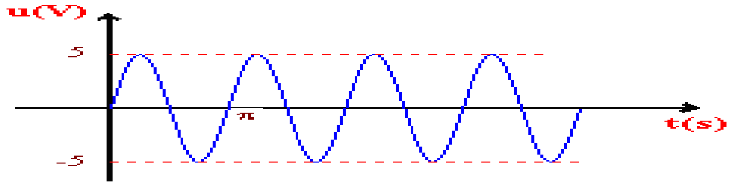
- The line whose equation is $U_C(t) = U_{C\max}$is:

☐ Tangent to the function at t = 0 ☐ Asymptote as t ⟶ ∞

- What is the initial state of the capacitor at t = 0 ?

☐ Charged ☐ Discharged

14. Observation of a sinusoidal alternating voltage given by the following graph:



The function represented in the figure is:

☐ $u(t) = 5\,cos(2t)$ ☐ $u(t) = 5\,sin(2t)$ ☐ $u(t) = -5\,sin(2t)$